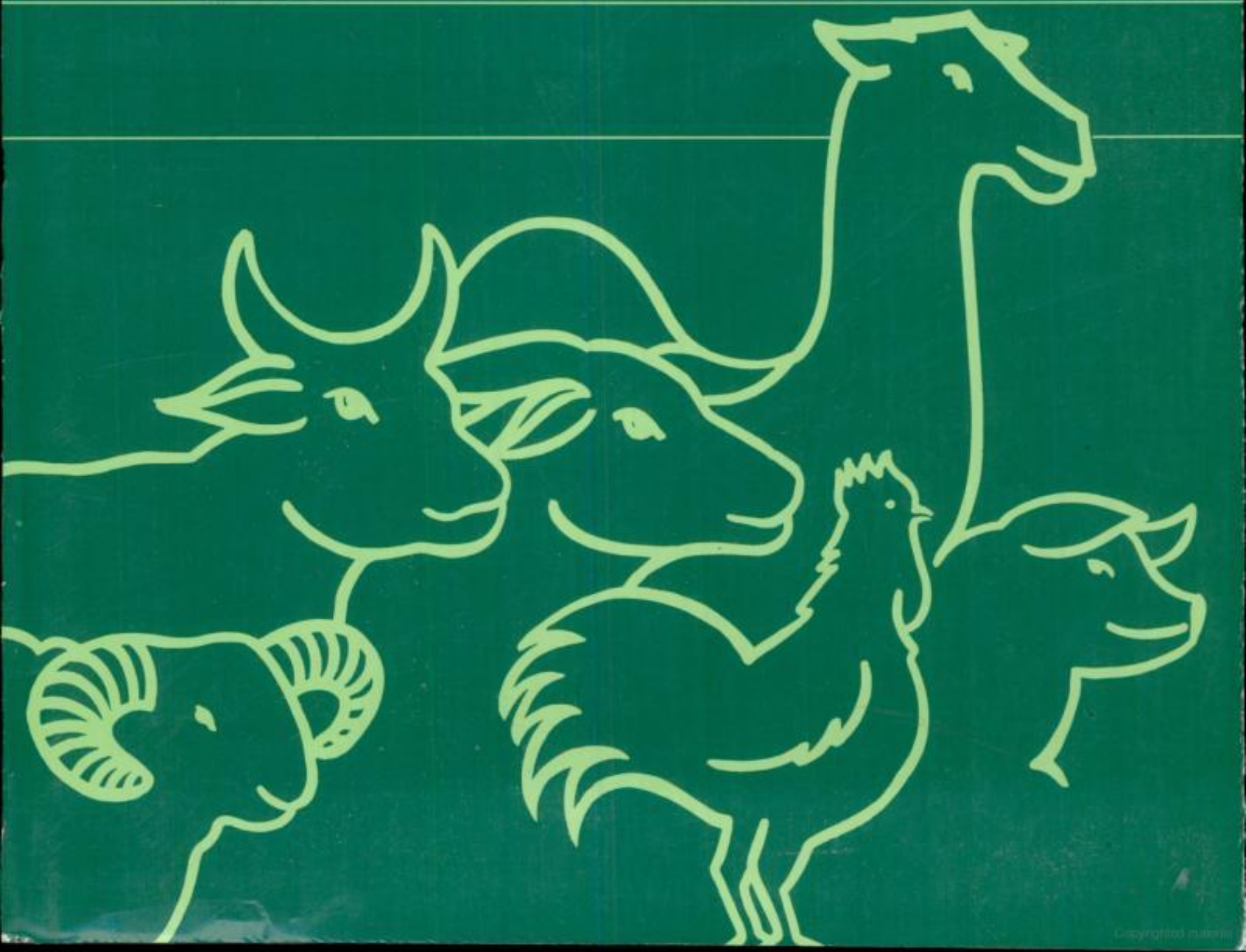
A TEXTBOOK OF
ANIMAL HUSBANDRY

G.C. Banerjee

EIGHTH EDITION



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1

TAXONOMY, DOMESTICATION AND ANIMAL HUSBANDRY IN INDIA

What is Animal Husbandry ?

By the word "Animal" although it includes any of the various organisms belonging to the kingdom *Animalia*,distinguished from plant kindgom by their non-photosynthetic methods of nutrition, non-cellulosic cell membrane and centralised nervous system but yet when we talk of animal husbandry, we mean only those domesticated animals which are reared mostly for economic or for recreation purposes in any particular region. such as Cattle, buffalo, sheep, goat, yak, camel, pig, horse, dog, poultry etc.

The word "Husbandry" comes from the management of domestic affair, but at present the word is also used in management of farming such as Crop husbandry and Animal husbandry. The term used in connection with animal husbandry includes proper feeding, breeding, health care, housing and many other activities.

Thus "Animal Husbandry" may be defined as a science as well as an art of management including scientific feeding, breeding, housing, health care of common domestic animals aiming for maximum returns.

Taxonomy

Taxonomy is the science of classification applied to living things and it involves their identification, naming and arrangement. The system of classification devised by Linnaeus (1707-1798), a Swedish botainist, has now been accepted universally as a means of reference. In this system each individual type of organism is called a *species*. Species or organism having close similarities are arranged in a group known as a genus (pl. genera). Genera with similar characteristics are put in the same family, simil lar families into orders and orders into classes. This system uses two Latin names to describe each organism. The generic name refers to its genus and is written with a capital letter and the specific names indicate its species and is written with a small letter. For example, the name *Homo sapiens* referes to species known as *sapiens* beonging to the genus *Homo* in case of a human being. The generic name is often abbreviated to one or two letters, e.g.B. for Bos, C. for *Capra*, E. for *Equus*. Most animals and plants can be classified according to their morphology, i.e. according to their shape, in conjunction with evidence obtained from fossils.

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Zoological Classification (Taxonomy) of Common domestic animals

Kingdom — ANIMAL

Phylum — CHORDATA *(with back bone)* — There is either backbone (in vertebrates) or the rudiment of backbone, the chordata

Class — MAMMALIA *(Suckle their Young)* — Worm blooded hairy animals that produce their young alive and suckle mammary glands.

Order —

- ARTIODACTYLA *(Even toed hoofed)*
  - **Family —** BOVIDAE *(4–chambered stomach ruminates, unbranched horns universal presence of gall bladder.)*
    - **Genus —** Ovis
      - **Species —** *O. aries* — SHEEP
    - **Genus —** Capra
      - **Species —** *C. hircus* — GOAT
    - **Genus —** Bos
      - **Species —** *1. B. taurus* (humpless) *2. B. indicus* (humped) — CATTLE
    - **Genus —** Bubalus
      - **Species —** *1. B. Bubalis* (all types of domestic river buffalo) *2. B. carabanesis (Swamp)* — BUFFALO
  - **Family —** SUIDAE *(stomach may have 1 or 2 diverticula)*
    - **Genus —** Sus
      - **Species —** *1. S. scrofa* *2. S. vittatus* *3. S. domestic* — SWINE
  - **Family —** CAMMELIDAE *(3–chambered stomach omasum lacking, ruminates)*
    - **Genus —** Camelus
      - **Species —** *1. C. bactrianus* (asian–two humped) *2. C. Dromedarius* (arabian, one humped) — CAMEL
- PERISSODACTYLA *(non–ruminant hoofed)*
  - **Family —** EQUIDAE *(single stomach with large caecum; unable to ruminate)*
    - **Genus —** Eqauus
      - **Species —** *1. E. Caballus* **Horse** *2. E. asinus* **Donkey or Ass**
- CARNIVORA (1)
  - **Family —** Canidae
    - **Genus —** Canis
      - **Species —** *C. familiaris* — DOG
  - **Family —** Felidae
    - **Genus —** Felis
      - **Species —** *F. catus* — CAT
- PROBOSCIDÆ (2)
  - **Family —** Elephantidae
    - **Genus —** Elephus
      - **Species —** *E. maximus* — INDIAN ELEPHANT
    - **Genus —** Loxondata
      - **Species —** *L. africana* — AFRICAN ELEPHANT
- LAGORMORPHA (3)
  - **Family —** Leporidae
    - **Genus —** Oryctolagus
      - **Species —** *O. cuniculus* — RABBIT

(1) Flesh eating mammals, powerful jaws and claws.

(2) Thick skin with scant hair, skull bones are thick with air passage (sinuses). Testis abdominal.

(3) Continually growing incisors are present. Locomotion by jumping method.

In general the taxonomic system is constructed according to the plan developed by Karl Von Linne in the middle part of 18th century:

1. Kingdom
2. Phylum
3. Class
4. Order
5. Family
6. Genus
7. Species

For example, a human being belongs to the Kingdom *Animal*, Phylum *Chordata*, Class *Mammalia*, Order *Primate*, Family *Hominidae*, Genus *Homo*, Species *spaiens*.

Table 1.1

FAO Statistics on Livestock Population

The Table below is the latest FAO Statistics on Livestock Population of the countries in Asia-Pacific Region, 1988. *(Unit: 1,000 heads)*

Country	Cattle	Buffalo	Pig	Sheep	Goat	Chicken	Duck
Bangladesh	23,500	1,964	—	1,123	10,700	64,000	32,000
Bhutan	409	7	63	27	32	—	—
China	73,946	20,860	335,116	102,650	77,932	1,850,000	323,000
India	201,401	75,605	10,519	56,980	108,493	206,000	9,000*
Indonesia	6,470	3,049	6,500*	5,488	13,704	434,000	29,000
Iran**	8,350	230	—	34,500	13,600	105,000	—
Japan	4,667*	—	11,725*	29	48	351,000	—
Kampuchea	1,950	700	1,500	1	1	7,000	3,000
Korea DPR	1,250	—	3,100	372	285	20,000	—
Korea REP	2,386	—	4,281	3	166	59,000	1,000
Laos	590	1,000	1,520	—	76	9,000	—
Malaysia	636	245	2,258	102	347	58,000	4,000
Mongolia	2,600	—	140	13,200	4,450	—	—
Myarmar (Burma)	10,000	2,200	3,000	295	1,100	34,000	6,000
Nepal	6,374	2,890	479	833	5,125	10,000	—
Pakistan	17,300	13,900	—	27,000	32,300	152,000	1,000
Philippines	1,600	2,890	7,580	30	2,130	60,000	5,000
Sri Lanka	1,831	1,029	101	28	510	9,000	—
Thailand	5,034	6,403	4,268	95	80	83,000	19,000
Vietnam	2,800	2,680	11,800	23	455	75,000	34,000
Australia	23,500	—	2,720	164,00	600	56,000	—
Fiji	160	—	30	—	60	2,000	—
New Zealand	7,999*	—	428*	64,800*	1,000	9,000	—
Papua New Guinea	123	—	1,523	2	17	4,000	—
Samoa, W.**	27	—	65	—	—	1,000	—
Tonga	8	—	65	—	11	—	—
Vanuatu	105	—	79	—	12	—	—
Asia-Pacific total	**405,114**	**135,654**	**408,860**	**471,697**	**273,250**	**3,663,000**	**466,000**
World	**1,265,976**	**140,648**	**889,141**	**1,171,403**	**521,974**	**9,661,000**	**528,000**
Indian livestock population as (%) percent of world	15.90	53,75	1.25	4.86	20.78	2.13	1.70

Note: * = Unofficial. ** = 1987 Figures.

Animals are also classified on the basis of their nature of rumination (regurgitation). Some of them are listed below :

List of common domestic animals classified on the basis of whether they are

Non-ruminants or Ruminants

Non-ruminants (having single stomach)	Ruminants (All ruminates; number of stomach may very from usual of Four)
1. Elephant	1. Cattle
Asian	Humped
African	Humpless
2. Rhinocerus	2. Buffalo
Indian	Asian
White	African
Black	Indian
3. Hippopotamus	3. Sheep
4. Horse	4. Goat
Domestic	5. Nilgai
Wild	6. Giraffe
Pony	7. Deer
5. Zebra	8. Bison
Grevy	9. Llama (3 chambered stomach)
Plains	10. Camels (3 chambered stomah)
Mountain	
6. Ass	Among species of the family *camelidae* which includes camels, vicunas, alpacas, llamas, the omasum is missing as it has been anatomically modified into small tubular and is structurally a part of the abomasum. Surprisingly enough, the reticulum contains glandular cells.
7. Pig	
8. Man	
9. Dog	
10. Monkey	
11. Rabbit	
12. Hamster	

THE BEGINNING OF ANIMAL HUSBANDRY

Man in the Old Stone Age (1,000 – 8,000 B. C.) made no attempt to domesticate animals but used to ate those animals that he was lucky to hunt. In the New Stone Age (8,000—6,000 B. C.)

Table 1.2 **Mature Body Weights and Ages of Selected Species**

Common Name	Species Name	Mature Body Weight (kg)	Mature Age	Longevity (year)	Maximum Recorded Lifespan (yr)	Birth Weight (kg)
Dairy cattle	*Bos taurus/indicus*	464–653	5 yr	20–25	30	25–45
Horse	*Equus caballus*	450	3–5 yr	20–25	50	45–55
Goat	*Capra hircus*	26–102	2 yr	10–15	18	2.5–3.5
Swine	*Sus scrofa*	70–128	—	16–18	27	1.0–2.0
Sheep	*Ovis aries*	34–80	2 yr	10–18	20	2.0–4.0
Rabbit	*Oryctolagus cuniculus*	3.0–4.9	1 yr	5–8	>13	.04–.08
Chicken	*Gallus domesticus*	1.5–3.3	20–30 weeks	2–5	30	.049–.065
Turkey	*Meleagris gallopavo*	5.0–14.8	28–35 weeks	—	12.3	0.52–.056

Altman and Dittmer, 1964, Fox ett al. 1984. Blakely and Bade, 1982. Cole and Garrettt, 1980; Acker, 1983

Table 1.3

Common Names for the Sexes, Young, Groups and Birthing of Various Animals

Animal	Male	Female	Young	Group	Name for giving birth
Antelope	buck	doe	kid	herd	kidding
Bear	boar	sow	cub	sleuth	cubbing
Beaver	boar	sow	pup	colony	—
Bird	cock/stag	hen	fledgling/ nestling	flock	hatch
Bison	bull	cow	calf	herd	calve
Bobcat	tom	lioness/queen	kitten	litter	—
Cat	tom	pussy/queen	kitten	clowder	queening
Cattle	bull	cow/heifer	calf	herd/drove	calve
Chicken	rooster/cock	hen/pullet	chick	flock	hatch
Deer	buck/stag	doe	fawn	herd	—
Dog	dog	bitch	pup/puppy	kennel	whelp
Donkey	jackass	jennet/ jenneyass	colt	herd	foal
Duck	drake	duck	duckling	flock	hatch
Elephant	bull	cow	calf	herd	calve
Fox	reynard	vixen	cub/pup	earth/skulk	pupping
Giraffe	bull	cow	calf	herd	calve
Goat	billy/buck	nanny	kid	trip	kidding
Goose	gander	goose	gosling	gaggle/flock	hatch
Hog	boar	sow/gilt	piglet/shoat	herd/drove	farrow
Horse	stallion/stud	mare/dam	foal colt (male) filly (female)	stable/herd	foal
Kangaroo	buck/boomer	doe/flyer	joey	troop/herd	—
Lion	lion/tom	lioness/she lion	cub	pride/flock	whelp
Ostrich	cock	hen	chick	flock	hatch
Owl	owl	jenny/ howlet	howlet/owlet	flock	—
Ox	steer	cow	stot	herd/drove	calve
Rabbit	buck	doe	kitten	colony	—
Rat	buck	doe	—	colony	—
Seal	bull	cow	pup	herd/harem/ rookery	—
Sheep	buck/ram	ewe/dam	lamb/ lambkin	flock/hurtle	lamb
Swine – see hog					
Turkey	tom	hen	poult	flock	hatch
Walrus	bull	cow	cub	herd	—
Whale	bull	cow	calf/cub/pup	herd/pod	pupping
Wolf	he-wolf	she-wolf	cub/pup	pack	whelp
Zebra	stallion	mare	colt	herd	foal

man changed from hunter to husbandman of animals by domestication. Domestication came after food cultivation. The first animals to be domesticated may have been the dog and goat probably 8,500 to 9,000 years ago from to-day. The place was the hills of South Western Asia in the Lebanese and Palestinian mountains.

Table 1.4 **Gestation Periods***

Species	(days)	Species	(days)	(months)
Livestock		**Wild Animals**		
Ass	365	Ape, Barbary	210	
Cattle:		Bear, black		7
Angus	281	Bison		9
Ayrshire	279	Camel	410	
Brown Swiss	290	Coyote	60–64	
Charolais	289	Deer, Virginia	197–220	
Guernsey	283	Elephant		20–22
Hereford	285	Elk, Wapiti		8½
Holstein	279	Giraffe		14–15
Jersey	279	Hare	88	
Red Poll	285	Hippopotamus	225–250	
Shorthorn	282	Kangaroo, red	32–34**	
INDIA N	282	Leopard	92–95	
Goat	148–156	Lion	108	
Horse, heavy	333–345	Llama		11
Horse, light	330–337	Marmoset	140–150	
Pig	112–120	Monkey, macaque	150–180	
Sheep:		Moose	240–250	
Mutton breeds	144–147	Musk ox		9
Wool breeds	148–151	Opossum	12–13	
Pets		Panther	90–93	
Cat	59–68	Porcupine	r 112	
Dog	56–68	Pronghorn	230–240	
Guinea pig	58–75	Raccoon	63	
Hamster	15–18	Reindeer		7–8
Mouse	19–31	Rhinoceros, African	530–550	
Rabbit	30–35	Seal		11
Rat	21–30	Shrew	20	
Fur Animals		Skunk	62–65	
Chinchilla	105–115	Squirrel, grey	44	
Ferret	42	Tapir	390–400	
Fisher	338–358	Tiger	105–113	
Fox	49–55	Walrus		12
Marten, European	236–274	Whale, sperm		16
Pine Marten	220–265	Wolf	60–63	
Mink	40–75	Woodchuck	31–32	
Muskrat	28–30			
Nutria (coypu)	120–134			
Otter	270–300			

*Adapted from *Merck Veterinary Manual*, 5th edition
**Delayed development as long as a "joey" is in the pouch

Table 1.5

Visual Parameters of Selected Species

Common Name	Species Name	Visual field (Degrees)	Binocular Vision (Degrees)	Colour Perception[a]
Dairy cattle	*Bos indicus*	330—360[b]	25—50[b]	Yes
Horse	*Equus caballus*	330—350[b]	30—70[b]	Yes
Goat	*Capra hircus*	320-340[b]	20—60[b]	Yes
Swine	*Sus scrofa*	310[b]	30—50[b]	Yes
Sheep	*Ovis aries*	330—360[b]	20—50[b]	Yes
Rabbit	*Oryctolagus cuniculus*	330[b]	10—35[b]	Yes
Chicken	*Gallus domesticus*	300[c]	10—35[c]	Yes
Turkey	*Melearis gallopavo*	300[c]	10—35[c]	Yes

a Based upon presence of cone cells.

b Fedde, M.R. (1976) Respiration in "*Avian Physiology*", 3rd edn Springer Verlag, New York, U.S.A.

c Kare, M.R., and Rogers, J.G. Jr. (1976) *Sense organs . In Avian Physiology*, 3rd edn, Springer Verlag, New York, U.S.A.

Table 1.6

Average Rectal Temperatures of Various Species

	Average		Range	
Animal	**°C**	**°F**	**°C**	**°F**
Stallion	37.6	99.7	37.2–38.1	99.0–100.6
Mare	37.8	100	37.3–38.2	99.1–100.8
Donkey	37.4	99.3	36.4–38.4	97.5–101.1
Camel	37.5	99.5	34.2–40.7	93.6-105.3
Beef cow	38.3	101	36.7–39.1	98.0–102.4
Dairy cow	38.6	101.5	38.0–39.3	100.4–102.8
Sheep	39.1	102.3	38.3–39.9	100.9–103.8
Goat	39.1	102.3	38.5–39.7	101.3–103.5
Pig	39.2	102.5	38.7–39.8	101.6–103.6
Dog	38.9	102	37.9–39.9	100.2–103.8
Cat	38.6	101.5	38.1–39.2	100.5–102.5
Rabbit	39.5	103.1	38.6–40.1	101.5–104.2
Chicken (daylight)	41.7	107.1	40.6–43.0	105.0–109.4

From Andersson, B.E. : Temperature regulation and environmental phisiology. In Dukes' Physiology of Domestic Animals, 10th Ed. Edited by M. J. Swenson. Ithaca, NY, Cornell University Press, 1984.

Table 1.7

Table of Norms

Features of the Reproductive Cycle (Pets)*

	Cats	Dogs	Guinea pigs	Hamsters	Mice	Rabbits
Age at puberty	6–15 months	6–12 months**	55–70 days	5–8 weeks	35 days	5½–8½ months
Cycle type	Provoked ovulation, seasonally polyestrous, spring & early fall	Monestrous, all year, but mostly late winter & summer	Polyestrous	Polyestrous	Polyestrous	Polyestrous, induced ovulation
Cycle Length	15–21 days	6–7 months	16 days	4 days	4 days	1 month or more
Duration of heat	9–10 days in absence of male, 4–6 days if mated	4–14 days standing heat	6–11 hours	10–20 hours	9–20 hours	1 month or more
Best time for breeding	Daily from day 2 of heat	On alternate days from day 2 to end of heat	10 hours after start of heat	At start of heat, 8–10 p.m.	At start of heat	Anytime
First heat after birth	4–6 weeks	3–5 months	6–8 hours	1–2 weeks after litter removed	2–4 days after litter removed	Immediate
Number of young	1–10	1–22	1–8	1–12	1–12	3–13

*Adapted from *Merck Veterinary Manual*, 5th edition
** Earlier in smaller breeds, later in larger breeds

ANIMAL HUSBANDRY IN INDIA—PRESENT AND FUTURE

India has basically been an agricultural country and it is likely to continue to be so for a long time to come. At present 70 per cent of Indians are dependent for their livelihood on agriculture. Thirty per cent of the total land holdings are held by 70 per cent of small and marginal farmers who held 80 per cent of the total livestock in the country. Crop agriculture in India depends mainly on bullocks which contribute approximately 40,000 MW of power to agricultural operations.

In spite of this the country has been unable to be assured of needed supplies of food grains and of animal products including milk till the middle of 1960s. During the period of last 25 years, however, it has been possible to achieve substantial progress and build up a buffer stock of few million tonnes of food grain every year. The indepth analysis carried out some 10 years back about the progress and prospects of Indian agriculture has shown the existence of potentialities. It is necessary to make everyone in the country aware of these potentials as also the tasks to be performed to realise these potentials for the good of the country in particular and the world in general.

The production and use of animal products in the human diet is receiving tremendous attention. With this object in view the need for developing Animal Husbandry is recognised very well. The other objectives are to provide animal power for farmings, adoptation of better land use pattern—the land which is not suited for arable cropping should be put under grass or trees—so much needed for protection to soil. Among other objectives of Animal Husbandry, the utilisation of agro-industrial by-products for converting those into valuable animal products so much needed by all of us. The creation of thousands of employment opportunities through out the year by adopting animal industry on large scale shall also be a part of the objectives of Animal Husbandry in India.

According to FAO statistics on livestock (1988), there are 201.4 million cattle, 75.6 million buffaloes, 56.98 million sheep, 108.49 million goat, 10.5 million pigs, 206 million chickens and 9.0 million ducks.

Cattle and Buffaloes

India has 14 per cent of the world's cattle and 50 per cent of the world's buffalo population. Cattle alone produces about 42 per cent (13.8 MMT) of the total milk produced (32.75 MMT) in the country during 1982. During the year 1987-88 the country produced 46.1 MMT, thus exceeding the target of 45.9 MMT, according to the annual report of the Department of Agriculture and Co-operation. Thus India is now occupying first position regarding its milk production among the developing countries of the world. When compared with the world the country occupies third position in quantum of total milk production. The gross value of output of milk and milk products amounts to over Rs. 7,500 crores, compared to other agricultural outputs such as rice—Rs. 11,573 crores and wheat Rs. 5,225 crores.

Although there has been a substantial increase in milk production over the years, the corresponding increase in human population has brought the per capita availability of 144 g milk per day which is far lower than the recommended level of 210 g per head per day. The average milk production of a milking cow is only 173 kg and that of buffalo is about 500 kg milk in one lactation. Sixty five million Indian buffaloes contribute about 54 per cent of the total milk produced in our country. Regarding animal commodity cattle and buffalo

contribute approximately 80 per cent of the total GNP (Gross National Product) of about Rs. 20,000 crores per annum.

Poultry

We also produced about 15 billion eggs per year and more than 75 million broilers in 1985 from a meagre figure of 4 million in 1971. Poultry meat coutributed to nearly 17 per cent of the total meat production value of one million tonnes in 1985.

The value of poultry production has risen from Rs. 65 crores in 1961 to Rs. 1,000 crores in 1985. When compared with per capita/year consumption it is only 20 eggs and 240 g poultry meat as against 260–300 eggs and 20–30 kg poultry meat consumption in some of the developed countries. Conservative industry projections place the turn of the century estimates at upwards of 30,000 million eggs and 400 million broilers thus raising the annual per capita availability of 30 eggs and 540 g poultry meat for an estimated human population of approximately one billion by that year. Such a fast expansion in egg and poultry meat production would require about 135 million improved laying stock, 450 million broiler chicks with feed requirement going upto about 7.5 million tonnes per year. The Five Year Plan allocation has now increased substantially to Rs. 602 million in the Seventh Plan from a figure of Rs. 28 million in the Second Plan.

Table 1.8

Meat production from slaughtered animals and poultry

(000 MT)

Species of animals	Meat Production in India				
	1974-76	1980	1981	1982	1983
Beef and veal	61	74	78	80	80
Buffalo meat	98	120	127	130	132
Mutton and lamb	102	120	125	127	132
Goat meat	228	270	277	288	288
Pig meat	54	70	75	80	80
Poultry meat	88	113	120	130	136
Total meat	714	870	916	945	958

Sheep

The country has around 45.03 million sheep in 1982 producing around 132 million kg of mutton comprising about 14 per cent of the total meat production from all species in the country. Although the sheep population remained almost static at around 48 million between 1951–1977, it registered a substantial increase between 1977–1982. The current wool production is around 39.8 million kg, most of which is in the form of variable carpet quality and only

around 5 million kg is useable in the worsted sector. The country is exporting handknotted carpets and hosiery worth Rs. 150 crore and is importing around 14 million kg of apparel wool.

Goats

According to 1982 census, the country has around 90 million goats. The species provide dependable source of income to 40 per cent of rural population below the poverty line in India and to many who do not possess any land. Inspite of 42 per cent annual slaughter of goats the population continues to increase at the rate of about 1.2 per cent per year. Its economic contribution to the national economy is to the tune of Rs. 350 crores annually through (i) the production of 9,55,000 MT of milk (comprising 2.9 per cent of the total milk production of the country), (ii) 305,000 MT of meat (which is obtained through sacrifice of 38.86 million goats annually and constitutes 40.7 per cent of the total meat produced in the country), (iii) 79,000 MT of fresh skin, (iv) 40 MT of pashmina, and (v) 340 million MT of manure. However, the average production of milk, meat and fibre per individual is much below the world average. In India a goat is primarily used as a meat animal. At present the internal demand is 20 times higher than the present production. It is thus apparent that an increase in individual production of the indigenous goat is essential to boost the natural production.

Livestock as National Economy

The present contribution of livestock to the national economy is estimated to be Rs. 15,000 crores mainly from milk and milk products (70 per cent); meat and meat products (11.5 per cent); poultry (8.8 per cent) and dung for fuel (7.8 per cent). In addition the value of other animal products as eggs, wool, leather goods etc., makes the total of Rs. 15,000 crores. Apart from above items, the value of draught power from 88 million bullocks including 8 million buffalo bullocks indispensable to agricultural operations is of the order of Rs. 5,000 crores. According to some other estimates, the market value of all the domesticated species in India is of the order of Rs. 40,000 crores.

Although there has been a substantial increase of cattle and buffalo population by about 32 per cent and 61 per cent respectively over the 1956 base and thereby increase in milk production both from cattle and buffaloes over the years, the corresponding increase in human population was 79 per cent. This has offset the gains made in milk production. Current trends of growth in human population suggest that since more and more land would be used for cereal production, the feed resources for livestock are likely to be further reduced.

The total human population by the year 2000 at the current growth rate would be around 997 million. To feed this population at the minimum recommended level (210 g per individual per day) we would need around 76 million tonnes of milk. The cattle and buffalo population by 2000 would be 246 (including 49 million cross-breds) and 109 million respectively, which together would produce around 68 million tonnes of milk including 4 million tonnes from goats and other species.

We are in deficit both in feed and fodder to a large extent. National Commission on Agriculture in 1976 indicated that India was short of 44 per cent concentrate, 38 per cent

green fodder and 44 per cent dry fodder. The commission also estimated the requirement of feeds by the year 2000. Projections were made on the assumption that with the addition of more and more high yielding cross-breds, we shall be able to reduce the numbers. This assumption does not seem to hold true as there has been an increase in cattle and buffalo population by 32 per cent and 61 per cent respectively over the 1956 base.

The available feed and fodder situation, however, demands that we reduce the numbers of cattle and buffaloes by selection.

With the diminishing land resources for agriculture due to urbanisation and fast increasing human population, the total cropped area is likely to be further reduced and most of the land would be used for cereal production for human consumption. The feed resources for livestock are thus likely to be further reduced.

In order to increase the per capita consumption of milk, meat and eggs, we have to think in terms of increased production considering the ever increasing population in one hand and overall scarcity of quality animals and their feed on the other hand. The disproportionately small output has been attributed to a number of causes. Chief among them are:

Feeding: Inadequate feed and nutrition to support our vast livestock and poultry population.

Breeding: Low genetic potentiality for high production due to the absence of selection for milk, meat, eggs and wool. Disorganised breeding programme is another factor.

Management: Lack of efficient and scientific management. Poor uniformity in data collection in the country regarding livestock.

Disease control: Lack of application of modern techniques to control diseases.

Considerable pioneering work in some of these areas are now being carried out by all the National Research Institutes, viz., National Dairy Development Board, Indian Grassland and Fodder Research Institute, Indian Veterinary Research Institute, Central Institute for Research in Buffaloes, Central Avian Research Institute, Central Sheep and Wool Research Institute, Central Institute for Research on Goat, National Research Centre on Camel, Agricultural Universities of the country and others.

There is no doubt that major improvements in animal productivity will take place through the traditional methods of giving attention to feeding, breeding, management and disease control, but it is no longer possible to obtain the targets of achieving production by using only conventional technologies. Nevertheless, it may thus be worthwhile for achieving maximum exploitation of our livestock and poultry by applying new approach of recent biotechnology in the field of animal nutrition, reproduction, breeding and management. Researchers in molecular biology and immunology have made their most significant rank in helping us to achieve the aim.

What is Biotechnology?

Biotechnology is a new scientific field, has crystallized and developed rapidly during the past 15–20 years. It is the application of biological organisms, systems or processes to manufacturing and service industries. In 1981 the European Federation of Biotechnology defined it as "integrated use of biochemistry, microbiology and chemical engineering in order to achieve the technological application of the capacities of microbes and cultured tissue cells" Agriculture and medical technology (e.g. the construction of heart-lung mechanism) are thus excluded from this definition.

The role of biotechnology in upgrading animal production is largely one of supplying tools to assist animal producers with breeding, feeding, management and disease control.

Animal Health

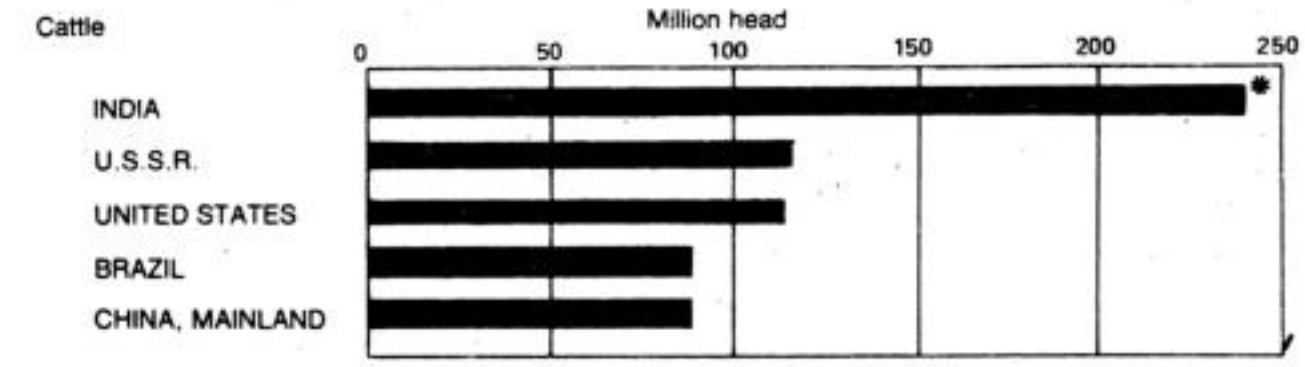
For providing health cover, currently, there are 14,849 veterinary hospitals and dispensaries in the country, besides there are 19,286 veterinary first aid centres. It is envisaged to increase the number of hospital/dispensaries to 19,452 by the end of Seventh Plan. There will be at least one veterinarian for every 10,000 cattle units, 5 regional disease diagnostic laboratories and in addition disease surveillance centres in 12 states. A central authority, independent of the drug controller, would be established to ensure quality control of all veterinary immuno-biologicals. The IVRI has set up a centre for animal disease research and diagnosis and strengthened its regional disease and diagnosis facilities.

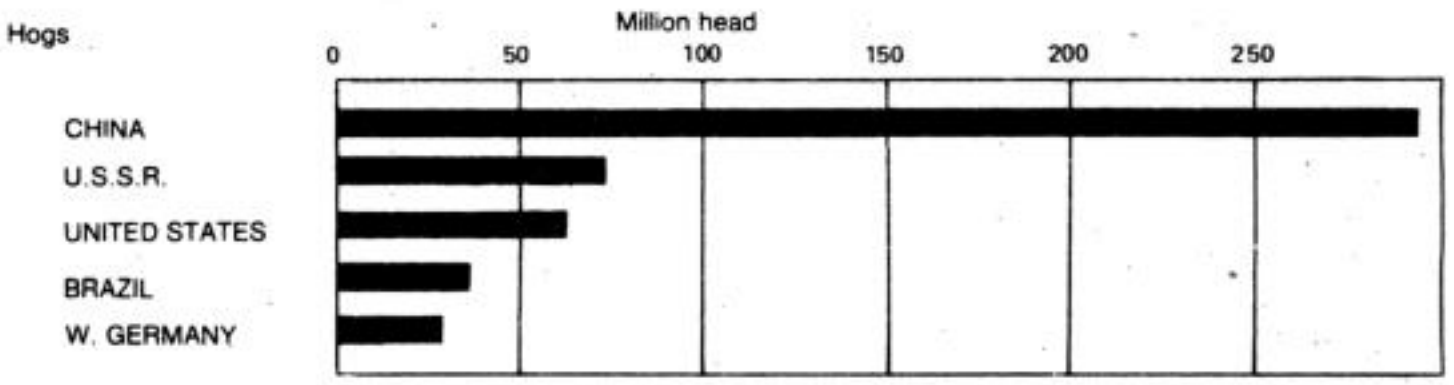
The production of veterinary immuno-biologicals is also being strengthened. It is expected that 50 million doses per annum will be produced by the end of the Seventh Plan programmes for control and eradication of nationally important diseases, viz. rinderpest and FMD, although contagious bovine pleuropneumonia in cattle, Marek's and pullorum diseases (Bacillary with diarrhoea) in poultry, swine fever in pigs and rabies in dogs will also receive attention. Efforts to develop disease free zones at least in three states are also in progress.

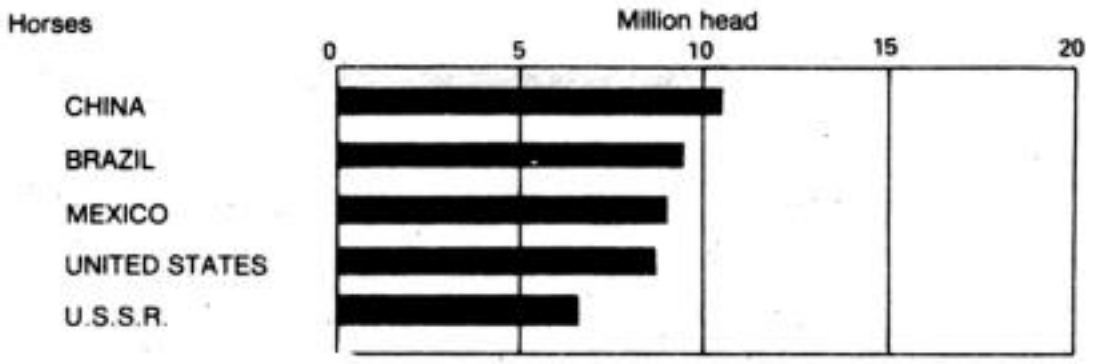
Veterinary, Dairy and Animal Science Education

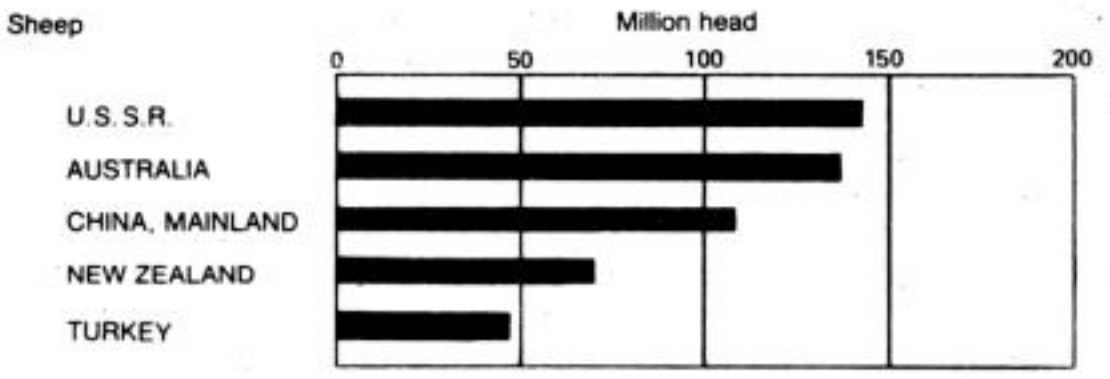
There are 25 Veterinary Colleges and 8 dairy technology colleges preparing graduates in veterinary and animal sciences and dairy technology respectively. In addition the IVRI and NDRI have formal training programmes in Veterinary and Dairy Sciences. RBS College at Agra and Allahabad Agricultural Institute are producing Master's degree holders in Animal and Dairy Science since few decades in the country. IVRI and NDRI are now recognised as "deemed to be University" preparing candidates in various disciplines of Veterinary & Animal Sciences both at post-graduate and doctorate levels.

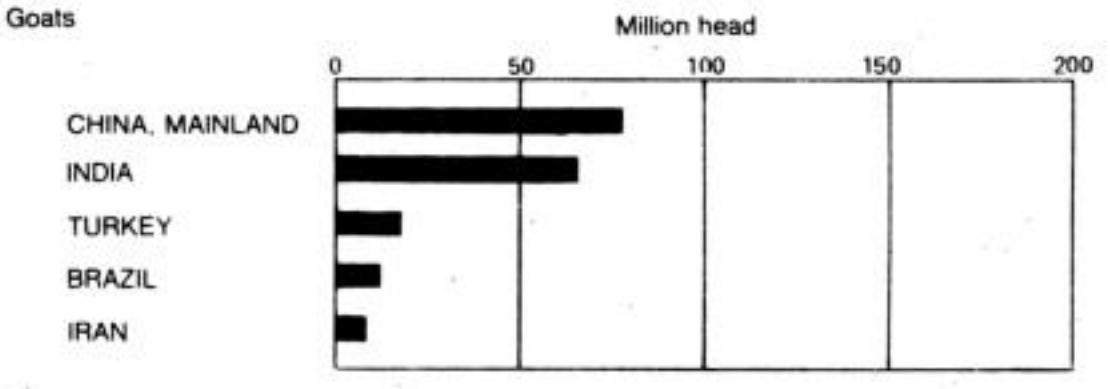
Countries that lead in the Production of Selected World Domestic Animals











*inc an est. 70 million water buffalo

Countries that lead in the Production of Selected World Animal Products

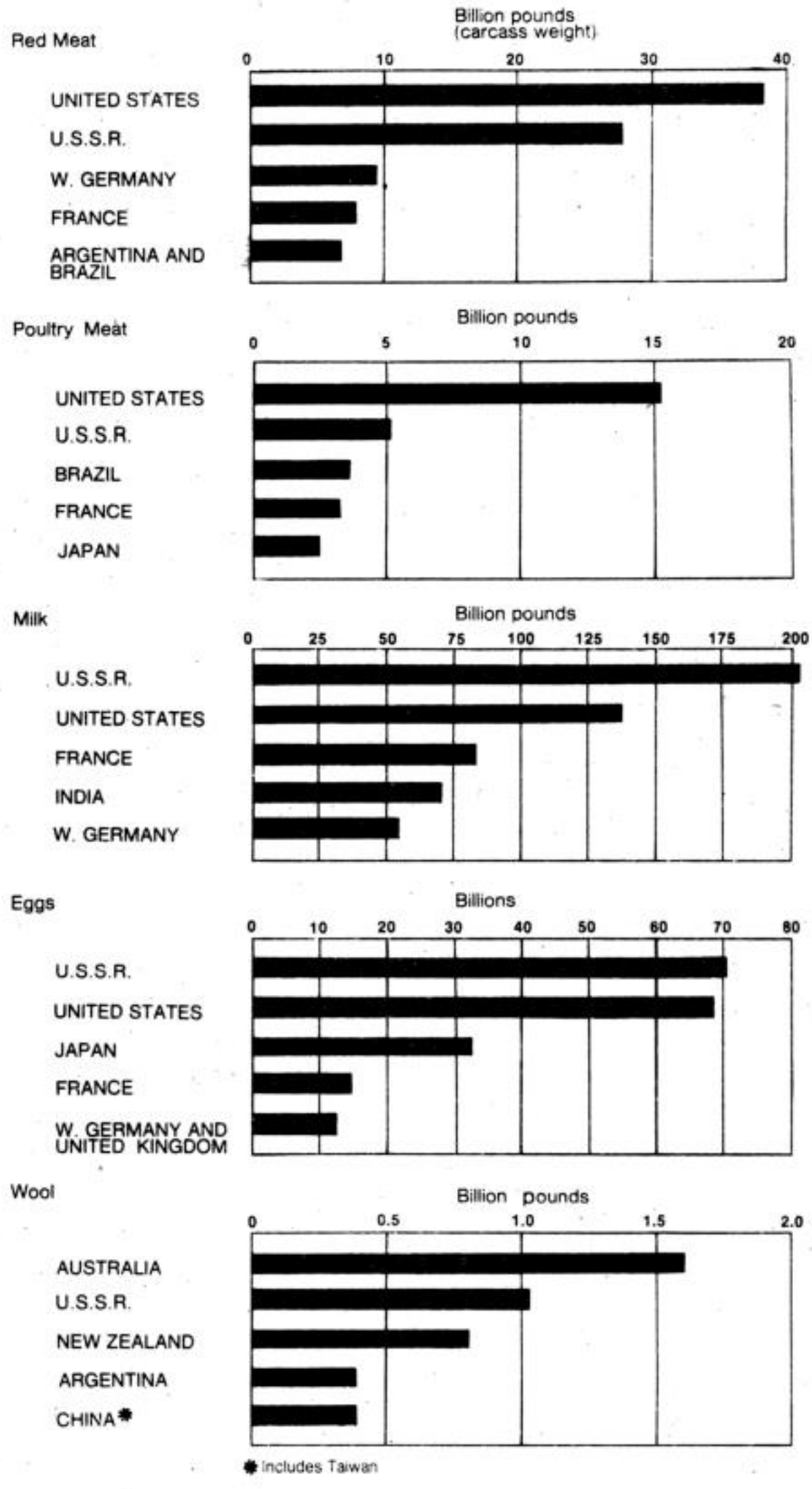


Table 1.9

THE DOMESTICATION OF ANIMALS

Species	When, B.P.,* years	Where	Why	How
Dog	8500–9000	Old and new worlds	Pet, companion	Wolf or jackal
Goat	8500–9000	Old world	Food, milk, and clothing	Wild goat
Pig	8000–9000	Old world	Food and sport	European wild boar
Sheep	6000–7000	Old world	Food, milk, and clothing	European mouflon and Asiatic urial
Cattle	6000–6500	Old world	Religious reasons	Aurochs
Chickens	5000–5500	India, Sumatra, and Java	Cockfights, shows, food, and religion	Jungle fowl
Horse	4000–5000	Old world	Transportation	Wild horse
Ducks	?	Probably China	Food and feathers	Wild duck
Geese	?	Greece and Italy	Food and feathers	Wild goose
Turkeys	?	Mexico or North America	Food and feathers	Wild turkey

*B.P. means *before present*.

GLOSSARY

Abattoir A slaughter house

Abomasum The fourth or true stomach of the cow, comparable in function to that of simple–stomached animals.

Acid detergent fiber (ADF) Fiber (principally lignin and cellulose) extracted from a feedstuff using a chemical technique employing an acidic detergent. Used to evaluate the quality of a forage.

Acidosis A condition of the blood which is brought about by an increase in acidity as a result of metabolic processes. There is a consequent reduction in the amount of alkali in the blood.

Active transport Energy–requiring translocation of a substance across a membrane, usually against its concentration or electrochemical gradient.

Adipose tissue Fatty tissue of animals

Ad libitum (ad lib) Term used to reflect the availability of a feed on a free–choice basis.

Aerobic A biological process requiring the presence of oxygen.

Afterbirth The fetal membranes that attach the fetus to the membranes of the pregnant female and which are normally expelled from the female within 3 to 6 hr after parturition.

Agalactia Failure to secrete milk following parturition.

Alimentary canal The tubulous passageway leading from the mouth to the anus. It includes the mouth, pharynx, esophagus, stomach, small intestines, large intestines, and rectum.

Alveolus A very small structure found in the mammary gland, almost spherical in shape, lined with a single layer of epithelial cells, in which milk is manufactured by the female.

Ambient That which surrounds (e.g., the temperature around us is the ambient temperature).

Amnion The innermost fetal membranes, which form a fluid–filled sac for the protection of the embryo.

Anarobe An organism able to live in the absence of free oxygen, or in greatly reduced concentrations of free oxygen.

Angstrom A unit of measurement : 1/10,000,000 of a millimeter (10^{-7}mm)

Anorexia Lack of appetite

Antibiotics Chemical compounds antagonistic to some forms of life produced by and obtained from certain living cells. Antibiotics are used in animal and human medicine to combat certain disease organisms and in animal feeding to enhance performance.

Antibody A substance produced in an animal as a protective mechanism to combat invasion by a foreign material (antigen).

Antigen A high–molecular–weight substance (usually protein) that, when foreign to the bloodstream of an animal, stimulates the formation of a specific antibody.

Apoenzyme The protein portion of an enzyme. The apoenzyme and coenzyme form the functioning holoenzyme.

ATP Adenosine triphosphate, a high energy organic phosphate of great importance in energy transfer in cellular reactions. Universal energy currency of cells.

Artificial insemination The injection of mechanically procured semen into the reproductive tract of the female without coition and with the aid of mechanical or surgical instruments.

Ataxia Failure of muscle coordination.

Atrophy A defect or failure of nutrition or physiological function manifested as a wasting away or diminution in size of cell, tissue, organ, or part.

Autopsy Examination, including dissection, of a carcass to learn the cause and nature of disease or cause of death. Also called Postmortem.

Backfat A term used in swine production that refers to the amount of fat deposited along the back in animals of either sex. Usually measured at typical market weights of 200–230 pound. An excessive amount of backfat is considered to be an undesirable trait.

Balanced ration The feed or combination of feeds that will supply the daily nutrient requirements of an animal.

Barrel That part of the animal's body between the fore and rear legs.

Barrow A male swine animal that was castrated at an early age before reaching sexual maturity and before developing the physical characteristics peculiar to boars.

Basal metabolism The chemical changes that occur in the cells of an animal in the fasting or resting state when it uses just enough energy to maintain vital cellular activity, respiration, and circulation.

Bedding Leaves or straw which is given to animals to lie on.

Biological Value The percent utilization of protein within the animal body, expressed by the formula

$$\%BV = \frac{\text{N intake}-[(\text{FaecalN}-\text{Metab.N}) + (\text{Urigenous N}-\text{Endogenous N})}{\text{N intake}-(\text{Faecal N}-\text{Metabolic N})}$$

Bleating The noise made by goats, specially females at œstrus.

Blind quarter In cattle, a mammary gland quarter that does not secrete milk or one that has an obstruction in the teat that prevents the removal of milk. A nonfunctional mammary gland.

Bloat A disorder of ruminants characterized by the accumulation of gas in the rumen.

Bolus A masticated morsel of food ready to be swallowed.

Bomb calorimeter An apparatus used to measure the heat of combustion of feeds, or feces.

Brainstem Made up of mid and hind brain. Coordinate automatic involuntary processes.

Breed Animal having a common origin and characteristics that distinguish them from other groups within the same species

Browse Feed taken from trees and shrubs (including leaves, twigs and bark).

Brush border A free epithelial cell surface bearing numerous microvilli.

Bull index (sire index) A measure of inheritance of milk and/or milk nutrient production that a bull tends to transmit to his daughters.

Calf starter A dry concentrate feed especially formulated for use with young calves from birth to 3 or 4 months of age.

Cannibalism Consists of one pig or chicken biting the tail or other body part of another. Most frequently observed in closely confined, growing–finishing pigsand chickens.

Carboxyhemoglobin The compound formed when carbon monoxide combines with hemoglobin. CO competes successfully with oxygen for combination with hemoglobin, producing tissue anoxia.

Centromere The point on the chromosome at which identical chromatids are joined and by which chromosomes are attached to a spindle fiber.

Chelating agent An organic compound that can bind cations (metallic ions) by forming a stable, inert complex that is soluble in water; used in softening hard water, in purifying sewage, and in eliminating high concentrations of undesirable metallic or radioactive elements in the blood or tissues.

Coenzyme A substance, usually non–protein and of low molecular weight, necessary for the action of some enzymes.

Colostrum The first milk produced by the female immediately after giving birth to young. It is highly nutritious and a rich source of antibodies.

Conception The fecundation of the ovum. The action of conceiving or becoming pregnant.

Coprophagy The ingestion of own faeces as in rabbit.

Cotyledon An area where the membranes of the fetus and the uterine lining are in close association such that the nutrients can pass to and wastes can pass from the circulation of the developing young.

Creep An area accessible to small calves, lambs, or pigs, but not to adult animals, to enable the young to consume additional feed to supplement nutrients obtained from nursing.

Critical temperature The atmospheric temperature below which vasomotor control of the body temperature (e.g., vasoconstriction, vasodilation, sweating, etc.) ceases to maintain body temperature.

Crude fiber The portion of feedstuffs identified by proximate chemical analysis that is composed of cellulose, hemicellulose, lignin, and other polysaccharides. These compounds make up the structural and protective parts of plants. Crude fiber level are high in forages and low in grains.

Crude protein In the proximate analysis of feedstuffs, a figure representing protein content arrived at by multiplying the tctal nitrogen in a feed by 6.25.

Cryptorchidism In the male, a condition where the testes are retained in the body rather than descend into the scrotum. Results in infertility.

Culling The process of eliminating nonproductive or undesirable animals.

Dentition Refers to the dental pattern in various species of animals. A dental formula includes both the numbers and types of teeth, temporary and permanent, in both the upper and lower jaw.

Dicoumarl A chemical compound found in spoiled sweet clover. It has an anticoagulant and can cause internal hemorrhages when eaten by cattle.

Diuretics Are substances which produce diuresis, that is, which cause a copious excretion of urine.

Docking Removal of the tail. A common practice in lambs.

Domesticate To bring a wild animal or fowl under control and to improve it through careful selection, mating and handling so that its products or services become more useful to humans.

Drenching A common method of administering medicine to an animal by mixing the medicine with water, elevating the animal's head, and giving the dose from a bottle.

Dressing percentage Carcass weight/live weight.

Dry cow A cow that is not producing milk

Drying off The act of causing a cow to cease lactation in preparation for her next lactation.

Dry period Nonlactating days between lactations.

Dual-purpose animal One which is kept for both milk and meat production.

Dysgenesis A defect in breeding so that hybrids cannot mate between themselves but may produce offspring with members of either family of their parents. Such offspring are sterile.

Dystocia Abnormal or difficult labor at parturition, causing difficulty in delivering the fetus and placenta.

Ear-notching A notch or series of notches made in the ear of animal as a means of identification

Edema The presence of abnormally large amounts of fluid in the intercellular tissue spaces of the body, as in swelling of mammary glands commonly accompanying parturition in many farm animals.

Efferent nerves The nerves that carry messages from the central nervous system to the effectors, the muscles and glands. They are divided into two systems : somatic and autonomic (automatic).

Efficacy Effectiveness. For e.g., the effectiveness of an antibiotic in the therapy of a certain disease.

Ejaculate Refers to the semen ejected from the male at the time of copulation or to the semen collected as a part of the procedure in artificial insemination.

Electron-transport Chain (Respiratory Chain) A series of enzymes that transfer electrons from substrate molecules to molecular oxygen.

Embryo A young organism in the early stages of development. In animals, the period from fertilization until life is noted.

Embryo transplant Artificial transfer of the embryo from the natural mother to a recipient female by mechanical means.

Encephalomalacia A Condition characterized by softening of the brain. A disease causing lesions of the brain in young poultry, caused by a deficiency of vitamin E in the diet.

Endemic (Enzootic) Pertaining to a disease commonly found with regularity in a particular locality.

Ensilage (silage) Plant material preserved in a wet state subsequent to fermentation ina silo.

Enteritis Any inflammatory condition of the intestinal linings of animals or humans.

Epizootic Designating a widely diffused disease of animals, that spreads rapidly and affects many individuals of a kind concurrently in any region, thus correspoding to an epidemic in humans.

Ergot A fungus found in feeds that is toxic to animals.

Eructation The act of belching or casting up gas from the stomach by mouth.

Escutcheon The area at the rear of a cow that extends upward just above and in back of the udder where the hair turns upward in contrast to the normal downward direction of hair.

Esophageal groove In ruminants, a semicanal providing passage for fluid materials from the esophagus to the abomasum in young animals. In mature animals the function of the esophageal groove is questionable.

Estrous cycle The period from one estrus, or heat period, to the next.

Estrus The period of heat or sexual excitement in the female.

Excrement Waste material discharged from the body, especially from the alimentary canal.

Exotic The term used to describe animals foreign to a region.

FAO Food and Agriculture Organisation. An agency of the United Nations that collects and disseminates information on the production, consumption and distribution of

food throughout the world. It was organized in 1945 and has some 120 member nations; it is headquartered in Rome.

Farrowing pen A specially designed pen in which sows are placed at the time of farrowing. These pens contain gurd rails to prevent the sow from laying on newly born pigs.

Fauna Usually refers to the overall protozoal population present.

Fecundity Efficiency ot an individual in production of young. Animals that bring forth young frequently, regularly, and in the case of those that bear more than one offspring at a birth, in large numbers, are said to e fecund.

Feed efficiency The units of feed consumed per unit of weight increase or unit of production (milk, meat, eggs).

Fibrinogen A soluble protein present in the blood and body fluids of animals that is essential to the coagulation of blood.

Fistula A permanent opening made in the body wall of an animal through which there is communication between the animal's interior and the external environment. An example is a rumen fistula – a permanent opening created surgically between the interior of the rumen and the outside.

Fleece The entire coat of wool as it comes from the sheep or while still on the live animal.

Flora In nutrition it generally refers to the bacteria present in the digestive tract.

Flushing The practice of feeding female animals especially well, just previous to the breeding season, in order to stimulate their reproductive organs to the maximum activity. This is thought to result in a higher percentage of conceptions.

Forage Roughage of high feeding value. Grasses and legumes fed at the proper stage of maturity and quality are forages.

Foster mother A doe or ewe that raises a kid or lamb of which she is not the natural mother.

Free-martin A heifer, usually sterile, born twin with a bull.

Friedman test A test for pregnancy in which a small amount of urine of the tested animal is injected into the bloodstream of a virgin rabbit. Pregnancy is indicated by certain changes in the ovaries of the rabbit.

Fungi (singular, Fungus) Plants that contain no chlorophyll, flowers or leaves. They get their nourishment from dead or living organic matter.

Gametes Reproductive cells. Sperm produced by the male and ova (or eggs) by the female.

Gluconeogenesis Formation of glucose from protein or fat.

Glycogenesis Conversion of glucose into glycogen

Glycogenolysis Conversion of glycogen into glucose

Glycolysis Conversion of carbohydrate into lactate by a series of catalysts. The breaking down of sugars into simpler compounds.

Ham The rear quarter of a pig or of a pork carcass.

Haylage Forage ensiled at a relatively low moisture content (usually 40 to 50%).

Heat increment (HI) The increase in heat production following consumption on food when an animal is in a thermoneutral environment. It consists of increased heats of fermentation and of nutrient metabolism. There is also a slight expenditure of energy in masticating and digesting food. This heat is not wasted when the environmental temperature is below the critical temperature. This heat may then be used to keep the body warm.

Hematopoietic An agent that promotes the formation of blood cells.

Herbivorous animals Animals that habitually rely upon plants and plant products for their food.

Heterosis The increased stimulus for growth, vigor, or performance often shown by a crossbred individual. Hybrid vigor.

Holocellulose Total structural carbohydrate in a plant. It excludes soluble sugars, starch, and pectins.

Homeotherm A "warm–blooded" animal. An animal that maintains its characteristic body temperature even though environmental temperature varies.

Horn–buds Small bumps on a young's head where horns are starting to grow.

Hulls The outer protective covering seeds.

Husks Refers to the fibrous covering of the grain after removal of hulls.

Impregnate To make pregnant; to fertilize.

Intrinsic factor A chemical substance in normal stomach juice necessary for the absorption of vitamin B_{12}.

In vitro Within artificial environment, as within a test tube.

In vivo Within the living body.

Iodinated casein (thyroprotein) A product produced when casein, a milk protein, is treated with iodine. The resulting product possesses thyroactivity and is sometimes fed to milk cows to stimulate milk production.

Ion An atom bearing a net charge due to loss or gain of electrons.

Lactation period The number of days a cow secretes milk following each parturition.

Legumes A family of plants which are usually high in protein and which naturally improve the nitrogen content of the soil.

Lethal characters Presence of hereditary factors in the germ plasm that produce an effect so serious as to cause the death of the individual either at birth or later in life.

Lignin A polymer of phenolic substances impregnating the cellulose frame work of certain plant cell wall resulting poor digestibility of Cellulose. Lignin is essentially indigestible.

Limiting amino acid The essential amino acid of a protein that shows the greatest percentage deficit in comparison with the amino acids contained in the same quantity of another protein selected as a standard.

Lipid Any of a group of biologically important substances that are insoluble in water and soluble in fat solvents such as ether, chloroform, and benzene. Principal chemical components of lipids are fatty acids and glycerol.

Loose housing A housing system for cattle whereby animals are untied and unstanchioned in a shelter and are free to move at will from the inside to the outside and from a feeding area to a resting area.

Lysozyme A substance present in human nasal secretions, tears and certain mucus. It is also present in egg whites, in which it hydrolyzes polysaccharidic acids. It is bactericidal for only a few saprophytic bacteria and is inactive against pathogens and organisms of the normal flora.

Mammary veins (milk veins) Blood veins visible on the underside of the cow and extending forward from the fore udder.

Marbling Fat deposits in the lean tissue in meat.

Mastectomy Removal of the mammary gland.

Micelle A microscopic particle made from an aggregation of amphipathic molecules in solution

Milk letdown The squeezing of milk out of the udder tissue into the gland and teat cisterns.

Milk replacer A feed material for young animals which has many of the nutritive characteristics of milk, is fed in a fluid form, and contains an appreciable level of nonfat dry milk solids.

Milk vein A large blood vessel which runs under the center of the animals belly towards the udder.

Milk well Opening in the cow's abdomen through which the mammary vein passes on its way to the heart from the udder.

Mohair The wool of Angora goats; a soft white wool in great demand for clothing.

Molt (Molting) The shedding and replacing of feathers of poultry birds. Snakes and certain arthropods also shed their outer coverings and develop a new one.

Monogastric Having only one stomach or only one compartment in the stomach. Examples of monogastric animals are swine, mink and rabbits.

Monoparous A term designating animals that usually produce only one offspring at each pregnancy. Horses and cattle are monoparous.

Needle teeth The small, tusklike teeth on each side of the upper and lower jaws in swine. In good swine management, the tops of these teeth are removed shortly after birth to avoid damage to the sow's udder by the nursing pig.

Negative balance A term used in animal nutrition or physiology that describes a situation where an animal is excreting or secreting more of a specific nutrient than it is ingesting.

Nondescript An animal of inferior quality that can not be identified as belonging to a specific breed.

Nonreturns The conventional method of measuring "fertility" in artificial breeding. If, after an original insemination, a cow is not reported for reinsemination within a certain designated period, she is considered a "nonreturn" and is assumed to be pregnant.

Nymphomania An abnormal reproductive condition in cattle in which the female is in more or less constant estrus.

Offal The parts of a butchered animal that are removed in dressing it. Generally has reference to the inedible parts.

Oxidation The loss of electrons by an atom or molecule.

Parous A term referring to females having produced one or more young.

Pashmina The undercoat of Cashmere goats, a soft wool in great demand for clothing.

Pasture Grassland used for animals to graze.

Pens Small enclosed areas inside a building which are used for keeping animals separately.

Persistency The quality of being persistent, as in the ability of lactating animals to maintain milk production over a period of time.

pH A numerical value that expresses degree of acidity or alkalinity of a material as the negative logarithm (to the base 10) of the hydrogen ion concentration.

Phagocytes White blood cells that destroy bacteria in the bloodstream.

Pheromone A substance secreted externally by certain animal species to affect sexual behaviour of the species.

Pica An appetite for materials not usually considered to be food such as is observed in phosphorus–deficient animals; a depraved appetite.

Pinning Collection of dung around the vent of very young lambs that has dried to the point of interfering with normal bowel movements.

Pork The meat that comes from swine.

Prolificacy Ability to give birth to a large number of young. This term can refer to individual animals, groups of animals, or species.

Proven sire A dairy bull whose genetic transmitting ability has been measured by comparing the milk production performance of his daughters with that of the daughter's dam and/or herd mates under similar conditions.

Proximate analysis A chemical analysis that represents the gross composition of a feed. The feed components identified by this procedure include nitrogen (crude protein), nitrogen–free extract, ether extract, ash, and dry matter.

Puberty The period of life at which the reproductive organs first became functional. This is characterized by estrus and ovulation in the female and semen production in the male.

Purebred Any animal that traces back through all its lines to the foundation stock of the breed it represents. In some breeds, animals resulting from four or five generations of crossing to purebred sires are recognized as purebreds.

Putrefaction The decomposition of proteins by microorganisms under anaerobic condition.

Regurgitate To cast up undigsted feed from the stomach to the mouth as done by ruminants.

Repeatability The tendency of an animal to repeat its performance (e.g., a dairy cow in successive lactations, a sheep in successive wool clips, etc.). In dairy bulls, this term is used to indicate certainty with which predicted difference reflects true transmitting ability.

Reproductive cycle The sexual cycle of the nonpregnant female. Characterizd by the occurrence of estrus (heat) at regular intervals (e.g., in the cow, every 21 days).

Respiratory quotient (RQ) The RQ is used to indicate the type of food being metabolized. This is possible because carbohydrates, fats and proteins differ in the relative amounts of oxygen and carbon contained in their molecules. Also the relative volumes of O_2 consumed and CO_2 produced during metabolism of each type of food vary. RQ is calculated as follows :

$$RQ = \frac{\text{Volume } CO_2 \text{ produced}}{\text{Volume } O_2 \text{ consumed}}$$

Respiration calorimeter An apparatus for measuring the gaseous exchange between an animal and the surrounding atmosphere. With this apparatus it is possible to measure the energy required for the various body functions and activities and the energy content of feeds.

Retained placenta Placental membranes not expelled at parturition.

Regor mortis The stiftness of body muscles that is observed shortly after the death of an animal. It is caused by an accumulation of metabolic products, specially lactic acid in the muscles.

Rumination ("chewing the cud") The process of regurgitating and rechewing food; unique to ruminants.

Selection Biologically, any process, natural or artificial, that permits certain individuals to leave a disproportionately large (or small) number of offspring in a group or population.

Selection index In animal breeding, a single overall numerical value derived by weighting values for several traits based on heritability and economic importance. Index values are used in determining which animals are selected for breeding and which are culled.

Serum therapy The treatment of clinical cases of disease with serum of immunized animals.

Sire Index A figure that is indicative of the transmitting ability of a sire. In dairy cattle this figure is expressed in terms of quantity of milk or a milk component such as fat or protein.

Slop-feeding A system of feeding animals (usually pigs) that involves mixing dry feed with a fluid, usually water or skim milk. Thus the animal consumes its feed in the form of a slurry.

Springer A term commonly associated with female cattle showing signs of advanced pregnancy.

Staple-length The length of the cut hair or wool of a goat or sheep.

Steer A male bovine castrated before development of secondary sex characteristics.

Sternum The breastbone

Stillborn Born lifeless; dead at birth.

Stover Fodder; mature cured stalks of grain from which seeds have been removed, such as stalks of corn without ears.

Strippings Towards the end of milking, the last bit of milk is harder to milk out; the removal of this last bit is called stripping.

Stud A unit or herd of selected animals kept for breeding purposes. Often referred to as a seedstock herd.

Succulence A condition of plants characterized by juiciness, freshness, and tenderness, making them appetizing to animals.

Supernumerary teats Extra teats (more than four) in a bovine. In good dairy herd management, supernumerary teats are removed at an early age before they become highly vascularized.

Superovulation The production by the ovaries of more than the usual number of eggs at the time of estrus. Usually induced by hormone treatment.

Symbiosis An association of two different kinds of living organisms with mutual benefit.

Syndrome A group of signs and symptoms that occur together and characterize a disease.

Tassel Cartilaginous outgrowth at the base of the throat in some goats and sheep.

Teaser A male (bull or ram) made incapable, by vasectomy or by use of an apron to prevent copulation, of impregnating a female.

Tethering A way of controlling the movement of animals by means of a rope or chain.

Total digestible nutrients (TDN) A term used in animal feeding that designates the sum of all the digestible organic nutrients. (Digestible fat is multiplied by 2.25 because of its higher energy content.) TDN is a way of expressing the energy content of a feed.

Uremia A toxic accumulation of urinary constituents in the blood.

Villi Numberous fingerlike projections extending from the intestinal wall into the lumen of the small intestine. Nutrients are absorbed from the intestine into the bloodstream through the villi.

Viscera The large internal organs of the thoracic and abdominal and pelvic cavitis of the body.

Volatile fatty acids Short chain organic acids that are volatile upon stream distillation. These compounds are formed in the rumen as a result of bacterial degradation of cellulose and other carbohydrates. Examples are acetic, propionic, and butyric acid.

Weaning Taking the nursing young away from the mother and depriving it of the opportunity to nurse. This term is also used when calves are removed from diets containing fluid milk or milk replacer.

X chromosome A sex chromosome found in mammals. All of the eggs produced by the female contain X chromosomes. When two X chromosomes are present in the fertilized egg, a female develops.

Y chromosome A sex chromosome found only in male mammals. When a fertilized egg contains an X chromosome and a Y chromosome, a male develops. About 50% of the sperm produced by the male contain Y chromosomes.

Zero-grazing A system of feeding in which animals are kept in buildings and yards and fodder is taken to them.

2

AN INTRODUCTION TO MICROBIOLOGY

Microbiology is the study of microorganism (microbes). Microorganisms are very small, usually single-celled, organisms which are not individually visible to the naked eye. They can only be seen with the aid of a microscope. They are widely distributed in the environment and are found in foods. Certain of them, if present in food in large enough numbers, can cause food poisoning. Microorganisms are the main cause of food 'going off', i.e. food spoilage. However, not all microorganisms are undesirable. In fact they are essential to all forms of life since they break down complex organic matter and return nutrients to the soil. Microorganisms are used by man in the production of certain foods, e.g. bread and yoghurt.

Although some of the effects of microorganisms have been known and utilised for thousands of years, these microscopic organisms were first seen and studied only 300 years ago. In 1675 a Dutch lens grinder, van Leewenhoek, made a microscope with lenses of sufficiently good quality that he was able to observe microorganisms in a variety of materials such as teeth scrapings and pond water. The significance of his findings was not appreciated at the time. It was nearly 200 years later that a Frenchman, Louis Pasteur, studied fermentation processes and demonstrated that it was microorganisms which caused an undesirable sour taste in some wines. He developed a process of heating wine to kill the microorganisms which caused the souring. This process is still used today to kill undesirable organisms in many food products and is known as pasteurisation. While Pasteur was working in France, Robert Koch, in Germany, demonstrated that anthrax, a fatal disease of sheep and cattle, was caused by a bacterium. From this time onwards great advances were made in the field of microbiology. The organisms responsible for a large number of diseases were identified. In Scotland, Joseph Lister introduced the idea of antiseptic surgery and greatly reduced the incidence of infection in patients during and after surgery.

Classification of Microorganisms

Microorganisms can be classified into five biological types:

1. Protozoa
2. Algae
3. Viruses
4. Microscopic fungi—moulds and yeasts
5. Bacteria

This list classifies microorganisms according to their structure. It is sometimes more convenient to classify them according to their role in relation to human beings. In this functional classification there are four groups:

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1. Pathogens

These are microorganisms which cause disease. All viruses are pathogenic but only some are pathogenic to man. Certain bacteria also cause disease in man. Some of these diseases can be transmitted by food, e.g. food poisoning, cholera and typhoid.

2. Spoilage Organisms

These microorganisms do not cause disease but they spoil food by growing in the food and producing substances which alter the colour, texture and odour of the food, making it unfit for human consumption. Examples of food spoilage including the souring of milk, the growth of mould on bread and the rotting of fruits and vegetables.

3. Beneficial Organisms

Many microorganisms have a beneficial effect and can be used in the service of man. Few people realise the important part they play in everyday life.

(a) Microorganisms are essential to life since they are responsible for the rotting or decay of organic matter. The complex organic components of dead plants and animals are broken down by microbial activity into simpler, inorganic compounds which are made available for new plant growth, and the whole cycle of life is able to continue.

In the treatment of sewage, microorganisms are used to break down complex organic compounds.

(b) Microorganisms are used at various stages during the manufacture of certain foods. Their activities are essential in the production of foods such as bread, beer, wine, cheese and yoghurt.

(c) Antibiotics, such as penicillin, are substances used to destroy pathogens in the body. Many are produced as a result of microbial activity. For example, penicillin is obtained from a mould called *Penicillium.*

(d) Certain microorganisms may be used as a concentrated protein foods in the future.

4. Inert Organisms

This group includes those organisms which are neither harmful nor beneficial to man. *Commensals* are organisms which live in human but which do not cause disease in the part of the body where they are normally present. For example, *Streptococcus faecalis* is a bacterium which is harmless in its normal habitat, the large intestine. However, some commensals can be pathogenic if they spread to areas of the body where they are not normally found. *Streptococcus faecalis*, for example, causes disease if it infects the kidneys.

Although it is convenient to use a functional classification, it must be emphasised that this is not a hard and fast division. An individual organism may, in differing circumstances, fall into each of the four groups. For example, the bacterium *Escherichia coli* is generally considered to be inert. However, in some cases it may be pathogenic since it can cause food poisoning. Certain strains can cause food spoilage without causing illness. It has been used for removing glucose from egg white prior to drying, so may therefore be considered useful.

Protozoa

Protozoa are small single-celled animals. They are motile, i.e. capable of independent movement. They mostly live in water, for example in ponds, rivers and the sea and in the water in soil. A common example is *Amoeba.*

They feed by engulfing tiny food particles and reproduce by binary fission i.e. dividing into two halves.

The majority of protozoa are non-pathogenic but there are a few pathogenic species of some importance. For example, *Entamoeba histolytica* causes amoebic dysentery, a type of dysentry common in the tropics. Malaria is caused by the protozoan *Plasmodium* which is transmitted by mosquitoes. Toxoplasma gondii is an organism sometimes found in animals which may be transmitted to man during the handling of raw meat (particularly pork and mutton). It is estimated that there are one million people in the world infected with the organism but the disease (known as toxoplasmosis) is relatively harmless.

Algae

Algae are simple plants. Some are macroscopic (large), e.g. seaweeds, but many are microscopic. They contain chlorophyll or a similar pigment which enables them to photosynthesis. This means that they do not require complex organic substances as food but can utilise carbon dioxide and water. Microscopic algae usually live in water. Although each cell is capable of an independent existence they tend to grow in a mass and are often visible as green slime on the surface of ponds. Some types of algae, such as *Chlorella*, can be grown on the surface of water, harvested and used as a source of protein.

Viruses

These are the smallest of all microorganisms, varying in size from 10 to 300 nanometer (1 nm = 10^{-9} metre). Most viruses are not visible under the light microscope. Viruses are acellular, i.e. they do not have a cellular structure. They are made up of a central core of nucleic acid surrounded by a protein coat. They cannot feed, grow or multiply in isolation; they must always live as parasites in larger living cells. A virus particle attaches itself to a cell and the core of the virus penetrates and directs the life of the cell so that many more virus particles are formed. These new particles are then set free to attack other cells. The host cell is injured or even destroyed by the invading virus. Therefore viruses are always pathogenic; they cause disease in man, animals, plants and other microorganisms.

Some examples of virus diseases

Host	Virus disease
Man	Common cold, Influenza, Measles, Mumps, Chickenpox, Smallpox, Poliomyelitis
Animals	Foot-and-mouth disease, Rabies, Distemper, Myxomatosis, Psittacosis
Plants	Mosaic diseases

Most virus diseases in man are transmitted by contact but some are known to be transmitted by contaminated food or water, e.g. infectious hepatitis and poliomyelitis. Some diseases may be transmitted to man from animals, for example rabies from dogs and psittacosis from parrots.

Most virus diseases of man confer immunity, i.e. an attack of the disease confers resistance to a subsequent attack. This is due to the production of antibodies, substances formed in the body in

response to infection. Artificial immunity may be conferred by means of vaccination. A vaccine consists of a weakened or dead form of a pathogen and when it is injected into the body it is practically harmless yet it induces antibody production.

Many virus diseases of animals and plants are of economic importance. Millions of rupees are lost annually due to destruction of crops and livestock by virus diseases.

Microscopic fungi

Fungi are plants but, unlike green plants, they do not possess any chlorophyll. They are therefore unable to photosynthesise and require complex organic compounds as food. Those that grow and feed on dead organic material are termed *saprophytes*, while those feeding on living plants and animals are *parasites*.

1. Moulds

Moulds are usually multicellular, i.e. each mould growth consists of more than one cell. However, each cell is capable of independent growth and therefore moulds may be classified as microorganisms. Moulds consist of thin thread-like strands called hyphae (sing. hypha). The hyphae grow in a mass on or through the medium on which the mould is growing. This mass of hyphae is known as the mycelium. There are basically two types of mould:

(a) *Non-septate moulds*. These do not possess cross walls (septae). The hyphae are continuous tubes containing many nuclei dispersed throughout the cytoplasm and are therefore considered to be multicellular.

(b) *Septate moulds*. These possess septae or cross walls which divide the hyphae into separate cells, each cell containing a nucleus.

Reproduction

Reproduction in moulds is chiefly by means of asexual spores. In non-septate moulds the spores are normally formed within a spore case or sporangium, at the tip of a fertile hypha. Most septate moulds reproduce by forming unprotected spores known as conidia. Conidia are cut off, either singly or in chains, from the tip of a fertile hypha.

When ripe the spores are released into the air. If they find their way to a suitable substrate (food) they germinate and produce a new growth of mould. Some moulds also produce sexual spores, by the fusion of two hyphae.

Many moulds cause food spoilage. Spoilage may occur even in refrigerated foods. However, certain moulds are used in food production particularly in cheese making; Danish blue, Roquefort and Camembert are mould-ripened. Moulds are also used in the manufacture of soya sauce and some products used in the food industry, e.g. citric acid.

A few moulds are pathogenic causing diseases in plants such as potato blight, and skin infections in man such as 'athlete's foot' and ringworm. Ergot, a fungus that attacks rye, can produce a serious illness (known as ergotism) in animal and human who eat products made from the infected grain.

One of the most spectacular developments in medicine in this century was the discovery of penicillin and other antibiotics produced by moulds.

2. Yeasts

Yeasts are simple single-celled fungi, they are mainly saprophytic and usually grow on plant foods. Yeast cells may be oval, rod-shaped or spherical. They are larger than bacteria and under a high-power microscope a distinct nucleus is visible.

Reproduction

Most yeasts reproduce asexually by a simple process known as 'budding'. In one part of the cell the cytoplasm bulges out of the cell wall. The bulge or 'bud' grows in size and finally separates as a new yeast cell. This process is shown below.

Yeasts may cause spoilage in certain foods, e.g. fruit juices, jams and meat. These yeasts are normally referred to as 'wild yeasts' in order to distinguish them from those used commercially in the production of alcoholic drinks and bread.

The economic importance of yeast lies in its ability to break down carbohydrate foods into alcohol and carbon dioxide. This process, known as *alcoholic fermentation*, is anaerobic, i.e. takes place in the absence of oxygen. Yeast contains a collection of enzymes known as zymase which is responsible for the fermentation of sugars, such as glucose, into ethanol (ethyl alcohol) and carbon dioxide. Alcoholic fermentation may be represented by the following equation:

Under anaerobic Condition

$$\underset{\text{glucose}}{C_6H_{12}O_6} \longrightarrow \underset{\substack{\text{ethanol}\\\text{(ethyl alcohol)}}}{2C_2H_5OH} + \underset{\substack{\text{carbon}\\\text{dioxide}}}{2CO_2}$$

If a plentiful supply of oxygen is available, yeast cells will respire aerobically. In this case yeast enzymes are able to break down sugars more completely, and carbon dioxide and water are produced.

Under aerobic Condition

$$\underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2} \longrightarrow \underset{\substack{\text{carbon}\\\text{dioxide}}}{6CO_2} + \underset{\text{water}}{6H_2O}$$

More energy is obtained from aerobic than from anaerobic respiration. It is important when yeast is being grown commercially that it is supplied with plenty of air so that sufficient energy is available for growth.

The two most important industrial uses of yeast are in breadmaking and for the production of alcohol. The species generally used in these processes is *Saccharomyces cerevisiae*.

Production of alcoholic beverages

All alcoholic beverages, such as beers, wines and spirits, are produced by the anaerobic fermentation of a carbohydrate material by yeast. A large range of starting materials can be used; the carbohydrate may be in the form of starch, e.g. in wheat, barley, rice or potatoes, or in the form of sugars, e.g. in fruits, molasses or added sugar (sucrose). In addition the following substances may be added.

1. *Diastase*. Yeast cells are not able to produce enzymes capable of breaking down starch. Therefore, if starch is used, a substance containing amylase (diastase) must be added. Amylase is an enzyme which catalyses the breakdown of starch into maltose. Malt (germinating barely) has a high amylase content and is used in the brewing of beer.

2. *Available nitrogen*. This is necessary for the synthesis of protein during the growth and multiplication of the yeast cell. This nitrogen may be provided by protein present in the carbohydrate-containing food used, e.g. by the wheat, or it may be added in the form of ammonium salts, or nitrates.

3. *Water*. Water is necessary for the growth of the yeast and also to increase the volume of the mixture.

The mixture is enclosed in a container and oxygen is excluded; this ensures that respiration is anaerobic rather than aerobic. It is then held at a warm temperature in order to encourage the yeast cells to grow and multiply. Fermentation is allowed to continue until the desired concentration of alcohol is obtained. The maximum concentration which can be achieved by fermentation is 16%, since if it increases further the yeast cannot grow. The alcohol content of fortified wines, spirits and liqueurs is increased by distillation.

Breadmaking

The main ingredients used in breadmaking are flour, water, yeast and salt. These are made into a dough and fat, milk and sugar may also be added. The flour provides starch, amylase and protein and is an excellent food for the yeast. The bread dough is allowed to ferment prior to baking and the carbon dioxide produced causes the dough to rise. During baking the carbon dioxide expands causing the loaf to rise further.

Bacteria

Bacteria (sing. bacterium) are a very important group of microorganisms because of both their harmful and their beneficial effects. They are widely distributed in the environment. They are found in air, water and soil, in the intestines of animals, on the moist linings of the mouth, nose and throat, on the surface of all animal and plant body.

Bacteria are the smallest single-celled organisms, some being only 0.4 μm (micrometre) in diameter. The cell contains a mass of cytoplasm and some nuclear material (it does not have a distinct nucleus). The cell is enclosed by a cell wall and in some bacteria this is surrounded by a capsule or slime layer. The capsule consists of a mixture of polysaccharides and polypeptides.

Bacteria are classified into four basic groups depending on the shape of the cells.

1. Coccus (pl. cocci)—spherical.
2. Bacillus (pl. bacilli)—rod-shaped.
3. Vibrio— short, curved rods.
4. Spirillum (pl. spirilli)—long, coiled threads.

When bacteria are grown on a culture medium in the laboratory the cells may be grouped together. Cocci, for example, may be joined in chains (Streptococci) or arranged in clusters (Staphylococci).

Motility

Some bacteria are motile, i.e. capable of movement. These bacteria posses long thread-like structures called flagella (sing. flagellum) which originate from inside the cell membrane. The flagella move in a whip-like manner and help to propel the bacteria through liquid, such as water. Bacteria can be classified further according to the number of flagella they possess and the position of the flagella on the bacterial cell.

Reproduction

Bacteria reproduced by a process known as binary fission. The nuclear material reproduces itself

and divides into separate parts and then the rest of the cell divides, producing two daughter cells which are equal in size. This process is shown hereunder.

Spore Formation

Spores are hard resistant bodies which are formed by some types of bacteria when conditions become adverse, i.e. when they are unable to survive in their environment and to obtain the materials necessary for growth. The spore is formed within the bacterial cell and then the rest of the cell disintegrates. Spores can survive adverse conditions for very long periods of time. When conditions become favourable the spore germinates producing a new bacterial cell. Spore formation occurs in only certain type of bacteria. The two groups of bacteria which form spores (*Bacillus* and *Clostridium*) are both rod-shaped.

Bacterial spores are resistant to heat and can survive in food when food is cooked. They are also resistant to cold (e.g. refrigeration) and to many chemical products designed to kill bacteria, such as disinfectants.

The normal cells of bacteria are described as *vegetative cells* to distinguish them from spores.

Toxins

Bacteria produce a variety of substances as a result of their metabolism. Some of these substances are harmful to man and animals and are known as toxins (i.e. poisons). There are two types of toxins:

1. Endotoxins

Endotoxins are produced within the bacterial cell and are not released into the body until the cell dies. Therefore, they tend to have a localised effect and usually cause harm in the region of the body where the bacteria are living. The symptoms of diseases caused by bacteria producing endotoxins usually do not appear untill some time after the living bacteria enter the body, since it is some time before the bacterial cells disintegrate. It should be noted that living bacteria must enter the body in order to cause this type of illness.

2. Exotoxins

Exotoxins are produced by bacteria and secreted into the surroundings. The toxin may act in the area around the bacteria but often it is carried by the bloodstream to produce its harmful effect in another part of the body. It is not necessary to ingest living bacteria; the illness is caused by the toxin alone. Some types of food poisoning illnesses are caused by eating a food containing an exotoxin, which has survived even though the bacteria which produced it have died. The symptoms of the illness may appear very soon after the exotoxin enters the body, although this is not always the case. Exotoxins tend to be more sensitive to destruction by heat.

Both types of toxins may be enterotoxins, i.e. substances which have a harmful effect on the digestive system. There is some confusion about the use of all three words to describe toxins and some texts give alternative definitions. This confusion may be due to the fact that some bacteria produce both types of toxins. Also in some cases it is not known exactly which type of toxin the bacteria produces.

3

ELEMENTARY ANATOMY AND PHYSIOLOGY

Anatomy

Anatomy is the study of the structure of the body. A knowledge of how the animal's body functions, helps with the understanding of animal husbandry and the reasoning of many management decisions concerned with feeding, growth and health of animals.

Table 3.1

Nomenclature for Systematic Anatomy

System	*Name of Study*	*Chief Structures*
Skeletal system	Osteology	Bones
Articular system	Arthrology	Joints
Muscular system	Myology	Muscles
Digestive system	Splanchnology	Stomach and intestines
Respiratory system	"	Lungs and air passages
Urinary system	"	Kidneys and bladder
Reproductive system	"	Ovaries and testes
Endocrine system	Endocrinology	Ductless glands
Nervous system	Neurology	Brain, spinal cord, nerves
Circulatory system	Angiology	Heart, vessels
Integumentary system	Dermatology	Skin
Sensory system	Esthesiology	Eye, ear

THE SKELETON SYSTEM

The animal's skeleton is living tissue. It has nerves and blood vessels, it can be damaged by disease, can break and repair and can adjust to changes in stress. The skeleton consists mainly of bone. Areas of cartilage are also present.

Functions of the Skeleton

1. To give shape to the body.
2. To provide anchor points for muscles and therefore movement.
3. As a reserve for minerals, mainly calcium, phosphorus and magnesium.

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4. For the production of red blood cells in the marrow of some long bones.
5. For the protection of vital organs, for example the rib cage protects the heart and lungs.

Bones of young animals are composed of about 60 per cent fibrous tissue while in old animals 60 per cent is composed of lime salts and thus it is more brittle than the former. Among inorganic substances, calcium, phosphorus and magnesium are the major elements which are never permanently retained by the bones. On the outside, bone is hard and compact but inside there is often a cavity, the medullary cavity, containing marrow (especially in long bones like those that form the limbs). Near the ends there is a type of bone known as 'spongy bone' although it is actually quite hard. Marrow is a soft tissue richly supplied with blood and is involved in the formation of blood cells. The outside of the bone is covered by a thin membrane, the *periosteum*, which is supplied with blood vessels and nerves.

The vertebrate skeleton has an axial and an appendicular (limb) part. The axial skeleton consists of the vertebrate, the ribs and sternum, and the skull; on the other hand the appendicular skeleton, includes the bones of both forelimb and hindlimb.

Axial Skeleton

The vertebra are arranged into a vertebral column or backbone extending from the base of the skull all the way caudally into the tail. There are fine distinct sections of the vertebrate column. The vertebra from each are specialized to perform their different functions.

Cervical Region

The cervical vertebrae are specialised to allow movement of the head in all directions.

Thoracic Region

The thoracic vertebrae are specialised for the attachment of the ribs. In mammals, each rib articulates with two thoracic vertebrae. The thorax provides bony protection for the thoracic and abdominal organs inside and attachment for the very important muscles of breathing and the extrinsic muscles of the forelimb. In Zebu (*Bos indius*) Indian Cattle, the spines of the last six thoracic and first three lumber vertebrae are divided dorsally. This bifidity is not seen in European cattle (*Bos taurus*).

Lumber Region

The lumber vertebrae can be distinguished by their well developed transverse processes. These are in some respects analogous to the ribs in that they serve as attachment for muscles of breathing. However, they also provide attachment for epaxial muscle as well.

Sacral Region

The sacral vertebrae are fused into a composite bone called the *sacrum*. On each side the sacrum bears a large flattened process for articulation to the ilium of the pelvic girdle.

Coccygeal Region

The caudal vertebrae are progressively reduced. These serve as sites for insertion of the muscles used in moving the tail.

Axial Skeleton of Fowl

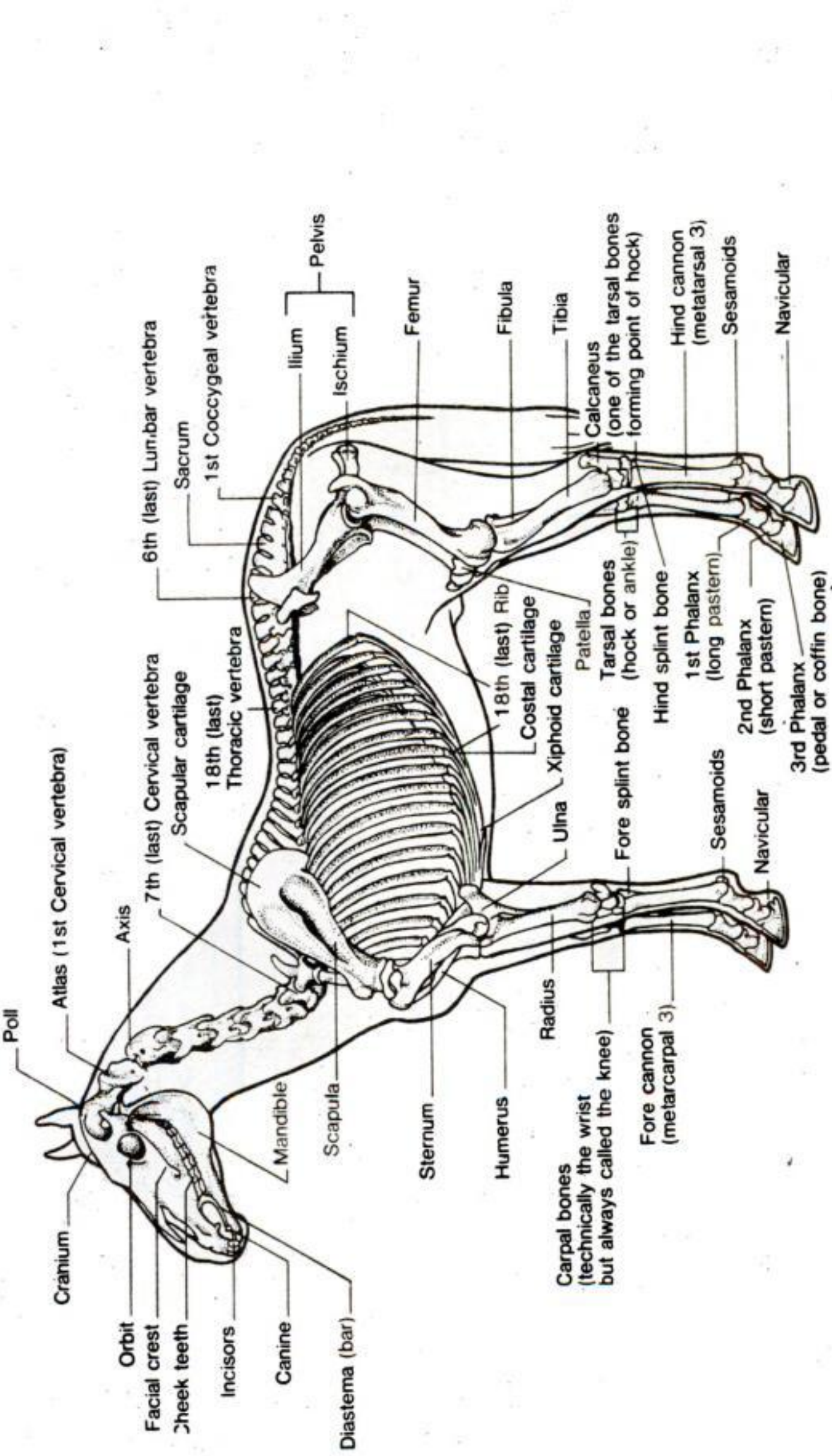


Fig. 3.1 Anatomy of the Horse.

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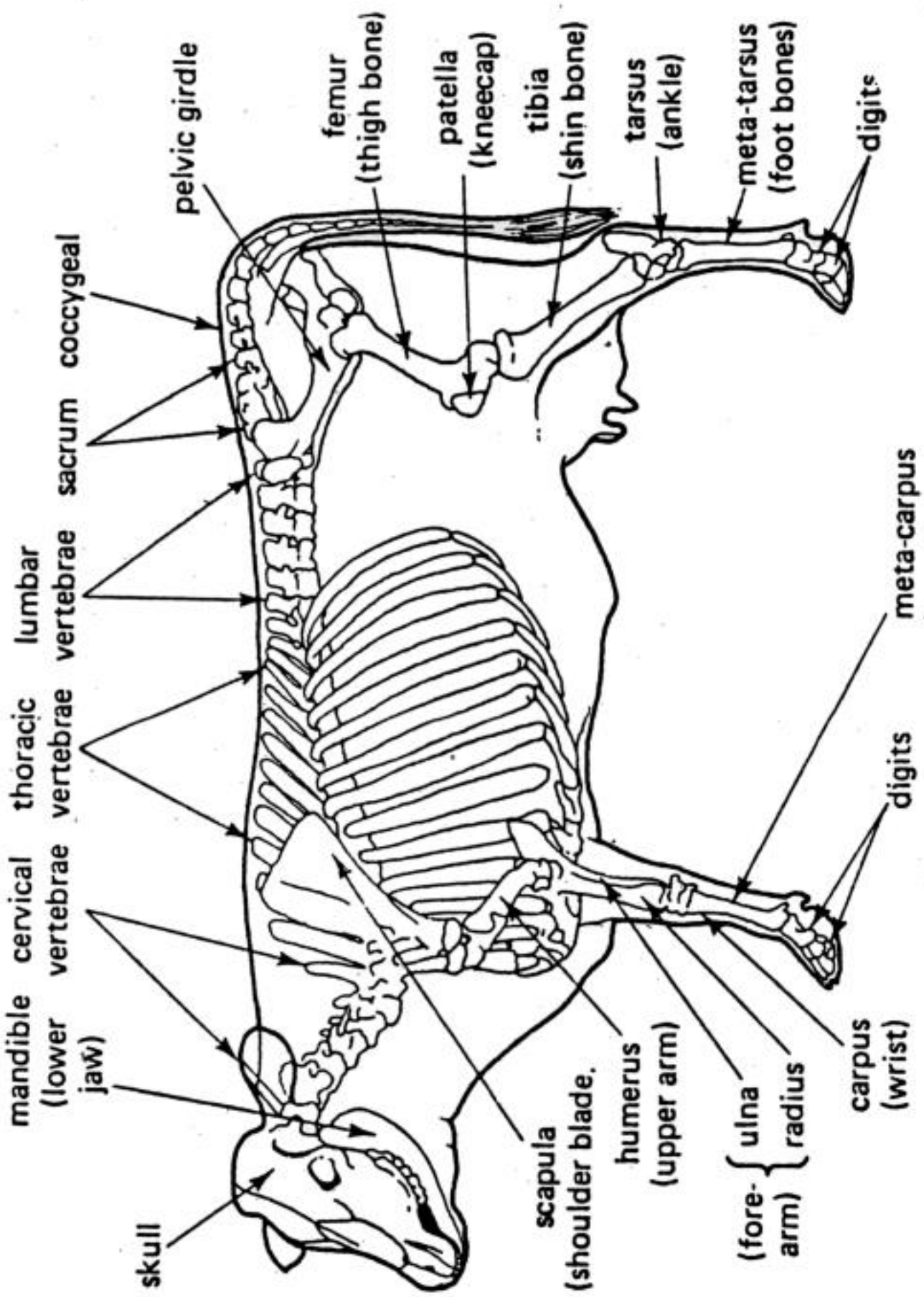
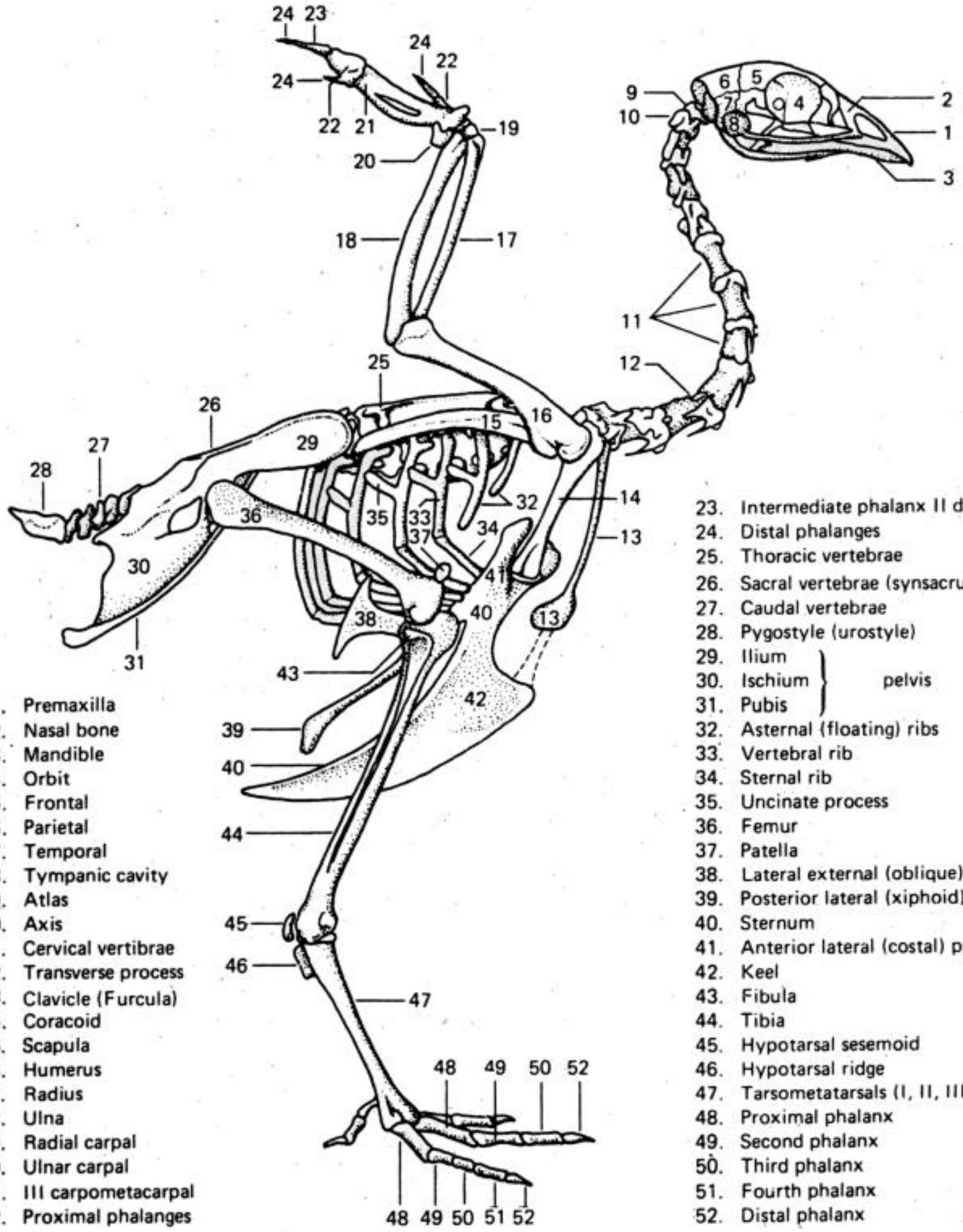


Fig. 3.2 Anatomy of the Cow.



1. Premaxilla
2. Nasal bone
3. Mandible
4. Orbit
5. Frontal
6. Parietal
7. Temporal
8. Tympanic cavity
9. Atlas
10. Axis
11. Cervical vertibrae
12. Transverse process
13. Clavicle (Furcula)
14. Coracoid
15. Scapula
16. Humerus
17. Radius
18. Ulna
19. Radial carpal
20. Ulnar carpal
21. III carpometacarpal
22. Proximal phalanges
23. Intermediate phalanx II digit
24. Distal phalanges
25. Thoracic vertebrae
26. Sacral vertebrae (synsacrum)
27. Caudal vertebrae
28. Pygostyle (urostyle)
29. Ilium
30. Ischium
31. Pubis

pelvis

32. Asternal (floating) ribs
33. Vertebral rib
34. Sternal rib
35. Uncinate process
36. Femur
37. Patella
38. Lateral external (oblique) process
39. Posterior lateral (xiphoid) process
40. Sternum
41. Anterior lateral (costal) process
42. Keel
43. Fibula
44. Tibia
45. Hypotarsal sesemoid
46. Hypotarsal ridge
47. Tarsometatarsals (I, II, III, IV)
48. Proximal phalanx
49. Second phalanx
50. Third phalanx
51. Fourth phalanx
52. Distal phalanx

Fig.3.3 Anatomy of the Chicken

In the fowl the axial skeleton shows some differences from that of the mammal. In the coccygeal region there is only one bone, the *pygostyle*. The avian lumber and sacral vertebrae are fused into a *synsacrum*. The number of ribs are variable, so there may be 5 or 6 thoracic vertebrae and 17 to 16 cervical vertebrae respectively. The last cervical and first three thoracic vertebrae are also fused together. Four of the ribs have two parts each: a vertebral part articulating with a thoracic vertebra and a sternal part articulating with the *sternum* or *breastbone*.

The Appendicular Part

It consists of limbs of farm animals which are very vulnerable to injury and infection, so it is important that the livestock owner should have a knowledge of its anatomy. The bones in the limbs of sheep are very similar to those of the cow, whilst, in the pig there is a slight variation.

The Fore Limb (Fig. 3.4)

1. *Scapula*. Farm animals have no collar bone on which to 'hang' the fore limb. Instead the scapula is held in place by being embedded in a band of very tough shoulder muscle.

2. *Radius and Ulna*. In humans these are two separate bones (in the forearm) to enable twisting at the wrist. In farm animals the radius and ulna are bound together by fibrous tissue, so on twisting movement is possible. The top of the ulna points upto to form the point of the elbow. This provides attachment for muscles and better leverage.

3. *Metacarpus*. In cows this looks like one bone, except at its lower end where it divides to form the start of the cow's two-part foot.

The hind limbs (Fig. 3.4)

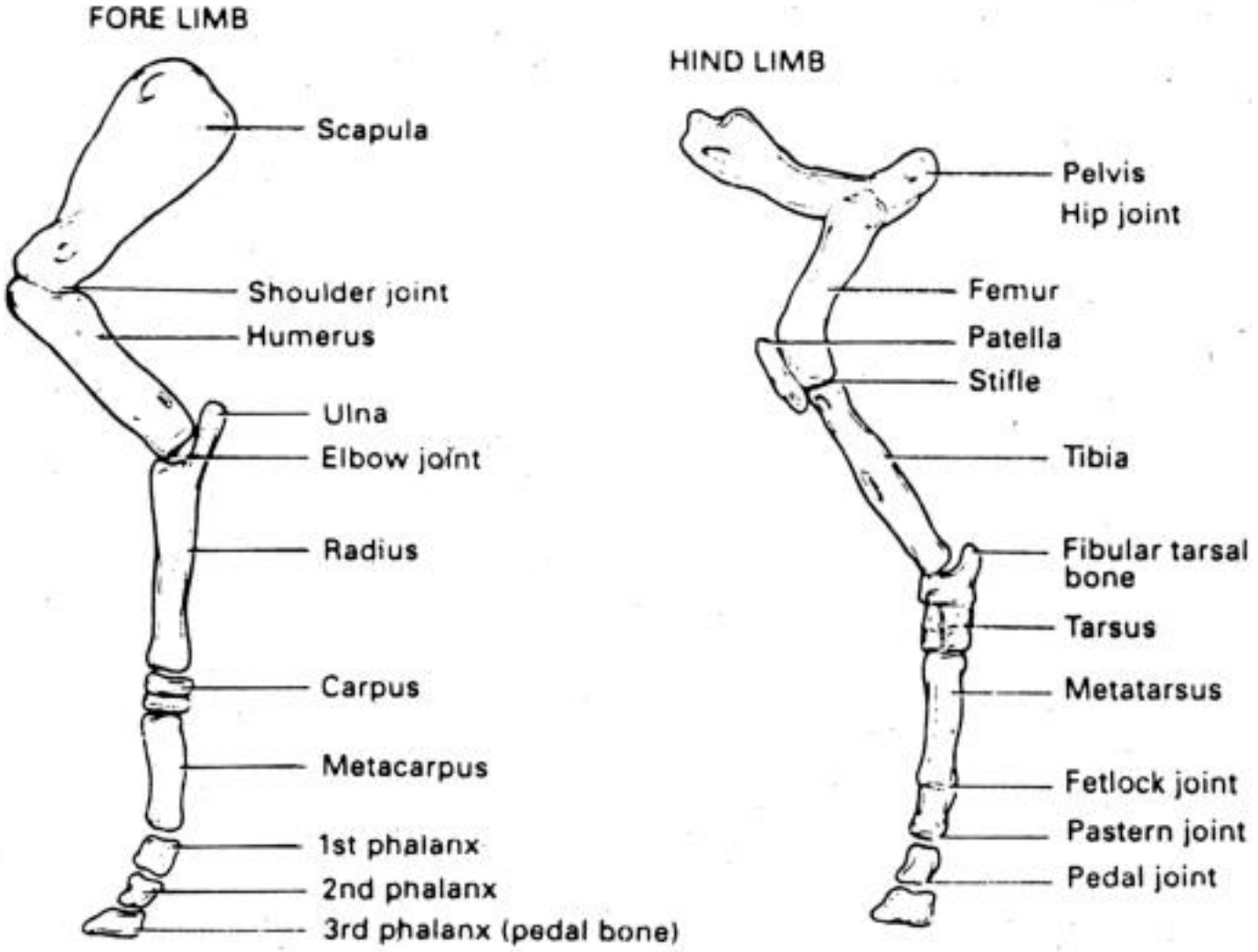


Fig. 3.4 The fore limb and the hind limb of a cow.

1. *Pelvis.* Three bones fused together to form the pelvic girdle. It is through this ring of bone that the young animal must pass at birth. In the case of the sow there are usually no problems as the piglets are so small, but problems can arise for the ewe and the cow. A common misconception is that the pelvic 'bones slacken for calving'. This is not so, it is the slacking of ligaments in the pelvic that gives the feeling of slackness.

2. *Femur.* One of the biggest bones in the body, heavily muscled, running downward and forward.

3. *Patella.* The equivalent of the kneecap in man.

4. *Fibular tarsal bone.* This projects upwards and backwards to form a lever for attachment of the *Achilles tendon.*

5. *Metatarsus.* As the metacarpus of the fore limb.

Foot/Hoof

Below the metacarpus (fore limb) and metatarsus (hind limb), all four feet have the same structure.

In cow's and buffalo's two-part foot (Fig. 3.5) each part is known as a digit and each digit is composed of three bones known as *phalanges* (singular : phalanx). The third phalanx, which has the same shape as the outer hoof, is commonly referred to as the *pedal bone.*

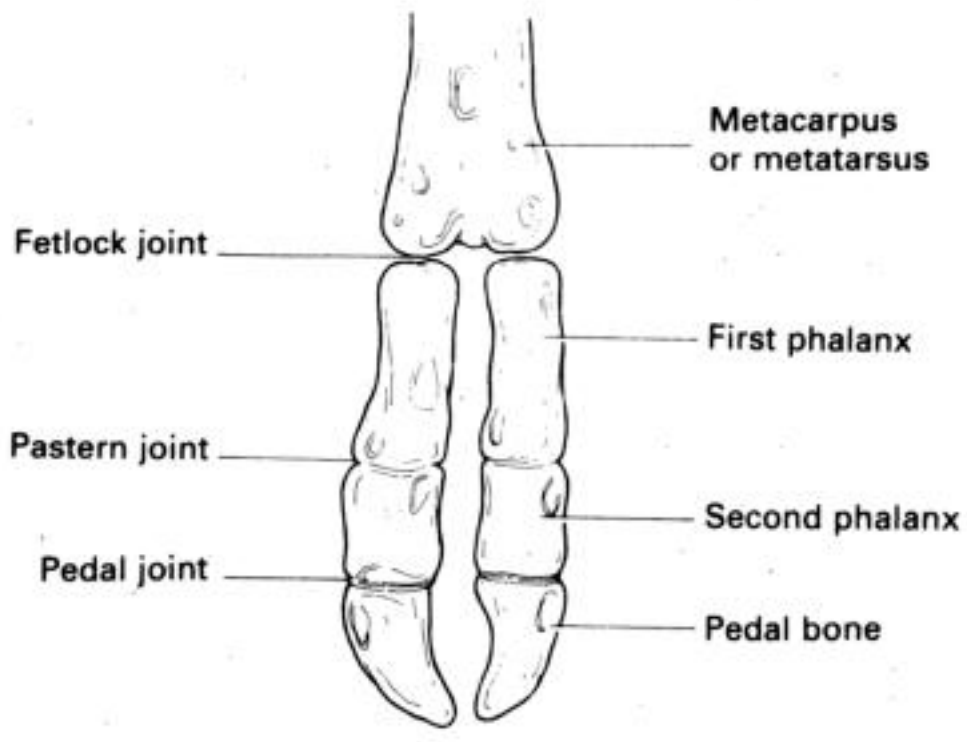


Fig. 3.5 The two-part foot of the cow.

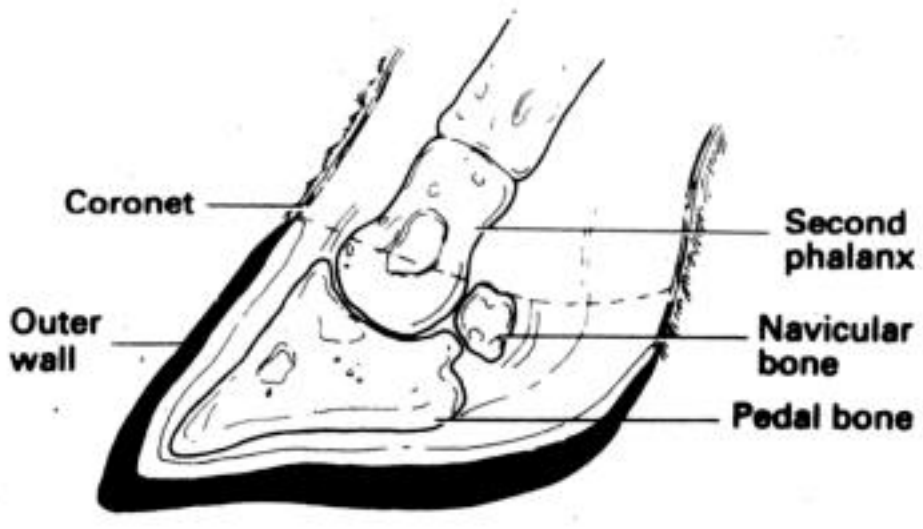


Fig. 3.6 Cross-section through a cow's foot.

In Fig. 3.4 it can be seen that the outer hoof (horn) comes up to almost the centre of the second phalanx, so little movement is allowed in the pedal joint. The area where the outer wall joins the skin of the leg is known as the *coronet*. The *navicular* bone is a small bone situated at the rear of the pedal bone.

The pedal bone is covered with a substance known as laminae or 'quick'. The laminae is very sensitive and is richly supplied with blood vessels. It has specialised cells which produce the hard outer wall of the hoof.

Growth and Repair of Bone

In the young animal there is a layer of cartilage within the bone that acts as a growing point. The bone will lengthen and thicken. This process is brought about by two specialised cells:

Osteoclasts — Which break down the cartilage.

Osteoblasts — Which deposit minerals onto bone to build a rigid material.

These two cells are also involved in the repair of bone; oesteoclasts dissolve any splinters of bone and osteoblasts build up new bone. The speed of any repair depends to a large extent on the blood supply to the bone. As the bone of young animals has a better blood supply than the bone of older animals, breaks in young bone will normally heal more quickly. The broken ends must be touching and immobilized for fibrous tissues to form in the break and so start the process of repair.

Cartilage

Cartilage is a flexible, elastic, glossy-looking substance composed mainly of a protein called *Chondrin*. It is present in joints to help with movement and is also found in noses, ears and the lower end of rib bones. The skeleton of a fetus is made up almost entirely of cartilage, but as the animal ages and develops, the cartilage slowly changes to bone, a process of bone formation, known as *ossification*.

JOINTS

These are the site of junctions or unions between two or more bones, especially one that admits of motion of one or more of the components. Movement in joints is caused by the contraction and expansion of muscles associated with joints. The muscles do not go directly over the joints from bone to bone. They are attached to the bones by tough, inelastic fibres, the *tendons*.

The muscle that move the joint work in pairs. One muscle contracts causing a pulling action in its tendons, the opposing muscle relaxes, increasing in length, and thus allowing the tendons to move forward.

Based on their structure and the material that unites them, joints may be classified as fibrous, cartilaginous and synovial joints.

Fibrous joints. These contain no joint cavity. The bones are united by fibrous tissue.

Cartilaginous joints. These contain no joint cavity. The bones are united by cartilage.

Synovial (Diarthrodial) joints. The general structure of most synovial joints is similar and includes the following: articular surfaces, articular cartilages, articular cavity, joint capsule, and ligaments.

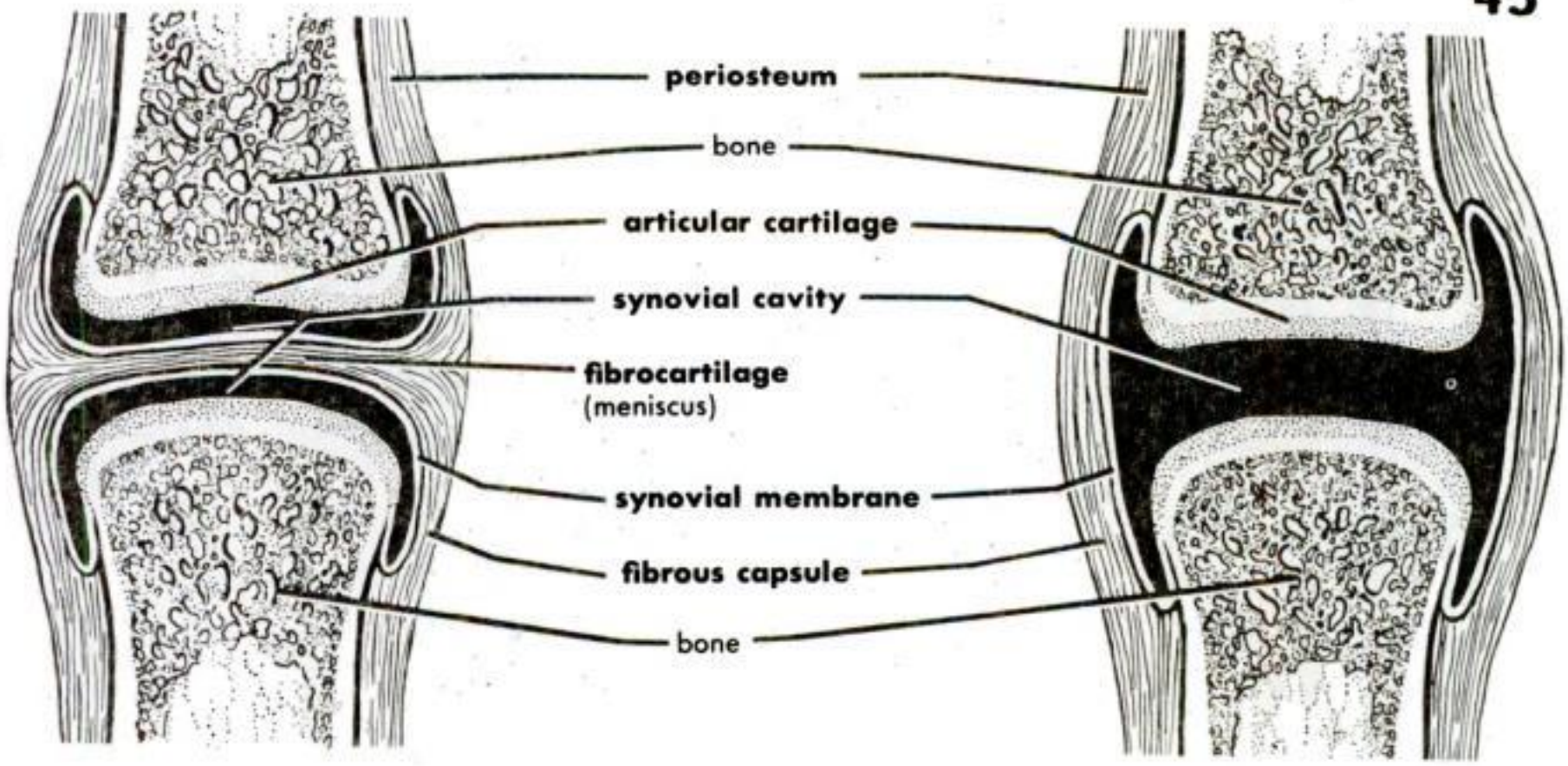


Fig. 3.7 Types of Synivial articulations.

DENTITION

Teeth can be considered as part of the skeleton, but they are really a modified form of skin. They contain the hardest substance in the animal's body, the enamel. There are three types of teeth in mammals:

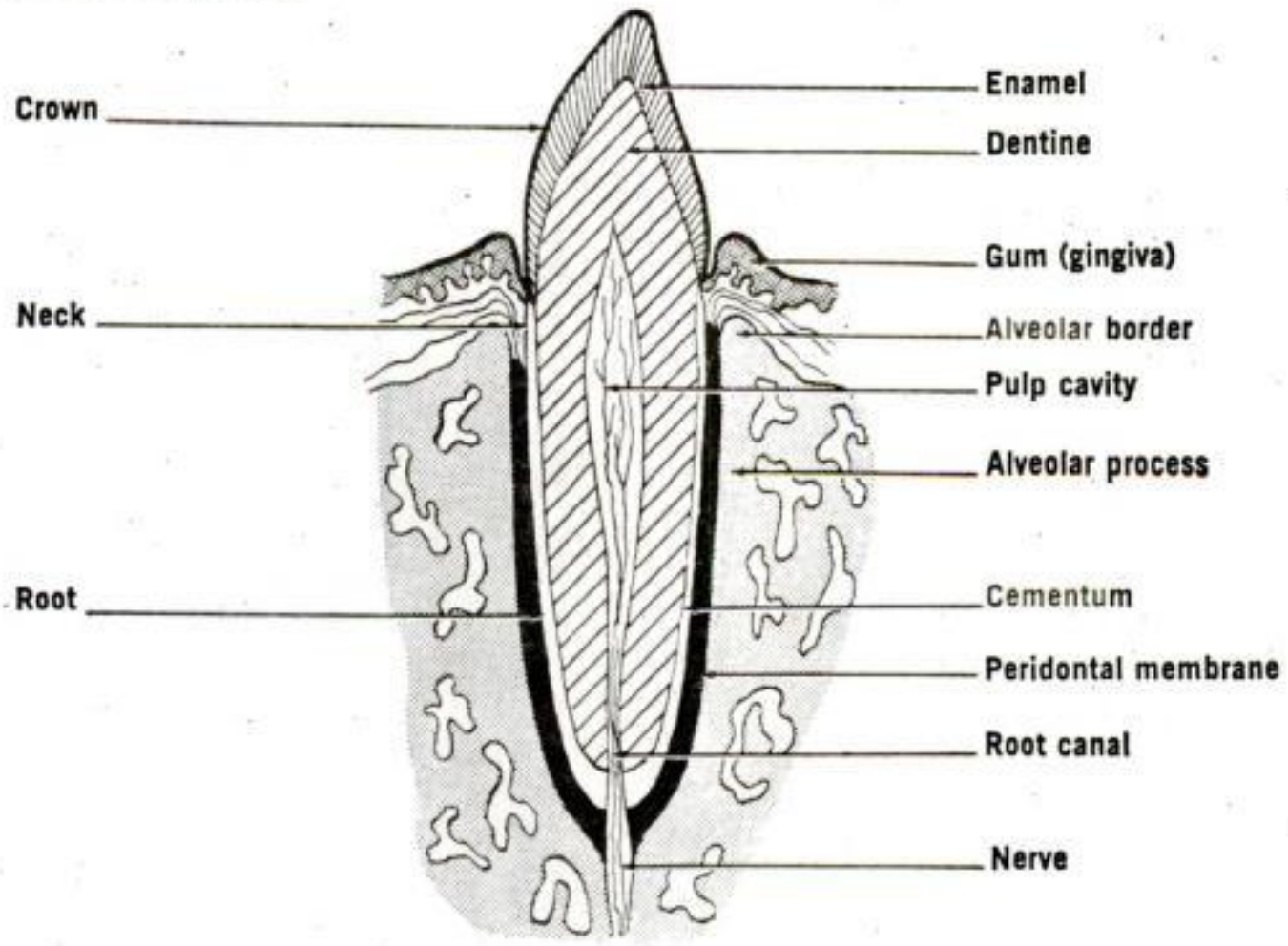


Fig. 3.8 Structure of a tooth.

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Incisors. These are the teeth located in the front of the mouth. Broad and sharp teeth used for cutting. They are present only in the lower jaw of cattle, sheep, goat and buffalo.

Canine. These are placed back to incisors. Sharp pointed small teeth used for gripping and ripping; present only in the lower jaw.

Pre-molars and molars. Broad, flat teeth with ridges are the largest and strongest of all teeth, found in the sides of the jaws and used for grinding. The grinding is an important function as it is at this stage that the saliva and digestive juices are mixed into the mass of chewed food.

Cattle

At birth calves will normally have eight temporary incisors ready to appear through the gums of the lower jaw (Fig. 3.9 *a*).

All of the incisors will be visible and ready to use about 1 month after birth. From then until the animal is nearing 1½ years old these calfhood incisor teeth will remain in position.

The replacement of the calf's incisor teeth by the permanent incisors is a gradual process, and the loss of calf incisors is followed by their replacement by the corresponding permanent incisors. This change of calf to adult teeth follows a definite and fairly regular pattern (Fig. 3.9 *b–f*)

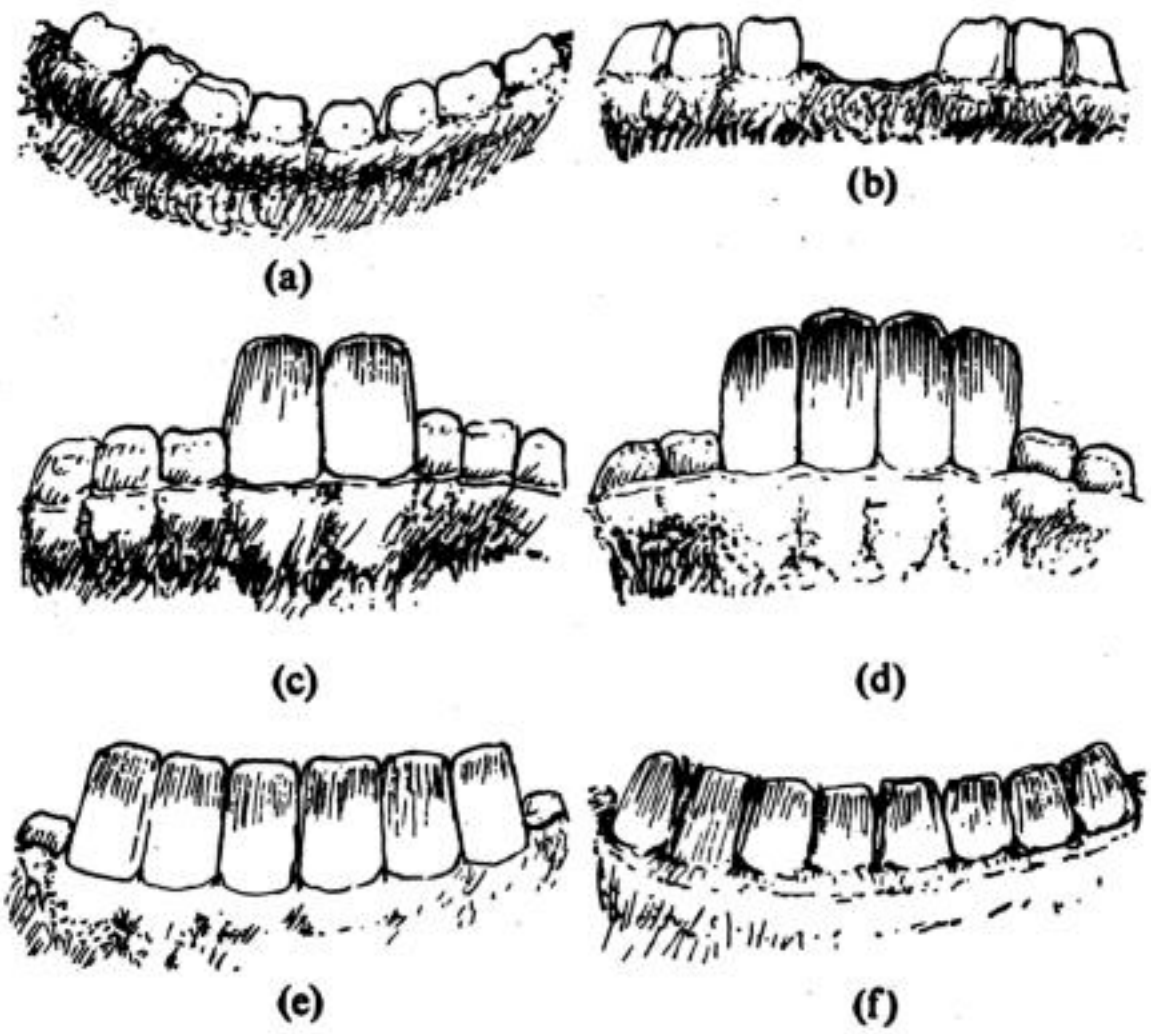


Fig. 3.9 Development of teeth in Cattle

(*a*) Temporary incisor teeth.
(*b*) At 1½ years: loss of central pair of temporary incisors.
(*c*) At 1 year 10 months: appearance of central pair of permanent incisors.
(*d*) At 2½ years: appearance of second pair of permanent incisors.
(*e*) At 3 years: appearance of third pair of permanent incisors.
(*f*) At 3½ years: appearance of fourth pair of permanent incisors—'full mouth'.

Sheep

A similar, but much speeded-up, pattern of change of teeth takes place with sheep (Fig. 20).

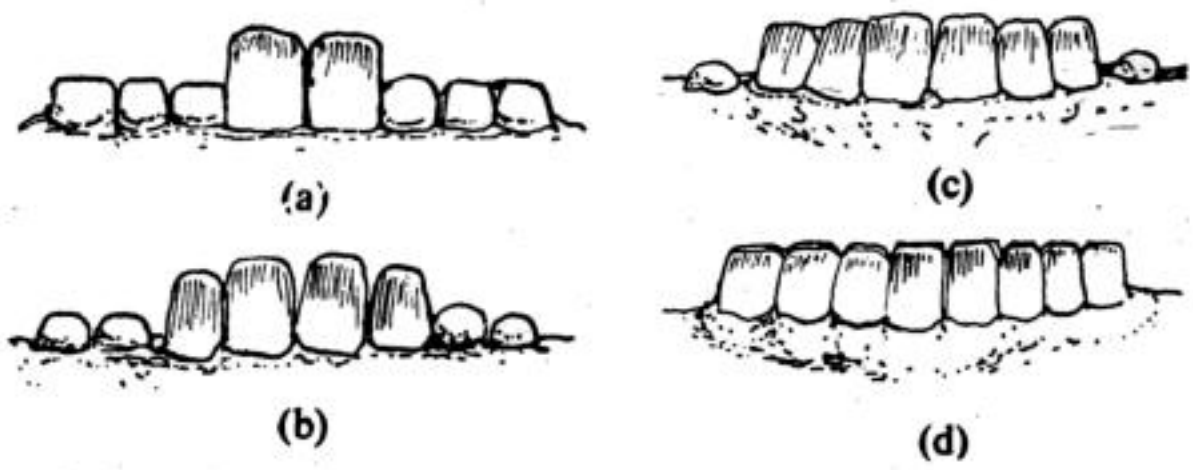


Fig. 3.10 Development of teeth in Sheep.

(*a*) At 1 year: appearance of first pair of permanent incisors.
(*b*) At 1 year 10 months: appearance of second pair of permanent incisors.
(*c*) At 2 years 3 months: appearance of third pair of permanent incisors.
(*d*) At 3 years: appearance of fourth pair of permanent incisors—'full mouth'.

Number and type of permanent teeth

	Incisors	Canine	Pre-molar	Molar	Total
Cattle upper jaw	0	0	6	6	32
Cattle lower jaw	8	0	6	6	
Sheep upper jaw	0	0	6	6	32
Sheep lower jaw	8	0	6	6	
Pigs upper jaw	6	2	8	6	44
Pigs lower jaw	6	2	8	6	

Animals are born with a temporary set of 'milk teeth'. These are later replaced by 'permanent teeth'. In cattle, buffaloes, seep and goat the incisors of the upper jaw are replaced by a hard dental pad.

THE MUSCLE SYSTEM

The selling of muscle (meat) is a major part of animal husbandry man. Indeed, the goat, sheep, pig and beef industries depend on it. Approximately 48% of the body is muscle mass.

Muscles are composed of bundles of muscle cells (muscle fibres), which are contractile. The main function of the muscular system is *locomotion* defined as progressive movement. Types of locomotion or gaits used by four-legged land vertebrates include the following:

1. In walking only one foot in four leaves the ground at a time.
2. In running only one foot touches the ground at a time.
3. In pacing, the natural gait of camels, the fore and hind feet on the same side.
4. In trotting (a pace between walking and running as found in horse with legs moving together diagonally), the left forefoot and right hind foot touch the ground at the same time, followed in turn by the right forefoot and left hind foot.

Locomotion is an essential element in the development and maintenance of healthy muscle. Muscle that is not used shrinks in size or atrophies. Excessive or abnormal body movement under stressful conditions, can affect muscle adversely, resulting in meat that loses flavour and deteriorates rapidly. There are three types of muscles viz. (1) Voluntary or skeletal muscle, (2) Involuntary or smooth muscle and (3) Cardiac (heart) muscle.

1. Voluntary or Skeletal Muscle

This forms the bulk of body muscle, and therefore, of 'meat'. The typical voluntary muscle has a tendon at each end, usually, fixed to a bone, with the muscle block in between. The muscle is composed of fibres grouped together in bundles (Fig. 3.11)

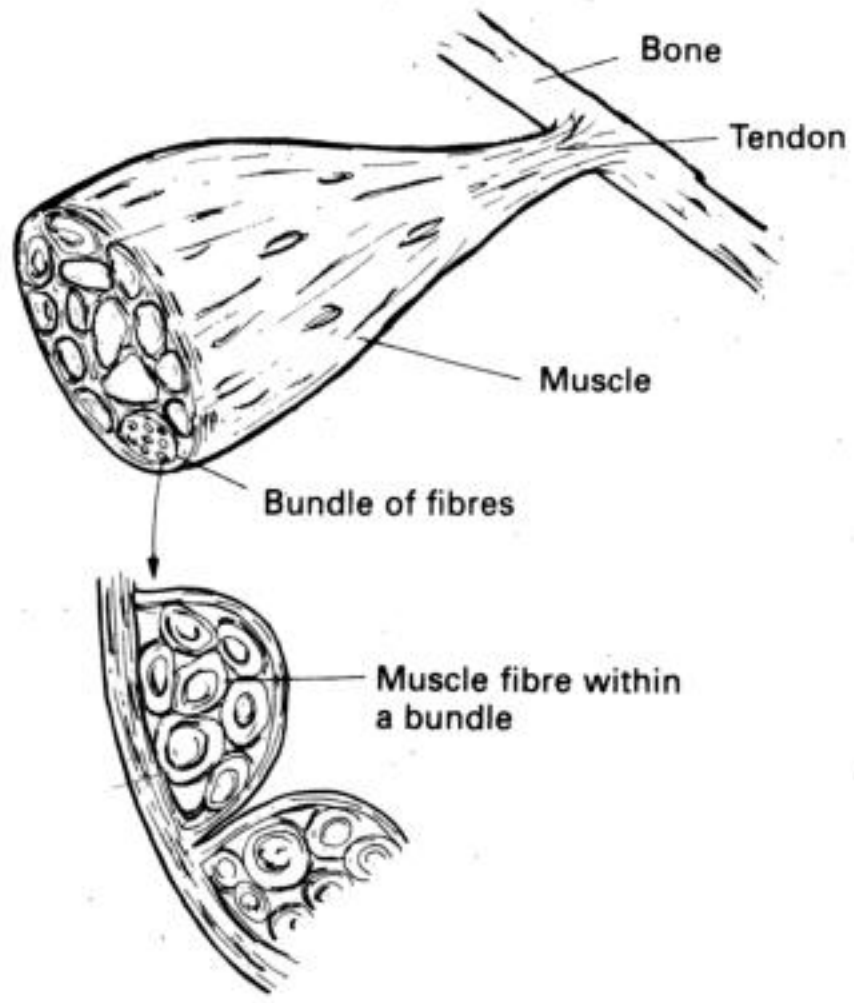


Fig. 3.11 Structure of voluntary muscle.

Each fibre is supplied with a nerve and a blood vessel. When the nerve is stimulated, the fibre contracts. The stronger the nerve impulse, more powerful the contraction. This can result in a reduction in the oxygen content of myoglobin (There are 2 major heme containing proteins, *myoglobin* and *haemoglobin* responsible for holding and transporting oxygen in the body). In the absence of oxidative metabolism, acidity of the muscle increases. Reduced oxygen content darkens meat as myoglobin, like hemoglobin, is darker when deoxygenated.

In the presence of high acidity, meat deteriorates rapidly even when adequately refrigerated.

Careful attention to humane (having the kind feelings proper to man) slaughter can thus save money for the butcher and is obviously a practice to be encouraged everywhere.

Voluntary muscle is under the direct control of the animal's will.

2. Involuntary or Smooth Muscle

This type of muscle, which has a different structure from voluntary muscle, is found around internal organs, e.g. the gut and blood vessels.

This means that food can be moved along the gut by wave-like contractions of the muscle (peristalsis) and that blood vessels can expand and contract when necessary. These muscles work independently of the animal's will and are controlled by the central nervous system.

3. Cardiac (heart) Muscle

This is an involuntary muscle with a different structure to both voluntary and smooth muscle. It has a short but very strong contraction followed by a period of rest, thus the beating action of the heart. One side of the heart contracts whilst the other rests. It acts independently of the body, but hormones can alter the speed of the beat such as adrenalin.

PHYSIOLOGY

Physiology deals with the science that states the function of various parts and organs of living organism i.e., it is concerned with how the body works.

THE DIGESTIVE ORGANS

This consists of the organs directly concerned in the reception, digestion and absorption of the food, its passage through the body and the expulsion of the unabsorbed portion. The system can be divided as (*A*) *Alimentary canal*—It runs from the lips to the anus. It has mouth, pharynx, oesophagus, stomach, small intestine, large intestine and rectum. (*B*) *Accessory digestive organs*—It includes teeth, tongue, salivary, liver glands and pancreas.

Digestive Organs of Ruminants

A. ALIMENTARY CANAL

The alimentary canal of the ruminants is much more complex than that of the non-ruminants. It has four compartments in the stomach namely, (*i*) the *Rumen*, or paunch; (*ii*) the *Reticulum*, or honey comb; (*iii*) the *Omasum*, or many plies; and (*iv*) the *Abomasum*, or the true stomach. The intestine represents a long tubule approximately 180 feet long in average dairy cattle. The first three compartments of the compound stomach are considered to be the enlargements of the oesophagus or gullet. This peculiar feature of the stomach in ruminants seems to have developed under the stimulus of coarse feeds and feeding on them in a hurry without proper mastication.

The Mouth

It is the organ of prehension, mastication, insalivation and rumination. The prehension

(food gathering) is assisted by the rough tongue and teeth of a ruminant. It is followed by a preliminary chewing called mastication and mixing of the saliva. Enormous amount of saliva (100-200 lit. per day in a cow) is secreted by the three pairs of salivary glands located in the mouth region. It is rich in sodium bicarbonate and its amount increases with dry and acidic feeds like hay and silage. It lubricates the bolus and facilitates its passage through the pharynx and the oesophagus to the rumen. There is no ptyalin (a digestive enzyme present in some other species) in the saliva of the ruminants, therefore, no digestion takes place in the mouth of the ruminants.

After prehension is complete, the cow starts chewing her cud called rumination. The rough materials which escaped through grinding during preliminary mastication, and are stored and exposed to bacterial action in the rumen, are forced back into the mouth (regurgitation) for further mastication. This is also known as rumination. The regurgitated bolus weighing from 90–120 gm requires 3 seconds to ascend, about 50 seconds for rechewing and 105 seconds to descend. Rumination is therefore, a long process and occupies about 8 hours. If the animal is alarmed or disturbed or goes sick it ceases to ruminate.

After the bolus is thoroughly masticated and mixed with saliva it is swallowed again with the help of the throat muscle. This time it remains almost semisolid and goes into the ventral sac of the rumen wherefrom it finally passes to abomasum through reticulum and omasum. Water and other liquid drinks reach the omasum and/or abomasum directly. This is made possible by the oesophageal groove.

The Oesophagus

The oesophagus, a direct continuation of the pharynx, is a muscular tube extending from the pharynx to the upper most part of the stomach known as *cardia* just caudal to the diaphragm. From the pharynx the oesophagus passes dorsal to the trachea and usually inclines somewhat to the left in the neck.

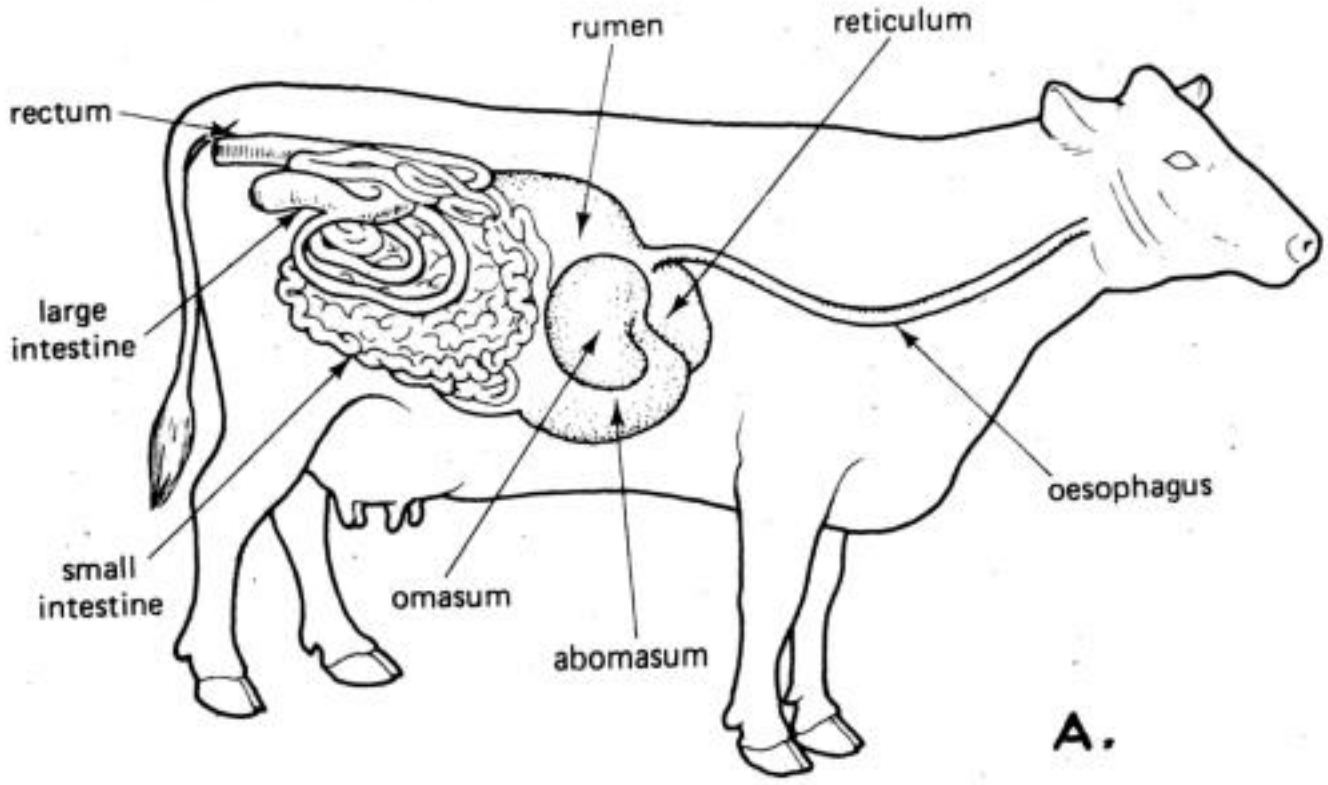
The muscular wall of the oesophagus consists of two layers that cross obliquely, then spiral and finally form an inner circular and outer longitudinal layer. The cardia is ordinarily tightly closed by contraction of a ring of muscle tissue, the *Cardiac sphincter*, but this muscle relaxes and the cardia relaxes and then cardia opens wide when boli are passing into or out of the rumen and when gas escapes.

The Rumen

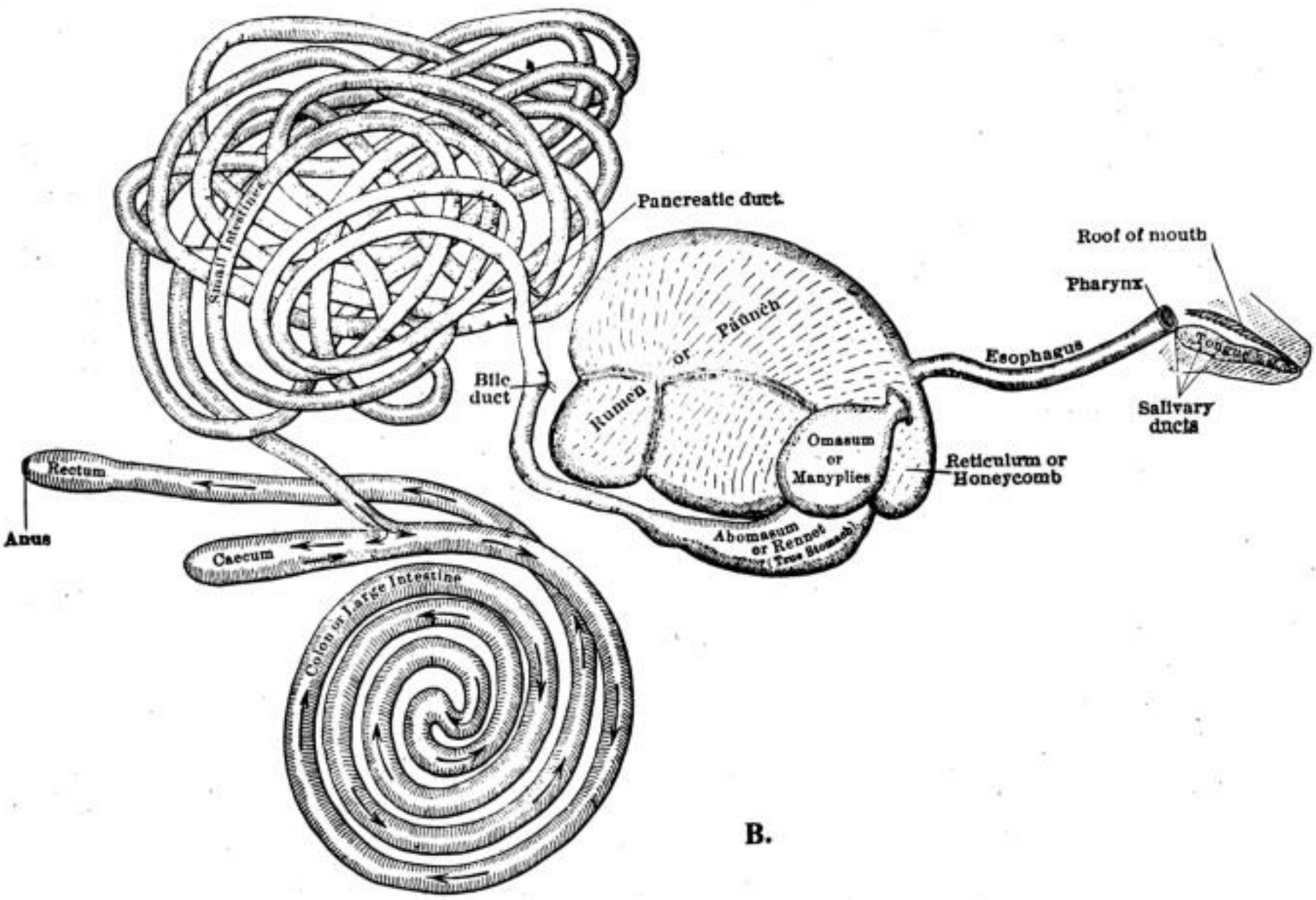
It is the largest compartment of the stomach and has a very great significance in ruminant digestion and has several functions to perform. Even fifty years ago, the rumen action was a deep dark mystery. Today, thanks to scientific research, much more is known about the rumen processes than were known, 60 years ago.

This large voluminous sac which extends from the diaphragm to the pelvis almost entirely fills the left side of the abdominal cavity. The rumen is subdivided into sacs by thick muscular boundaries known as pillars, which appear from the exterior of the rumen as grooves. The dorsal and ventral sacs are separated by a nearly complete circle. The dorsal sac is the largest compartment. The dorsal sac overlaps the ventral sac and is continuous cranially with the reticulum over the *ruminoreticular* fold, which separates the floor of the rumen from the floor of the reticulum.

Caudally the dorsal sac is further subdivided by the dorsal coronary pillars, which form as incomplete circle bounding the dorsal blind sac. The caudal part of the ventral sac is a



A.



B.

Fig. 3.12 (A) Digestive tract inside a Cow. (B) The same schematic tract in more details.

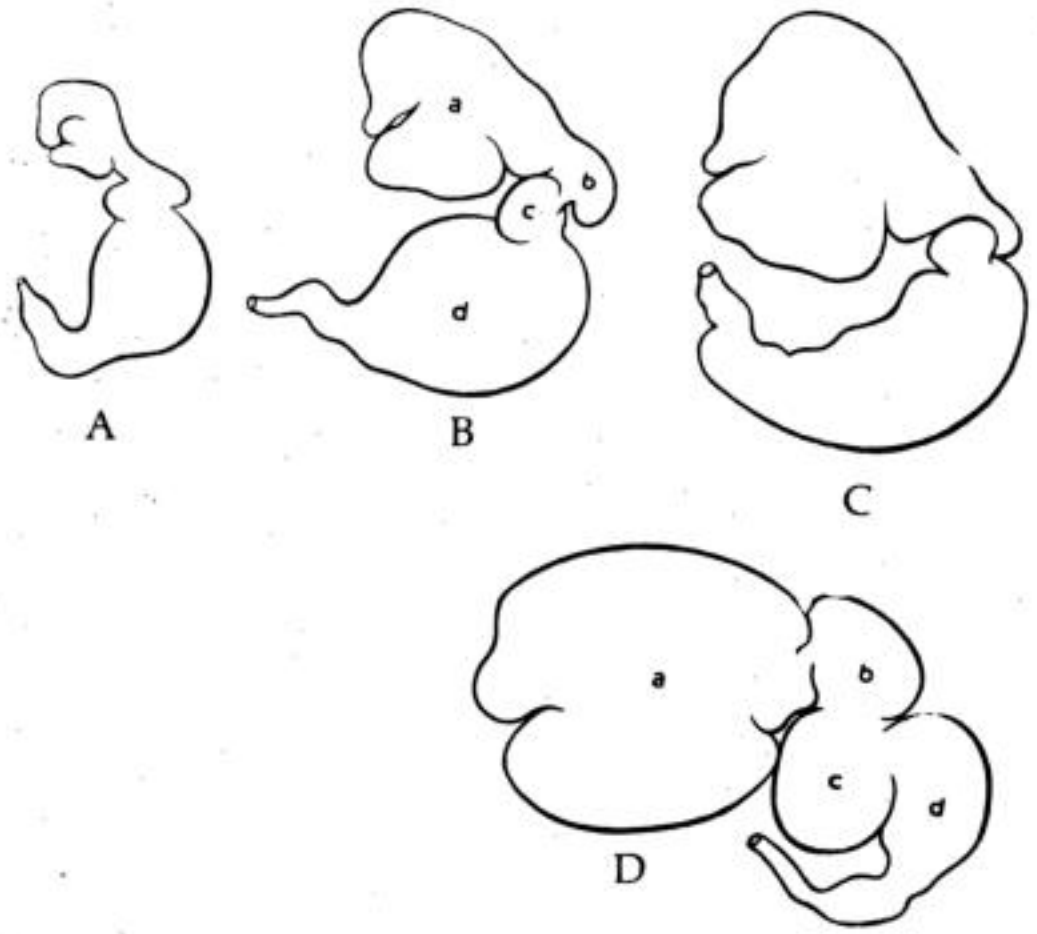


Fig. 3.13 ***Relative sizes of the bovine stomach compartments at various ages.*** **A.** 3 days old. **B.** 4 weeks old. **C.** 3 months old. **D.** Adult. *a*, rumen; *b*, reticulum; *c*, omasum; *d*, abomasum. From Nickel, R., Schummer, A., and Seiferle, E.: The Viscera of the Domestic Mammals. 2nd Ed. Berlin, Verlag Paul Parey, 1979.

diverticulum separated from the rest of the ventral sac by the ventral coronary pillars.

The mucous membrane lining the rumen is glandless stratified squamous epithelium. The most ventral parts of both sacs of the rumen contain numerous papillae up to 1 cm. in length, but papillae are almost entirely absent on the dorsal part of the rumen.

Rumen environment

The liquid phase of the rumen contents contains about 10 – 20% by weight of organic matter and has a pH between 5.8 to 6.8. With large amounts of readily fermentable carbohydrate entering the rumen, however, the pH may fall to around pH 4.0. Conversely, on very poor forages, the pH may rise to pH 7.5 or more, but these are the extremes of the pH range.

The pH of the reticulo-rumen is maintained at a fairly constant level by the alkalanity of the large volumes of saliva (pH = 8.0) entering the rumen, by the buffering capacity of the HCO_3^- content of the saliva and by removal of the acidic end products of microbial fermentation through the rumen wall at a rate approximately equal to that at which they are produced.

The temperature of the contents of the reticulo-rumen is stable at around 39°C.

The gas phase above the digesta in the reticulo-rumen consists of approximately 65% CO_2, 25% CH_4, 7% N_2 and trace amounts of H_2 and O_2. The CO_2 and CH_4 are derived from microbial fermentation as in the small amount of H_2. The N_2 and O_2 enter the gas phase of the reticulo-rumen along with ingested forage.

The liquid phase of reticulo-rumen has an oxidation-reduction potential of about – 350 mV, thus it is clear that reticulo-rumen environment is extremely reduced and almost devoid of oxygen.

The inorganic solutes present in the reticulo-rumen are derived from the saliva. Of the cations present in the rumen, only Na^+ is transported across reticulo-ruminal wall in gradient

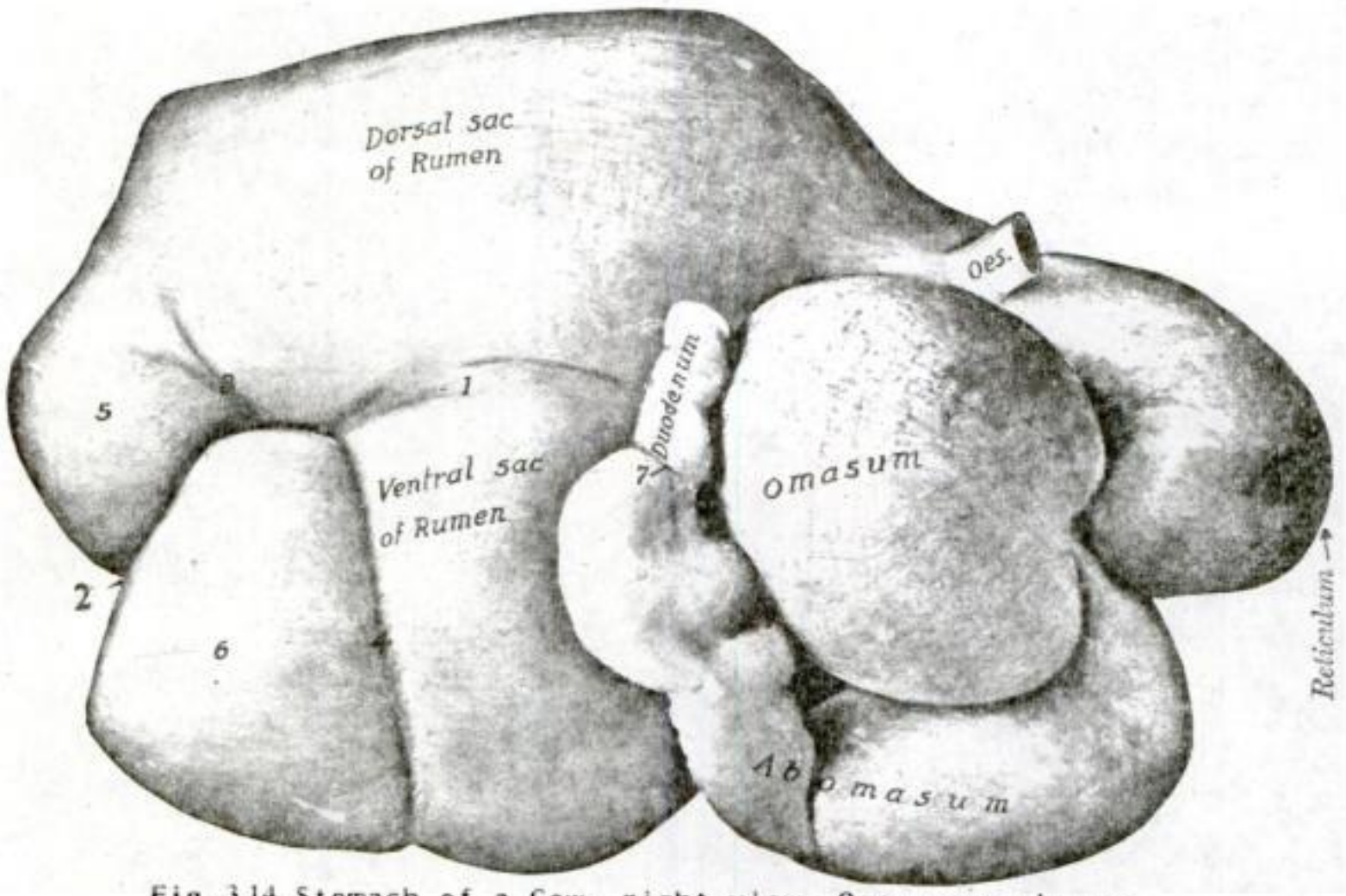


Fig. 3.14 Stomach of a Cow, right view. Oes., oesophagus; 1, right longitudinal groove of rumen; 2, posterior groove of rumen; 3, 4, coronary grooves; 5, 6, posterior blind sacs of rumen; 7, pylorus.

which occurs between the rumen and the blood stream. As a consequence of this, the ionic content of the rumen closely reflects that of the saliva.

The Reticulum

The reticulum is the most cranial compartment. It is also called the honey comb, and as the names imply, it is lined with mucous membrane containing many intersecting ridges which subdivide the surface into honey comb like compartments. The surface is stratified squamous epithelium. The location of the reticulum immediately behind the diaphragm places it almost in opposition to heart, so any foreign objects such as wire or nails that may be swallowed tend to lodge in the reticulum and are in a very good position to penetrate into the heart. The reticular groove commonly referred to as the oesophageal groove, extend from the cardia to the omasum, and is formed by two muscular folds which can close to direct materials from the oesophagus into the omasum directly, or open and permit the materials to enter the rumen. The groove appears to be less functional in adult ruminants than in suckling animals. However, it has been demonstrated that in drenching sheep, the drench enters the abomasum directly.

The Omasum

The omasum is a spherical organ filled with muscular laminae, bearing pointed papillae arranged in such a manner that food is moved from the *reticulo-omasal* orifice between the laminae, and on to the *omaso-abomasal* orifice. Each lamina contains three layers of muscle, including a central layer continuous with the muscle wall of the omasum.

The floor of the omasum as well as the leaves are covered with stratified squamous epithelium.

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At the junction of the omasum and abomasum is an arrangement of folds of mucous membrane, the *vela terminalia*, derived from the omasum in the cow, but from the abomasum in the sheep.

The large size of the reticulo-rumen has already been mentioned and, as the turnover rate of the reticulo-rumen is of the order of 1-1.5 volumes per day, it is clear that a very large volume of liquid enters the omasum from the reticulo-rumen. The material entering the omasum contains 90-95% water and the primary function of this organ is to remove water by about 50%.

In addition to removing water, the omasum also absorbs VFA.

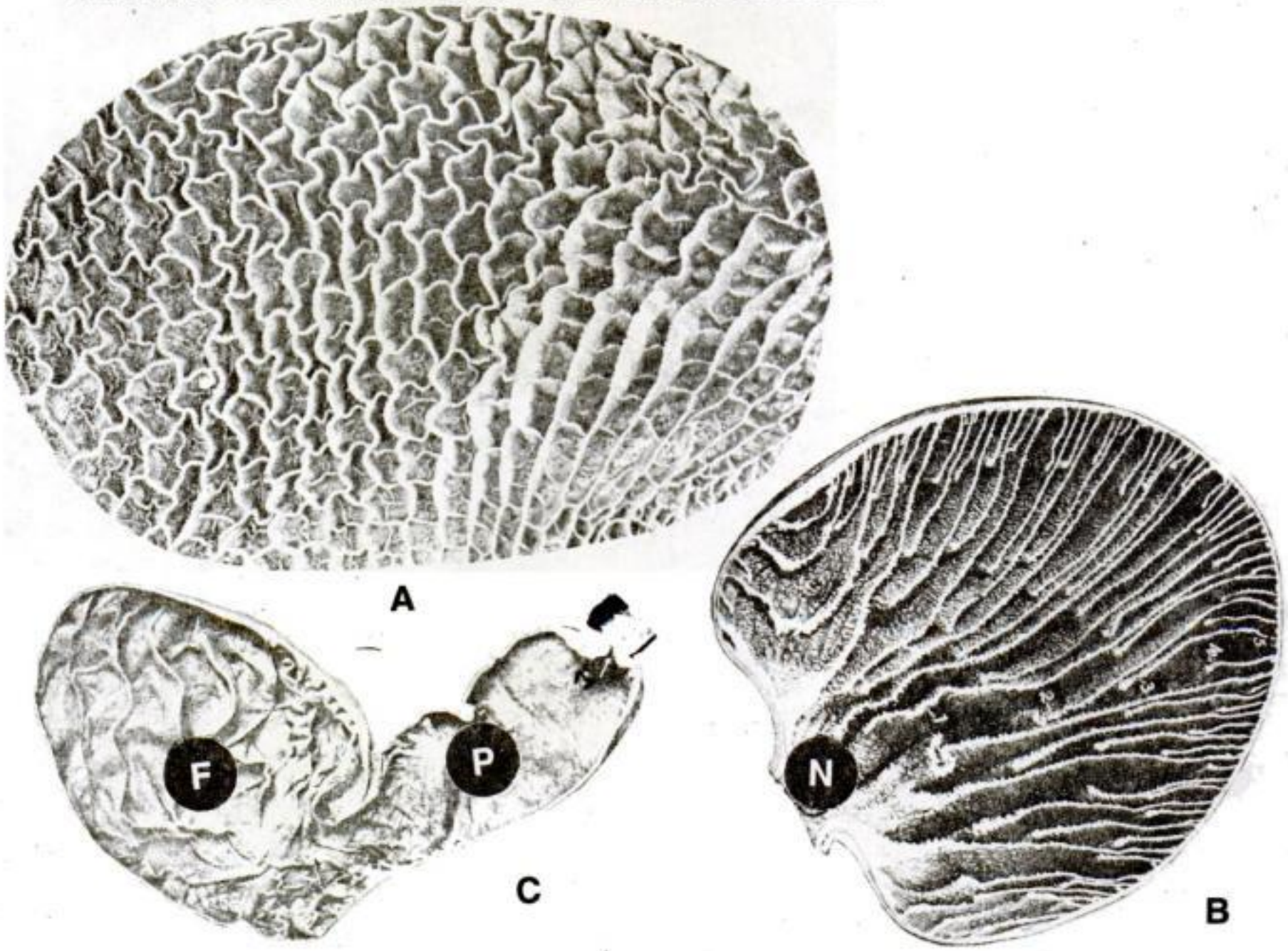


Fig. 3.15 (A) The interior of bovine reticulum. Note typical 'honey combed' cell structure; (B) Cross section of bovine omasum with the ingesta washed out. 1, 2, 3, 4, 5, are laminae of different sizes. N, is the neck of the omasum; (C) The interior of bovine abomasum; (F) The Fundus gland region; (P) The pyloric region; (I) The pylorus.

The Abomasum

The abomasum (true stomach) is the first glandular portion of the ruminant digestive system. It is located ventral to the omasum and extends caudally on the right side of the rumen. The pylorus (terminal part of the abomasum) is a sphincter (thickening of circular smooth muscle fibres) at the junction of the stomach and small intestine.

The epithelium of the abomasum changes abruptly from the stratified squamous epithelium of the omasum to a tall simple columnar epithelium capable of producing mucus. Presum-

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ably the mucus covering the stomach epithelium prevents the digestive juices from digesting the stomach cells.

The abomasum corresponds in structure and function to the fundic region of the stomach of non-ruminants. The abomasal epithelium possesses cells which secrete electrolytes, specially HCl, pepsin and mucus. The pH of this section is in the range of pH 1.0 – 1.3 and overall pH of abomasal contents is about pH 2.0. The low pH of abomasal contents is responsible for the death of the microbes entering the abomasum ; it also provides optimum conditions for activity of the peptic enzymes responsible for the digestion of microbial protein in the abomasum.

The acidity of stomach contents varies among the domestic animals, being highest in carnivores (pH 1 or less in dogs), and lowest in monogastric herbivores (pH 1.1-6.8 in horses). In carnivores the stomach will virtually empty it-self between each meal. In herbivores ingesta may remain within the stomach for several days.

The control of gastric secretion involves several regulatory phases as follows :

(1) *Cephalic or Reflex phase*

Gastric secretion may be initiated by such things as the sight, smell or taste of food which may not enter the stomach. Stimuli reach the stomach by way of the vagus nerves to the myenteric plexus. (the nerve net work of the stomach wall). Herbivorous animals do not appear to have a cephalic phase of gastric stimulation.

(2) *Gastric phase*

It accounts for about 75% of the total gastric juice secretion and occurs when food reaches the stomach. The distension of the stomach also results in a vasovagal reflex by which impulses are sent to the brain and then back to the stomach by way of the vagus nerves to stimulate the flow of gastric juice and also release of the hormone gastrin.

The hormone is synthesised and released by the "G" cells in the antrum of the stomach. It causes the parietal cells to secrete HCl and intrinsic factor (IF), and the chief cell to secrete pepsinogen and stimulates gastric motility.

(3) *Intestinal phase*

It involves small amount of gastric juice that continue to be secreted as long as chyme remains in the small intestine, even though no food remains in the stomach.

Factors that inhibit gastric secretion are as follows :

(1) Feedback mechanism depends on the distention of the duodenum, fluidity of the chyme in the duodenum, and the concentration of amino acids and chyme acidity in the duodenum. As any of these substances increase in the duodenum, it also decreases the release of gastrin from the G cells, which in turn decreases the HCl secretion from the parietal cells.

(2) A second factor is involved in the control of gastric secretion. Two hormones, *secretin* and *cholecystokinin* (CCK) are synthesised by and secreted from mucosal cells in the duodenum in response to the same stimuli (i.e. chyme, pH, fluidity, digestive state). These hormones are secreted directly in the blood and are carried back to the stomach by the vascular system. In the stomach they decrease motility, inhibit the release of gastrin and thus inhibits HC secretion.

(3) The stomach has a direct mechanism also, when the pH becomes low due to a high HC concentration, this will inhibit the release of gastrin from the antral G cells, which in turn will inhibit the further secretion of HCl.

The Small Intestine

The small intestine is divided into three parts, duodenum, jejunum and ileum, because of histological or microscopic structural difference.

The *doudenum* is the first part of the small intestine. It is closely attached to the body wall by a short mesentery, the mesoduodenum. Ducts from the pancreas and liver enter the first part of the duodenum.

The *jejunum* is indistinctly separated from the duodenum. It begins approximately where the mesentery starts to become rather long. The jejunum and ileum are continuous, and there is no gross demarcation between them.

The *ileum* is the last part of the small intestine. It enters the large intestine at the *ileo-ceco-colic junction.*

It is impossible to give a definite location for the jejunum and ileum, but they tend to be located toward the left ventral portion of the abdominal cavity in non-ruminants. The terminal part of the ileum, however, joins the *cecum* (horse) or cecum and colon (other animals) in the right caudal part of the abdominal cavity.

The small intestine is the chief site of absorption in most of the domestic animals. The mucus membrane of only the small intestine consists of numerous tiny finger like projections known as *villi.* Animals with the most rapid digestive and absorptive processes have a more highly developed system of villi to provide a greater surface area for absorption. Each villus is further surrounded by innumerable fingerlike projections known as *microvilli* for the sake of unimaginable greater surface area for the absorption of nutrients. Villi undergo rhythmic (pumping) contractions, pendulum movements and tonic contractions and is controlled by a hormone, *villikinin* and thus aids in absorption.

The duodenum receives both bile from the gall-bladder and pancreatic secretions from the pancreas via a duct which at the point of entry into the duodenum is common to both organs since the bile duct and pancreatic duct fuse some 2-3 cm from this point.

Bile consists largely of bile acids and bile pigments, with small amounts of cholesterol, lecithin, electrolytes and protein. Bile acids before entering the duodenum conjugated of either glycine, giving glycocholic acid salt or taurine, giving taurocholic acid salts. Esterification takes place at the terminal carboxyl group of the parent acid.

The secretions of the pancreas include the proteolytic enzymes trypsinogen (converted to the active form, trypsin, by enterokinase secreted by the duodenum), chymotrypsinogens and procarboxypeptidases (both activated by trypsin) and carboxypeptidase. Proteolytic enzymes constitute some 70% of the total protein secreted by bovine pancreas. Also present in the pancreatic secretions are DNA ase, RNA ase, pancreatic lipase and an alpha amylase similar to that present in the saliva. These enzymes together with the pepsin secreted by the abomasum are responsible for the degradation of the microbial cells entering the region of the gastro-intestinal tract posterior to the reticulo-rumen and also of the feed protein which have escaped reticulo-ruminal degradation (bypass amount).

The secretions present in the small intestine appear to consist largely of electrolytes, particularly Na^+ and Cl^-. The pH of the small intestine differs along its length, ranging from pH 7.1 in the region of jejunum to approximately pH 8.0 at the ileum. These pH values are maintained through the presence of HCO_3^- ions.

Extensive degradation of microbial cells takes place in the small intestine as is evidenced by the presence of fatty acids with odd numbers of carbon atoms and of double bond positional isomers characteristic of bacterial fatty acids. However, degradation of carbo-

hydrate polymers (other than starch) which have escaped microbial degradation in the reticulo-rumen does not take place to any large extent. The feed lipids which have escaped reticulo-rumino fermentation (bypass portion) also gets digested at small intestine.

The Large Intestine

In the ruminant the large intestine consists of the cecum and colon. This cecum has one blind end that projects caudally. Cranially, it is continuous with the colon. This junction is marked by the entrance of the ileum at the ileo-ceco-colic orifice.

The colon passes forward between the two layers of mesentary which support the small intestine. Here it is arranged in coils, the *ansa spiralis*. The first portion spirals toward the

Table 3.2 LARGE INTESTINES

	Horse	*Cow*	*Sheep*	*Pig*	*Dog*
Size	(a) Large colon: 10 to 12 ft. (3 to 3.5 m.) long, 10 in. (25 cm.) diameter, (average) (b) Small colon: 10 to 12 ft. (3 to 3.5 m.) long, 3 in. (7.5 cm.) diameter	35 ft. (10.5 m.) long, 3 in. (7.5 cm.) average diameter	15 ft. (4.5 m.) long, 2 in. (5 cm.) average diameter	10 to 15 ft. (3 to 4.5 m.) long, 2 in. (5 cm.) average diameter	2 ft. (0.6 m.) long, 1 in. (2.5 cm.) diameter. Size varies with breed
Specific characters	Sacculated with longitudinal bands. Vary in number from 1 to 4 on large colon, to 2 on small colon	Tubular, no bands or sacculations. Part is coiled in two directions (ansa spiralis). No differentiation into large and small colon	As cow	Coiled like cow Cecum 3 bands and 3 sacculations. First part of colon 2 bands and 2 sacculations extending to coils. Remainder has no bands	Short and like shepherd's crook. In 3 parts: (i) ascending, (ii) transverse, and (iii) descending. No bands
Position	Large colon: Mainly in ventral abdominal cavity as dorsal and ventral coils. Extends from sternum to pelvic brim. Origin and termination situated dorsally caudal to stomach. Small colon: Lies dorsal to large colon and mingled with small intestines	In dorsal abdominal cavity, to right of median plane with small intestines. Coiled part in lower right flank	As cow	On each side of median plane, mainly to the left caudal to the stomach. Coiled part in ventral part of abdominal cavity, dorsal to umbilicus	Short ascending part lies along right flank, with long descending part on left of median plane extending to the pelvic cavity

centre of the coils (centripetally) and the next part spirals away from the centre (centrifugally). After leaving the *ansa spiralis* the colon crosses to the left side and continues caudally to the rectum and the anus, the terminal part of the digestive tract.

The environmental conditions in the large intestine and caecum are not dissimilar to these in the rumen, both having redox potentials of the order of—350 mV and a typical pH range of the order of 6.5—7.0

The VFA which occur as the major end products of microbial fermentation in the rumen are also found in large intestine and caecum due to microbial degradation of polysaccharides as well as other carbohydrates which have escaped digestion at a lower total concentration. (Rumen, 100—150mM ; Caecum, 60 mM and in large intestine 7 mM).

An important aspect of microbial fermentation in the large intestine and caecum from the host animal's point of view is that the microbial cells synthesised in these regions of the intestinal tract are not subjected to subsequent digestion, and therefore, are not available as potential sources of protein to the host animal.

Table 3.3 CECUM

	Horse	*Cow*	*Sheep*	*Pig*	*Dog*
Capacity	4 to 5 gal. (18 to 22 liters)	1 to 1.25 gal. (4.5 to 5.5 liters)	1 quart (1 liter)	3 pints to 1 gal. (1.5 to 4.5 liters)	Less than 0.5 pint (0.25 liters)
Size	4 ft. long, 8 to 10 in. diameter (1.25 m. × 20 to 25 cm.)	30 in. long, 5 in. diameter (75 × 12 cm.)	10 in. long, 2 in. diameter (25 × 5 cm.)	8 to 12 in. long, 3 to 4 in. diameter (20 to 30 cm. × 7.5 to 10 cm.)	5 to 6 in. long, 1 to 1.5 in. diameter (12 to 15 cm. × 2.5 to 4 cm.)
Shape	Comma-shaped. Sacculated with four longitudinal bands. Two extremities, one rounded (base), other pointed (apex)	Tubular with rounded free extremity	As cow	Tubular and sacculated with three longitudinal bands. Extremity rounded	Tubular and coiled
Position	Base extends from 15th rib to tuber coxae on right of median plane. Longitudinal axis extends ventrally over right flank to xiphoid region generally. Cranial border lies parallel with and 5 to 6 in. (12.5 to 15 cm.) ventral to costal arch	Extends along right flank from near the ventral end of the last rib to the pelvic inlet	As cow	A vertical position in the left or right flank, reaching the abdominal floor between the umbilicus and the pubis	On the right, midway between flank and median plane, dorsal to the umbilical region
Openings	The ileum and large colon enter at lesser curvature of the base. Openings are 2 in. (5 cm.) apart	Colon and cecum continuous. Ileum joins obliquely	As cow	As cow	Ileum and colon continuous and cecum joins obliquely

It would not be unreasonable to suggest that the volatile fatty acids of hind gut and caecal origin contribute about 30% of the total VFA entering ruminant bloodstream, the remaining 70% being largely of ruminal origin. Water is also absorbed from the large intestine and caecum to the extent of 1.0—1.25 liters per day in sheep. Amino nitrogen @0.5—1.6 gram/day are also absorbed in sheep in the region of large intestine.

B. ACCESSORY DIGESTIVE ORGANS

The Salivary Glands

The main salivary glands consist of three pairs of well defined glands viz., *parotid*, *mandibular*, and *sublingual*. The other salivary glands include *labial*, *buccal*, *lingual* and *palatine* glands. The dog has also a zygomatic salivary gland near the eye. *The parotid salivary gland* is located ventral to each ear in relation to the caudal border of the mandible. The duct penetrates the mucous membrane of the cheek near the upper third or fourth cheek tooth. The *mandibular* or *submaxillary salivary gland* is located ventral to the parotid gland just caudal to the mandible. The mandibular salivary duct opens ventral to the tongue on a little papilla located in the fold that holds the tongue to the floor of the mouth. The *sublingual salivary gland* is located deep to the mucous membrane along the ventral side of the lateral surface of the tongue near the floor of the mouth. With the exception of the horse, the gland has a monostomatic portion that empties on to the floor of the mouth by way of major sublingual duct.

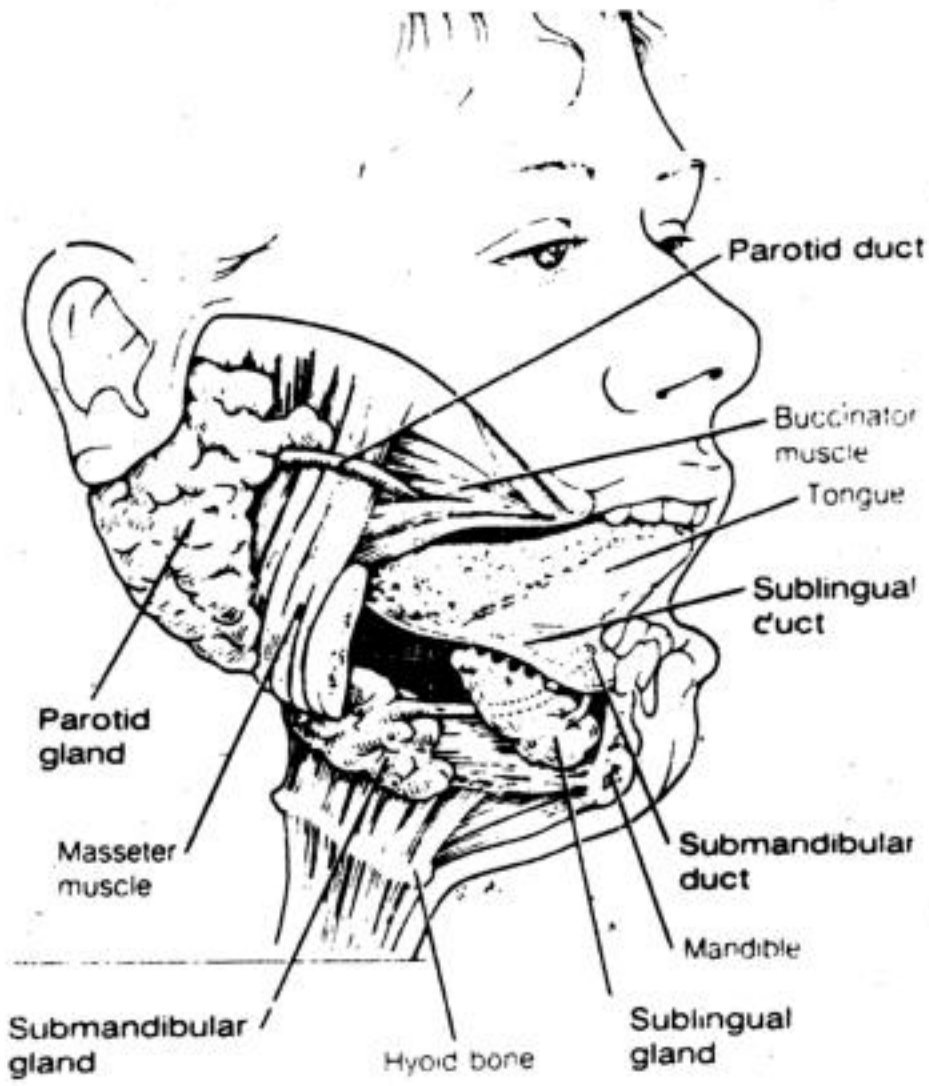


Fig.3.16 The salivary glands. Glandular secretions are carried to the mouth through ducts.

The secretion of the saliva in ruminants is continuous, but the rate is greatly increased by stimuli associated with feeding, rumination and the presence of coarse feeds. An adult human may produce about 1.5—2 liters of saliva daily. In cattle total volume may range from 100—200 liters per day or sometimes equivalent to the volume of the rumen.

Paired parotid, inferior molar and buccal salivary glands produce thin watery secretions, highly alkaline having high concentration of HCO_3^- ions with very little mucoprotein. Saliva from the paired submaxillary, sublingual, and labial salivary glands as well as the unpaired pharyngeal gland secrete a glycoprotein, mucin. The saliva of ruminants tends to be slightly alkaline (pH about 8). The uses of saliva in digestion are manyfold, including the following :

1. **Lubricant.** These secretions act as aids in mastication, formation of the bolus and swallowing.
2. **Buffering capacity.** A large quantity of bicarbonate is secreted in saliva, serving as a buffer in the ingesta.
3. **Nutrients for rumen microorganisms.** Saliva contains considerable amounts of urea, mucin, phosphorus, magnesium and chloride which all are utilised by rumen microbes.
4. **Prevention of frothing.** Gas can accumulate in the rumen and may cause bloat condition when eruction process is impaired. Saliva—acting as a surfactant—helps to prevent this problem.
5. **Taste.** Saliva solubilises a number of the chemicals in the feed which, once in solution, can be detected by the taste buds.
6. **Protection.** The membrane within the mouth must be kept moist in order to remain viable which saliva provides.
7. **Source of digesting enzyme.** Saliva of the dog and pig contains some amylase capable of digesting starch. Saliva in the cow, sheep and goat does not contain amylase, but the saliva of the horse may contain small amount of amylase.

2. The Pancreas

The second main accessary digestive gland is the pancreas. It weights 350 to 500 gram in the ox, and 50-70 gram in the sheep and goat. The pancreas is a dual organ. Its exocrine portion forms the great mass of the gland and secretes pancreatic juice into the duodenum. The endocrine tissue consists of the tiny spherical *islets of langerhans* which account for less than 1 per cent of the whole. The mixed exocrine and endocrine glands is elongated. The pancreas is a soft, lumpy organ with a large head, long body and tapering tail. The head lies within the concavity of the duodenum.

Table 3.4

Composition of pancreatic juice

Enzyme precursors	—	Trypsinogen, chymotrypsinogen
Active enzymes	—	Elastase, amylase, lipase
Cations	—	Sodium, potassium, calcium
Anions	—	Chloride, bicarbonate
pH	—	7.5--8.0

N.B. : The inactive enzyme precursor *trypsinogen* is converted to the active *trypsin* by the enzyme *enterokinase*, which is liberated from unidentified cells of the duodenal mucosa. Trypsin also acts on the precursor *Chymotrypsinogen* to form the active chymotrypsin.

Exocrine pancreas: This is a compound tubulo-acinar gland, the acini are composed of cells which contain granules of the digestive enzymes (Zymogen granules) The acini are connected with excretory ducts which finally coalesce into a single duct which enters the duodenum.

FUNCTIONS OF PANCREATIC JUICE. (1) The alkalinity of the juice aids in the neutralisation of the acid chyme passing into the duodenum from the stomach. This is an important function, since the enzymes of the pancreatic juice act optimally in an alkaline medium.

(2) Trypsin is formed from its precursor trypsinogen which hydrolyses the protein ingested to polypeptides and amino acids. The enzyme has its optimum pH at 8.0—9.7.

(3) Chymotrypsin, when formed from chymotrypsinogen has the action of curdling milk.

(4) The α-amylase converts all forms of starch rapidly into maltose.

(5) The pancreatic lipase converts neutral triglycerides to di-and monoglycerides and free fatty acids.

Regulation of Pancreatic Secretion

The exocrine secretory activities of the pancreas are controlled both hormonally and neurally. Two hormones, *secretin* and *cholecystokinin*, are released into the blood-stream from the mucosa of the duodenal and jejunal portions of the small intestine when gastric acid or chyme enters the intestine. Secretin which is released primarily in response to the presence of HCl, stimulates the release from the pancreas of a watery fluid that contains large amounts of bicarbonate ions. Secretin has little effect on the release of pancreatic enzymes.

Cholecystokinin (also known as pancreozymin), which is released principally in response to the presence of breakdown products of digestion protein of fats and carbohydrates in the duodenum mainly promotes the release of digestive enzymes from the pancreas—by circulating through blood. These two duodenal hormones also feed back to the stomach, as explained earlier, by decreasing secretion in the stomach and slowing the process of peristalsis.

Neurally, pancreatic secretion may be stimulated by way of the vagus nerves and the effect is mostly on enzymatic secretion. The response is specially evident during the cephalic and gastric phases of stomach secretion.

3. The Liver and Biliary System

The liver is the largest gland in the body. It is an important organ of intermediate metabolism. It has also an exocrine section, the bile, which is conveyed to the duodenum by the ducts of the liver, which convey bile from and within the liver to duodenum, and the gall bladder which stores and concentrates bile. All domestic animals except the horse have this gall bladder. Bile leaves the liver through the *hepatic duct*, which joins the *cystic duct* coming from the gall bladder to form the *common bile duct*, which then passes to the first part of the duodenum.

The composition and the role of bile will further be explained in connection with the digestion and absorption of lipids in non-ruminants in the later part of this chapter.

Regulation of Bile secretion

The rate of bile-secretion is chemically, neurally and hormonally controlled.

Chemical substances that increase bile flow are called *Choleretics*. Bile salts present in the

Table 3.5 Functions of Gastrointestinal Secretions

Organ	*Secretion (Secreted by)*	*Principal Components and enzymes*	**Action of components including end products of digestion**
MOUTH AND PHARYNX	Saliva (Salivary glands)	Water, Mucus, Salts, SALIVARY AMYLASE (ptyalin),MALTASE	Softens food, Makes food slippery, Provide neutral medium for action of salivary amylase and help to preserve teeth against acids formed by bacteria, Splits cooked starch into dextrin and maltose or some glucose.
RUMEN		Various enzymes from microorganisms	Enzymes act on carbohydrates yield VFA; splits protein and non-protein nitrogenous compounds into ammonia, Hydrolyzes the triglyceride and galactolipid, releasing free fatty acids (FFA) and allowing the glycerol and galactose to be fermented to volatile fatty acids (VFA), Enough microbial protein (dead) will pass out to stomach and so on; vitamins B and K are also produced.
STOMACH (abomasum)	Gastric Juice (HCl acid & Mucus) from glands of the stomach walls	Water, Mucus, Hydrochloric acid, PEPSIN (secreted as pepsinogen), RENIN	Further softens food; Prevents gastric juice from damaging the stomach wall; Stops the action of salivary amylase and allows pepsin to work. Kills many germs. Splits certain proteins into proteoses and peptones, i.e. shorter chain polypeptides, Curdles milk in adults (when rennin scare or absent and in any case ineffective). Curdles milk in many young mammals. Presence in man doubtful. Regulate emptying of dissolved food into small intestine; solubilyze food particles.
DUODENUM (small intestine)	Pancreatic juice (pancreas)	Water, Alkaline salts PANCREATIC LIPASE, PANCREATIC AMYLASE, TRYPSIN (secreted as trypsinogen) CHYMO-TRYPSIN (secreted as chymotrypsinogen), CARBOXYPEPTIDASE, CHOLESTEROLESTERASE	Help to increase alkalinity in intestine and combine with fatty acids to form soaps ; Splits fats into fatty acids and glycerol (Acts more effectively than gastric lipase). Splits all forms of starch and dextrin into maltose. Split certain proteins, proteoses and peptones into shorter polypeptide chains and liberate some amino-acids. cholesterol esterifies with falty acids.
	Bile (stored in the gall bladder of liver)	Water, Bile pigments, Bile salts	Waste materials–excreted with faeces or absorbed and re-excreted later, Alkaline therefore , neutralise acidity of chyme and stop action of pepsin but allow action of intestinal enzymes. Emulsify fats.
SMALL INTESTINE	Intestinal juice from Duodenal glands and Goblet cells throughout the small intestine	Water, Mucus ENTERO-KINASE, PEPTIDASES (Carboxypeptidase, Aminopeptidase, Dipeptidase) MALTASE, SUCRASE, LACTASE) PLOYNUCLEOTIDASE	Protects intestinal mucosa, Activates trypsinogen forming trypsin; trypsin then activates chymotrypsinogen, Split amino-acids, one at a time, from the acid and amino ends, respectively, of the polypeptide chains. Splits the final dipeptide residues, Splits maltose into glucose, splits sucrose into glucose and fructose, splits lactose into glucose and galactose. In ruminants glucose and fructose formation is extremely low. Galactose formation is high in young mammals.
LARGE INTESTINE		Cellulase from microorganisms	Storage and concentration of undigested matter by absorption of salt and water; mixing and propulsion of contents. Cellulose and other undigested polysaccharides gets digested to form VFA.. Microbial protein, B-vitamins and vitamin K are formed.

plasma as a result of enterohepatic circulation act as powerfull choleretics that stimulate bile flow.

Stimulation of the vagus nerves can also increase the rate of hepatic bile secretion.

In response to the presence of fat and protein breakdown products in the chyme, the hormone *Cholecystokinin* (CCK) previously known as *pancreozymin* is released from the duodenal mucosa which strongly stimulates gall bladder to contract. Secretin apart from its effect as stimulator for pancreatic bicarbonate also causes secretion of bile (not the rate of bile acid production).

Digestive Organs of Non-ruminants

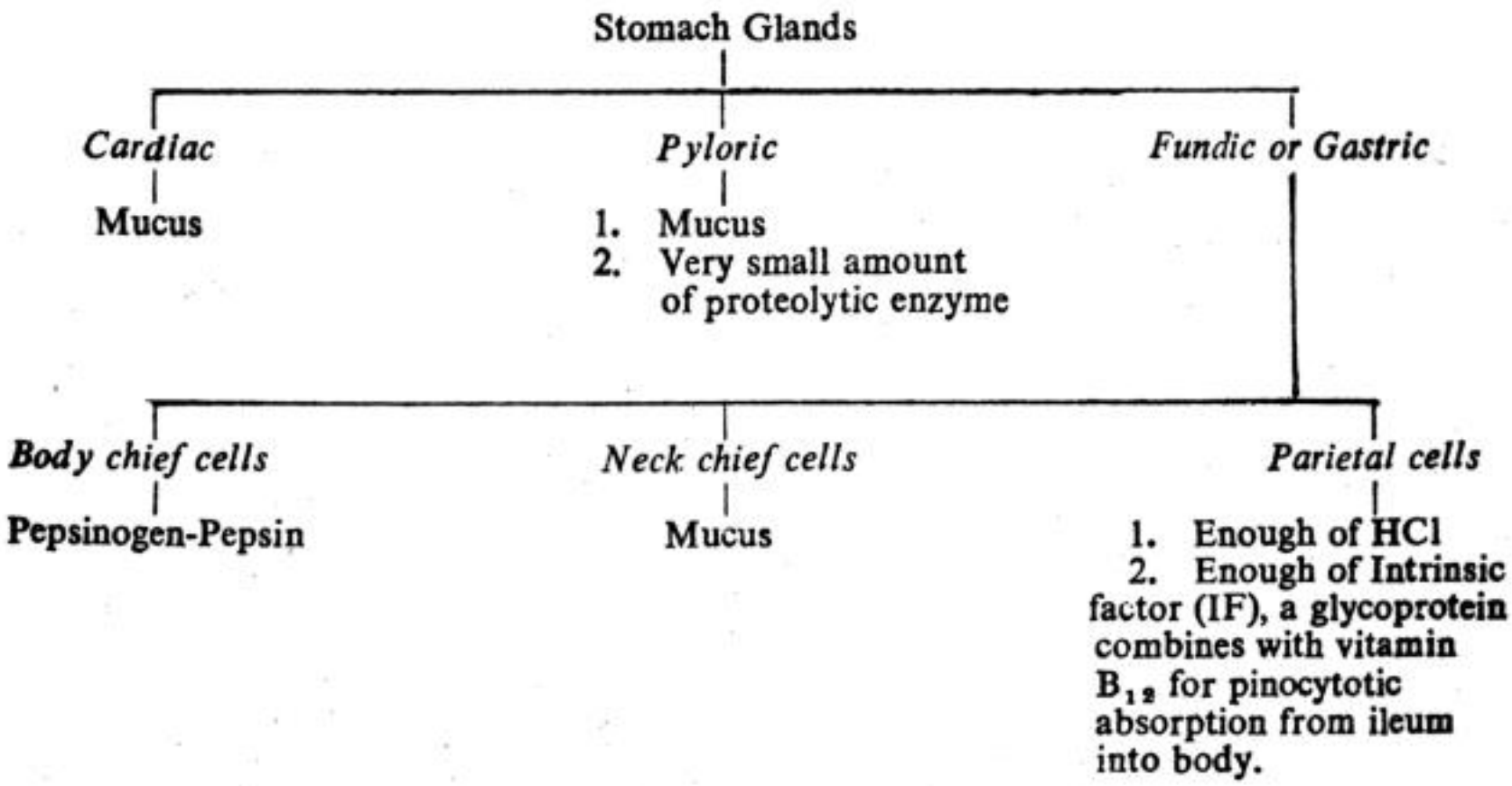
The digestive organs of non-ruminants are much simpler. They differ from ruminant system mainly, in the structure of stomach and large intestine, and hence these two sections of the alimentary canal will be discussed here. The general description of other parts may be at present taken as more or less like ruminants.

The Non-ruminant stomach

The simple stomach is divided into three regions : *Cardiac, fundic* and *pyloric*. These vary considerably in size and shape between species. The fundic and pyloric regions are the principal centers of glandular activity.

The cardiac region is closest to the oesopageal region and contains the cardiac glands. They are mucous glands, and do not produce enzymes.

The body of the stomach is called the fundic region and contains the *fundic* or *gastric glands*. These are composed of three types of cells, (1) *body chief cells*, (2) *neck chief cells* and (3) *parietal cells*. Body chief cells are found in the body and deeper parts of the gastric



glands. They are enzyme producers and contain so called *zymogen granules* (substances from which gastric enzymes are derived), Neck chief cells line the gastric glands near their openings and are mucus secreting cells. Parietal or border cells produce HCl and "intrinsic factor".

The posterior part of the stomach is called the pyloric region and contains the pyloric glands. The products of their secretion are mucus and small amounts of proteolytic enzymes.

Gastric juice = All substances contributed to the stomach lumen by the mucosal cells. It includes H_2O, cations, anions, HCl, IF, pepsinogen, rennin etc.

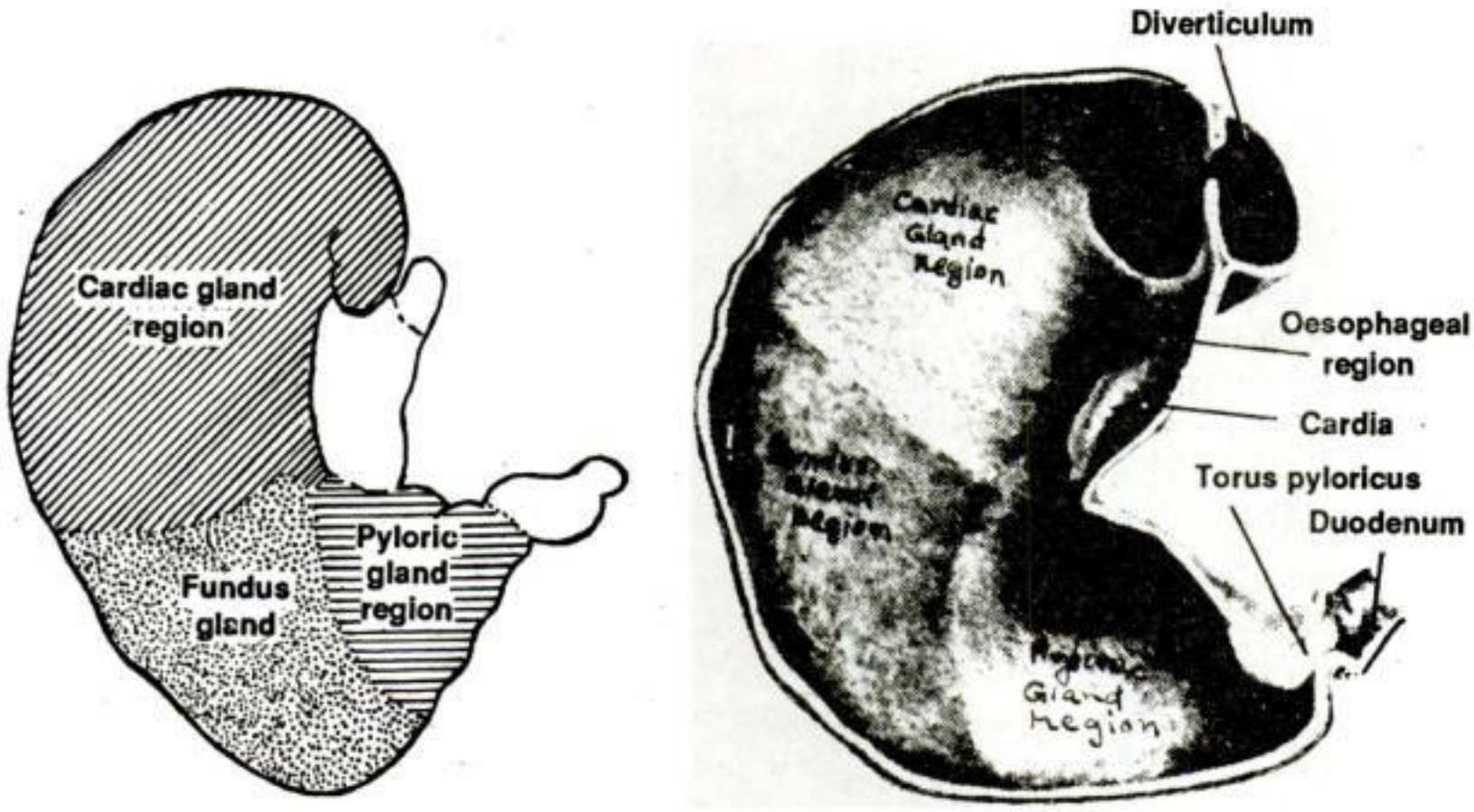


Fig. 3.17 Stomach of a Pig.

In the non-ruminant stomach the esophageal region compares to the forestomachs of the ruminant. in that it is lined with non-glandular stratified squamous epithelium. The rest of the stomach has those glandular region. The esophageal region is large in the horse, small in the pig and practically absent in the dog. The cardiac gland region is large in the pig but smaller in the horse and the remainder of the non-ruminant stomach is divided between fundic and pyloric gland regions.

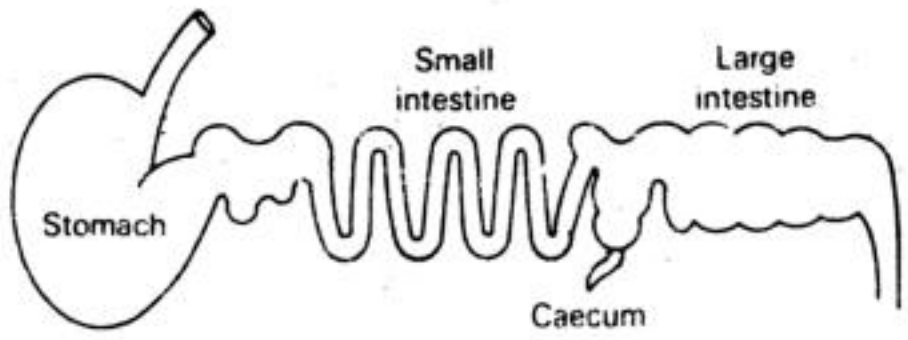
The Non-ruminant Large Intestine

The large intestine consists of the cecum, which is a blind sac and the colon, which terminates as the rectum and anus. There is considerably more variation in the large intestine from one species to another than in the small intestine

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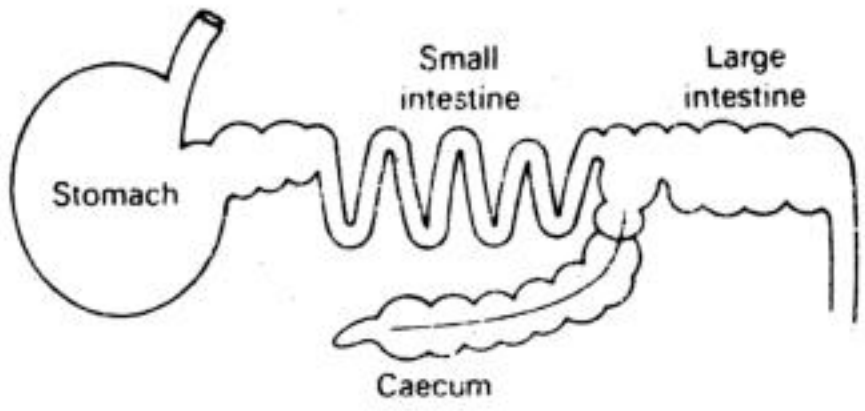
Type I
Simple system

Man:	omnivore
Monkey:	omnivore
Pig:	omnivore
Dog:	carnivore



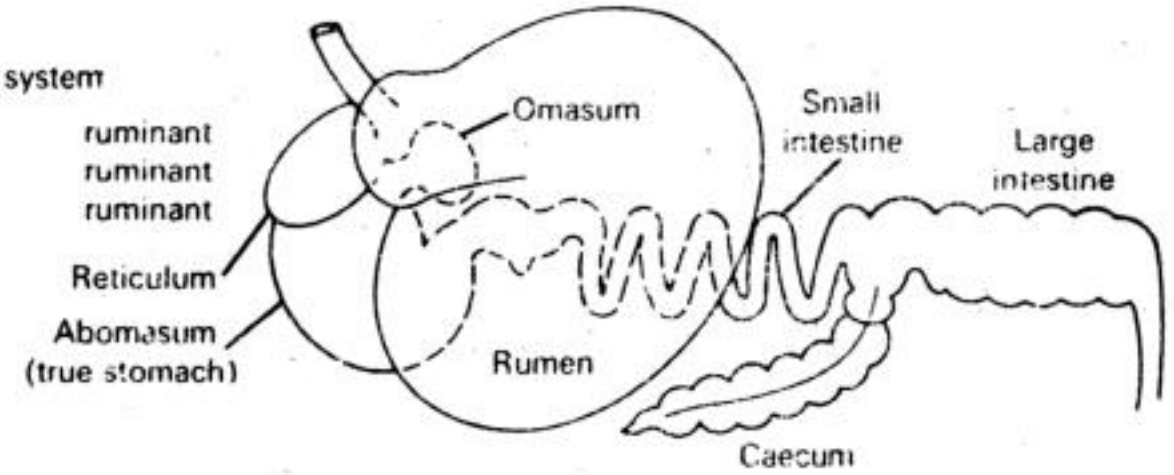
Type II
Simple system
with functional caecum

Horse:	herbivore
Rabbit:	herbivore
Guinea pig:	herbivore
Hamster:	omnivore
Rat:	omnivore
Mouse:	omnivore



Type III
Multiple system

Cow:	ruminant
Sheep:	ruminant
Goat:	ruminant



Type IV
Avian system

Chicken:	omnivore
Turkey:	omnivore
Duck:	omnivore
Goose:	omnivore

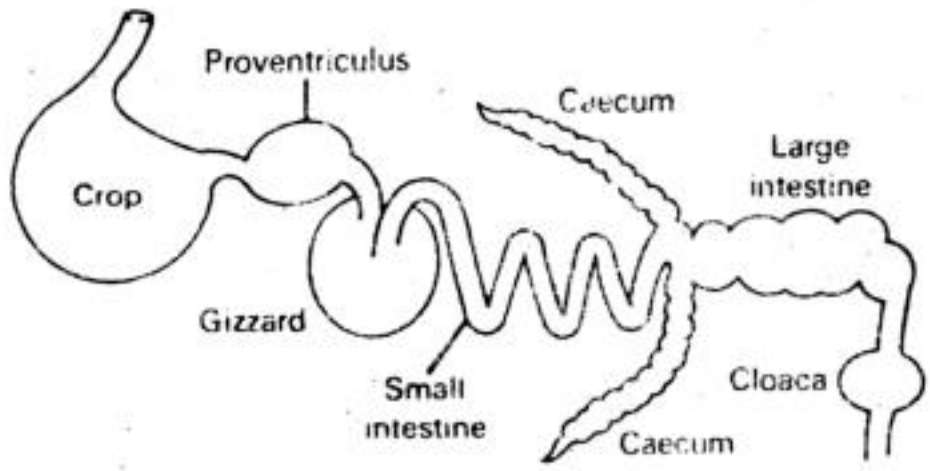


Fig. 3.18 Classification of animals according to type of digestive systems.

Table 3.6

Absolute capacity of the parts of the gastrointestinal tract of various animals

Parts of digestive tract	*Man*	*Pig*	*Dog*	*Horse*	*Sheep*	*Cattle*
Average body wt.	*68 kg*	*200 kg*	*18 kg*	*680 kg*	*75 kg*	*450 kg*
	Capacity (Litres)					
Rumen	—	—	—	—	23	202
Reticulum	—	—	—	—	2	8
Omasum	-	—	—	—	1	19
Abomasum	1	8	4.3	18	3	23
Small Intestine	4	9	1.6	53	9	66
Cecum	0	1	0.1	44	1	10
Large Intestine	1	9	1.0	96	5	28
Total G.I. Tract	6	27	7.0	211	44	356

Table 3.7

Relative capacity of the parts of G.I. tract of various mammals
(% *Total digestive system*)

Parts of digestive tract	*Man*	*Pig*	*Dog*	*Horse*	*Sheep*	*Cattle*
Rumen	—	—	—	—	53	53
Reticulum	—	—	—	—	5	3
Omasum	—	—	—	—	2	5
Abomasum	17	30	61	9	7	6
Small Intestine	66	33	24	25	20	20
Cecum	0	4	1	21	2	2
Large Intestine	17	33	14	45	11	11
Total G.I. Tract -	100	100	100	100	100	100

THE RESPIRATORY SYSTEM

This is the process of breathing. Air is *inspired* through the nasal passages, via the wind pipe on trachea, into the lungs, and later *expired.* There is a general rhythm to respiration.

The purpose of respiration is to supply oxygen, through lungs, to the blood as a vital need to the the life of the animal, and to rid the system of unwanted CO_2 and water vapour

All domestic animals have a pair of lungs suspended in the thoracic body cavity one on either side of the chest. They are extremely elastic and spongy. The heart is considerably smaller and lies between the lungs.

Table 3.8

	Air inhaled %	*Air exhaled %*
Nitrogen	79.04	79.04
Oxygen	20.93	16.02
Carbon dioxide	00.03	4.38

Atmospheric air inspired through the larynx and long cartilaginous tube called trachea and then through the two major *bronchi* (bronchial tube), one going to each lung; smaller bronchioles; until the terminal, dead end, sac like structures, the *alveoli* are reached.

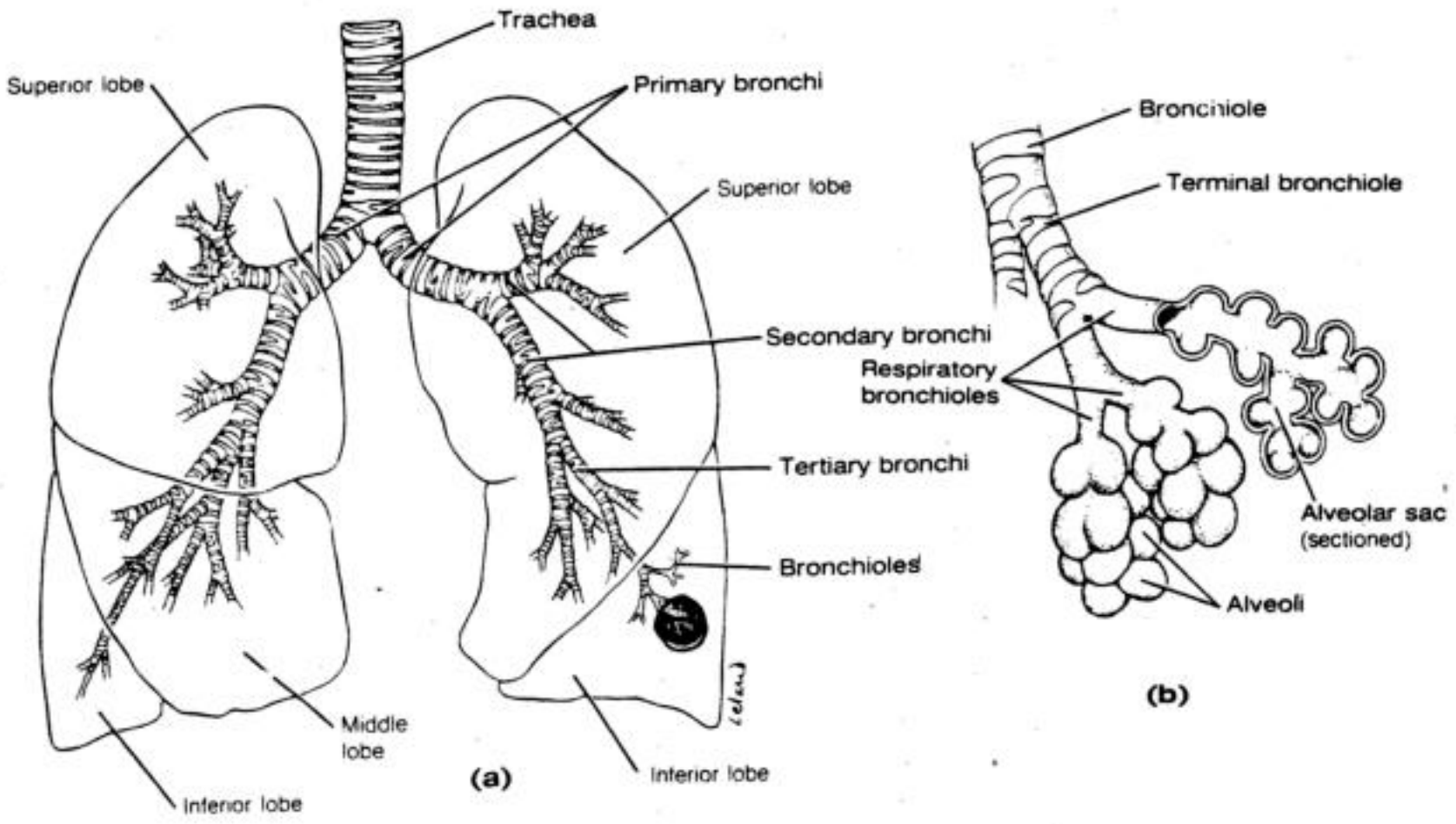


Fig. 3.19 (a) The trachea, the bronchi and the lungs.
(b) The termination of bronchioles into alveoli.

The actual exchange of the respiratory gases takes place between the alveoli and the blood which flows through very fine neighbouring capillaries.

Rate of respiration

The speed of the respirations varies with many internal and external factors. It is faster during fever, after exercise, during powerful emotions, such as fear, anger, sexual excitement, etc.; during very cold or very hot weather, when the body condition is very fat, or when radiation is obstructed through too thick a covering of wool, fur etc., or too much clothing.

It is slower than normal during resting, either when lying or when sleeping.

Normal rates in adult domesticated animals are as follows:

Table 3.9

Horse	8–12 per minute
Ox	12–16 per minute
Sheep and Goat	12–20 per minute
Pig	10–16 per minute
Dog	15–30 per minute

With poor ventilation there lies great danger that some diseases of the lungs, e.g. tuberculosis and virus pneumonia will spread, through the expired breath of diseased animals, and set up the trouble in those which are still healthy.

Malfunctions of the Respiratory System

1. ***Pneumonia*** **has many causes resulting in fluids in the alveoli causing difficult breathing:**
2. ***Pleurisy*** **is inflammation of the lining of the thorax, causing fluid accumulation and difficult breathing.**
3. ***Tuberculosis*** **results in loss of lung tissue due to microbial infection.**

THE EXCRETORY SYSTEM

Normal cellular activity (metabolism) results in the formation of waste products. In large quantities some of these products can be toxic and need to be excreted. The waste products that require excretion are:

1. Carbon dioxide (through lungs)
2. Water (through sweat glands)
3. Salts (through sweat and urine)
4. Nitrogen products (mostly through urine)

These are transported in the blood system to the organs which make up the excretory system—the lungs, the skin and the main excretory organ, the kidneys.

The Lungs

These have been dealt with in previous section "The Respiratory System". Carbon dioxide and some water diffuse from the blood stream and are excreted by the lungs.

The Skin

The skin is a protective outer layer to the body. It has many nerve endings which transmit the sensations of heat, cold and touch to the brain. The outer layer, the *epidermis*, is a mass of cells with no blood supply or nerve endings. Its main function is protection and it varies in thickness according to the area that needs protection. Below the epidermis is the true skin, the *dermis*, with a blood supply and nerve endings. It contains hair follicles and sebaceous or grease glands which produce a protective film or oil. This oil, such as the oil lanolin in sheep's wool, protects the coat from water penetration.

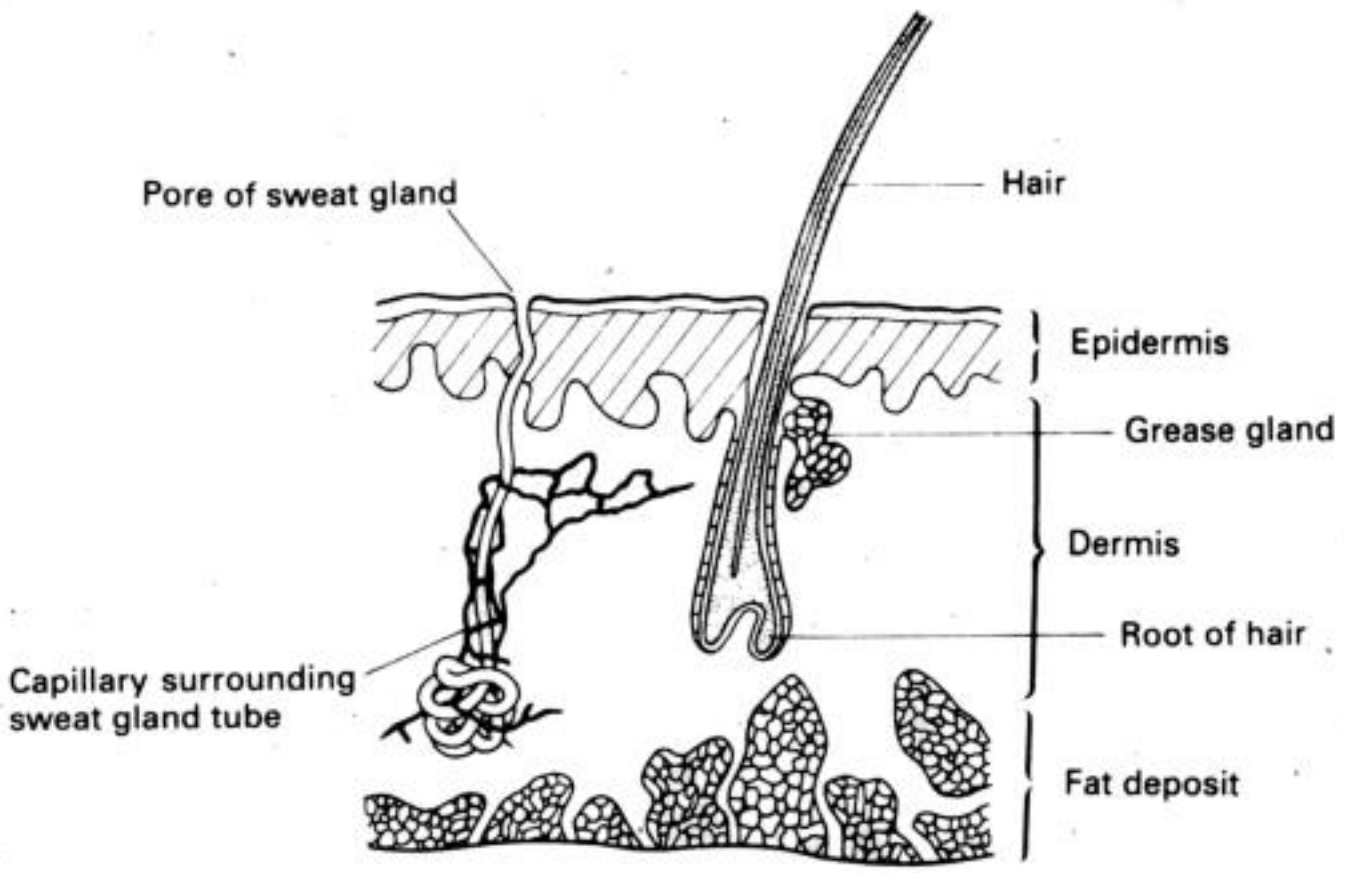


Fig. 3.20 Cross-section through skin.

The skin also contains many sweat glands. Each gland consists of a tube with one end opening as a pore on the skin surface, the other end being blind. The tube is surrounded by blood capillaries. *Water and salts diffuse out from the capillaries and into the sweat tube.* This travels to the skin surface where it evaporates to aid cooling of the body.

Sweat glands are present in the skin of all livestock except the goat. Cattle and pigs sweat only from the nose and snout, whilst a sheep has a thin supply of sweat glands all over its body. So much for the saying 'sweating like a pig'.

Excretion of Water and Salt through Skin

During the period when environmental temperature increases, then also the animal cannot avoid generating heat, except by taking rest, this may be reduced to a minimum. At high temperature the arterioles of the skin are then dilated. Blood flows freely and the skin is kept at a high temperature. The sweat glands will then start secreting. Most farm animals, however, are not efficient sweaters, but they have a technique which results in the evaporation of water. They breathe very rapidly, causing a lot of air to pass rapidly in an out of the mouth. Sheep and cattle pant in this way, but the dog is the most efficient because it has a relatively large, wide opening mouth and a highly mobile tongue which is allowed to flop out. The mouth and tongue are kept very moist.

This is a technique which man cannot imitate, for he always over-ventilates the lungs, removes carbon dioxide too rapidly and becomes dizzy.

The pig is not an efficient sweater, nor has it the power of effectively disposing heat by panting. Its method of cooling is to wallow in water or mud. When it is in a very hot building and cannot follow this instinct it will urinate on the floor and wallow in its own urine, first on one side then the other, thus continuously exposing a wet side to the air.

It may be noted that water has got the highest latent heat of evaporation, 589 cal. per gram which means that to change 1 gm of liquid water to 1 gm. of water vapour without any change in temperature, 589 cal. are required. By this means the body is able to rid itself of 589 cal. of heat for every gm of water it evaporates.

The Kidney

The lungs, skin and parts of the intestine contribute to the elimination of waste products from the body. The two kidneys, however, are the primary adult excretory organs in the mammal. They along with the passages through which the urine passes, constitute the urinary tract.

The kidneys perform two related and essential excretory functions:

1. They remove the nitrogenous waste products of protein metabolism such as *urea* in mammals,

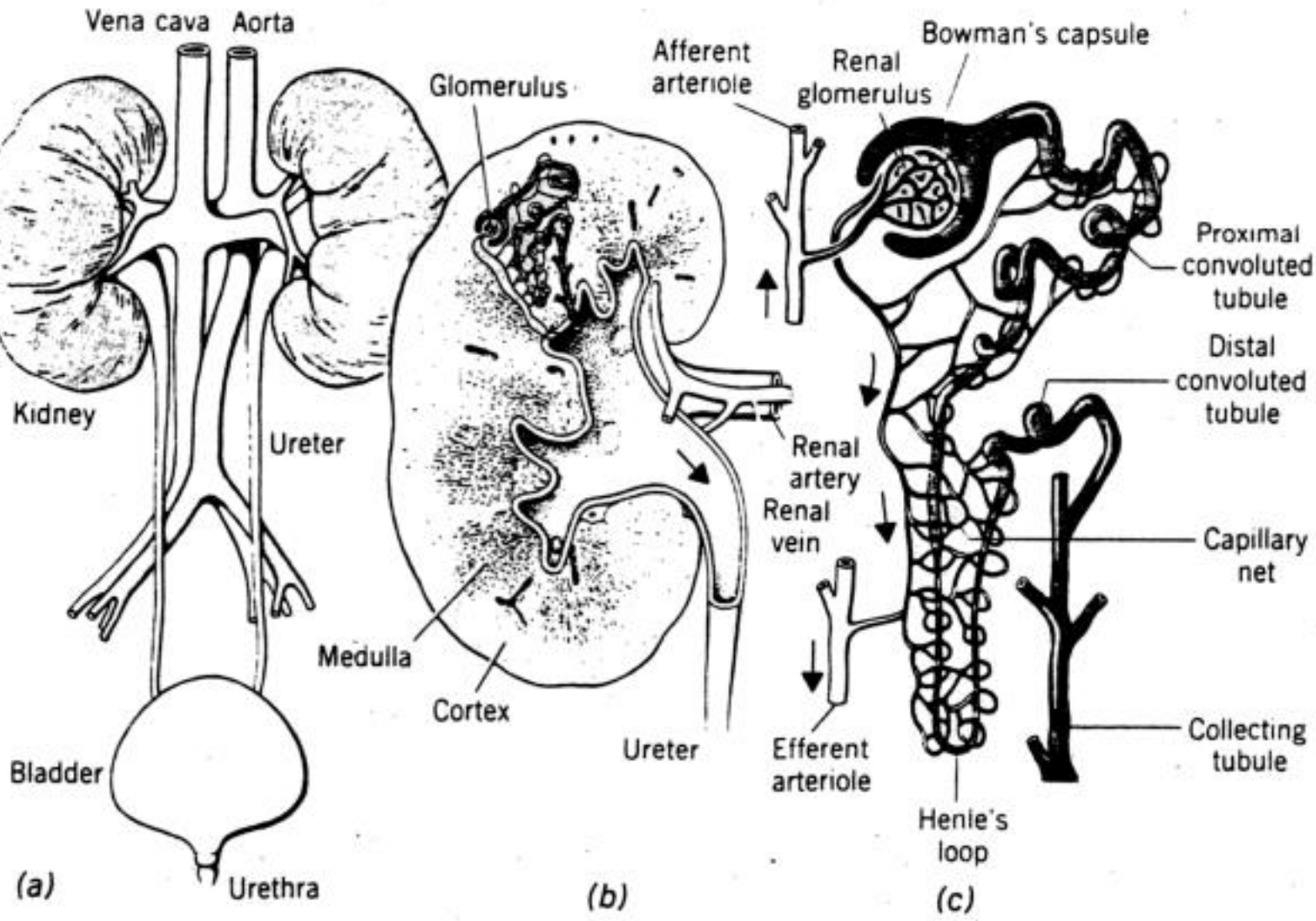


Fig. 3.21 The kidneys. (*a*) Principal parts. (*b*) Location of nephrons. (*c*) Details of nephron and associated capillary bed. Each kidney has about 1 million nephrons. Fluids and solutes (but not colloids, lipids, or cells) leave the blood in the glomerulus and selectively return in the promixal and distal tubules. Final electrolyte adjustments are made primarily in the distal tubules.

and amphibians; uric acid in birds, reptiles and in some insects and many mammals, ammonium ion in most aquatic invertebrates, thus kidney filters waste products from blood.

2. They regulate the acid-base balance (pH) of the animal's internal environment by eliminating controlled amounts of water and inorganic salts.

Blood from all parts of the body carries nutrient molecules, water and waste products of tissue metabolism to the kidney. The structure of the kidney is such that it is able to filter out some of these and to reabsorb the useful ones.

Gross Anatomy of the Urinary Tract

The gross location and appearance of kidneys in all warm blooded animals is similar. The left and right kidneys are located on the dorsal wall of the abdominal cavity. In sheep and pigs they are the normal 'bean' shape. In cattle and birds, the kidneys have distinct subunits or lobes. In cattle and buffaloes the left kidney being able to 'float' in order to accommodate the changes in shape of the rumen.

If the kidney is cut mid-sagittally, two regions, are readily apparent. In the uni-lobed kidneys (in sheep, pig, horse, human etc.) the entire, outer region, the *cortex*, appears lighter than the inner region, the medulla. In other animals like in cattle, buffaloes and birds each subunit or lobe is subdivided into cortical and medullary areas. Each kidney is supplied with blood from the *renal artery*, wih the *renal vein* taking blood away (Fig. 3.22). There is also a tube called the *ureter* which takes the mixture of excretory products, the urine to the bladder.

The arrangement of the remaining excretory passages, the *ureters*, the *urinary bladder* and *urethra*, varies somewhat between species. In birds, the ureters empty into the cloaca. In mammals, however, the ureters carry urine to the urinary bladder for storage.

Each kidney has many urine collecting tubules arranged radially. A cup-shaped structure called *Bowman's capsule* (Fig 3.22) forms one end of the tubule, the other end opening into the ureter.

The renal artery supplies each kidney with blood that contains water, salts and urea which need to be removed. Inside the kidney the renal artery divides into smaller branches, with each branch

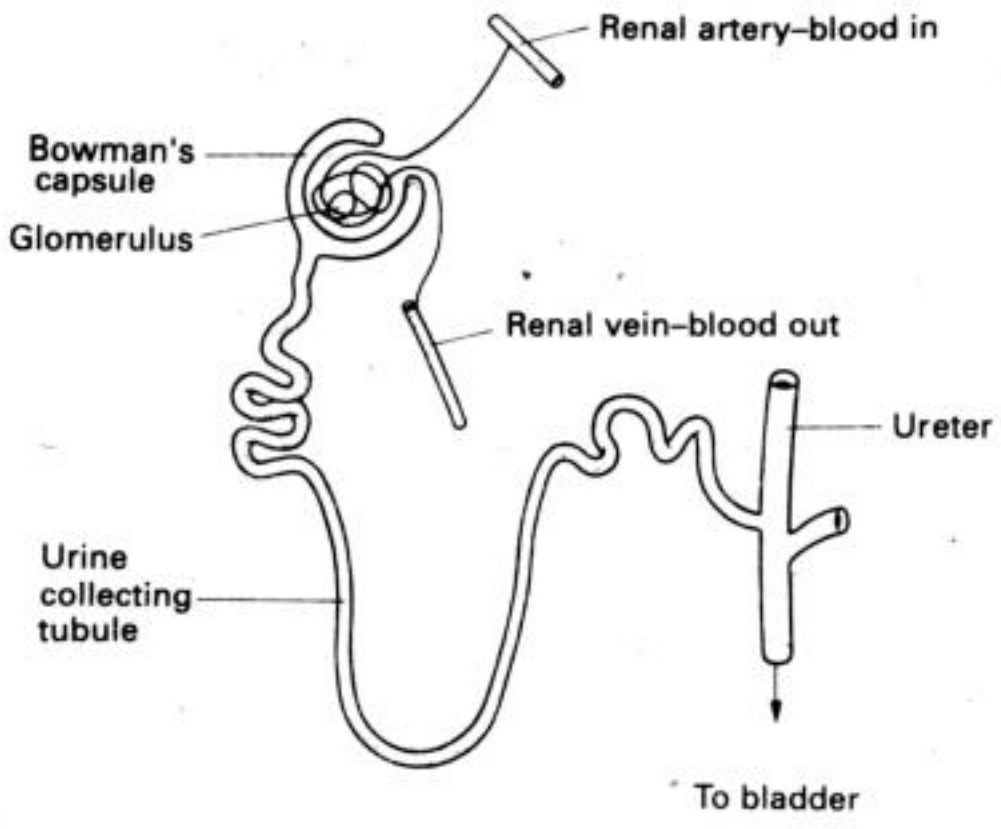


Fig. 3.22 The urine excretory system.

forming a small bunch of capillaries inside the Bowman's Capsule. This bunch of capillaries is called the *glomerulus*. Waste products in the blood diffuse out of the capillary walls into the capsule, with the resulting urine passing into the ureter.

The kidneys are responsible for maintaining the balance of water under the overall control of hormones, in the body. As urine passes down the tubule the required amount of water is absorbed back into the body. The Capillaries from each Bowman's capsule rejoin to form the renal vein which now carries blood that is cleaned of excess salts, water and urea.

Mechanism of Kidney Function

The kidney's two main functions are the excretion of waste (and excess) materials from the bloodstream; and, secondly, the maintenance of the correct proportions of water in the blood, the correct levels of its chemical constituents, and the correct pH.

Blood is supplied to the kidney by the renal artery. It enters the nephron through the afferent arteriole which leads to a filtration chamber known as Bowman's capsule. This capsule contains a conglomeration of capillary blood vessels known as the glomerulus, which filters the blood. The heart supplies the energy to run this efficient "filtration pump."

The unfiltered blood consists of cellular and plasma constituents. It passes out of the glomerulus by way of the efferent arteriole which ramifies around the tubules after breaking up into a second set of capillaries.

The filtrate passes into Bowman's capsule before going into the tubules. The filtered components are water, electrolytes, such as NaCl, (NH_2) HPO_4, KCl, $NaHCO_3$, and low molecular weight organic substances such as glucose, essential nutrients, and urea. These must be reabsorbed (urea 30-40%) to a great degree to maintain the volume and composition of extracellular fluid. Glomerular filtration separates a large amount of fluid; however, during its passage through the proximal tubule, the loop of Henle, and the distal tubule, a considerable amount of filtrate must be reabsorbed to maintain homeostasis. In the process of tubular reabsorption, 98 to 99 per cent of the water of the glomerular filtrate, together with electrolytes and organic compounds including glucose etc. are reabsorbed through the cell walls and back into the bloodstream. The composition of this material must closely approximate that of the extracellular fluid to prevent distortions in fluid composition. The kidney cells provide energy for the reabsorption process which has a dual role of controlling electrolyte balance and maintaining a constant hydrostatic pressure. This results in the reabsorption of the necessary physiological amounts of water, sodium, potassium, and chloride ions into the bloodstream, and the excretion of urea, uric acid, creatinine, water and excess electrolytes in the filtrate. The filtrate residue enters the collecting duct and is eventually eliminated from the kidney as urine.

The control of urine formation is believed to be due to either the rate of glomerular filtration, rate of tubular reabsorption, or a combination of the two. The rate of glomerular filtration may be varied by changes in the glomerular blood pressure and flow, changes in the number of functioning nephrons, and the colloid content of the blood plasma.

The rate of tubular reabsorption, the main determinant of urine volume, is influenced by the rate of passage of the glomerular filtrate along the tubules, the osmotic pressure of the fluid in the tubules, and of the colloids. The hydrostatic pressure of the blood in the tubule capillaries and the activity of the tubule cells are also important factors. Neural factors have little effect on the kidney.

Hormonal Effects on Kidndy Function

The adrenal cortex and the posterior lobe of the pituitary influence the reabsorption of sodium, chloride, potassium, and water. The antidiuretic hormone, vasopressin from the posterior pituitary inhibits the reabsorption of sodium and chloride but increases the absorption of water in the distal convoluted tubule. Hormones from the adrenal cortex (desoxycorticosterone and aldosterone) are essential for the reabsorption of normal amounts of sodium and chloride in the same part of the tubule.

Regulation of Acid-base Balance

In normal metabolism, the acid-base balance is maintained as follows:

1. $CO_2 + H_2O \xrightarrow{\text{carbonic anhydrase}} H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$
2. $NaHPO_4^- \rightarrow Na^+ + NaHPO_4^- \rightarrow$ glomerular filtrate
3. $NaHPO_4^- + H^+ + NaH_2PO_4 \rightarrow$ urine
4. $HCO_3^- + Na^+ \rightarrow NaHCO_3 \rightarrow$ plasma and urine

The bicarbonate ions which pass the glomeruli and enter the filtrate are all reabsorbed. This occurs by means of an exchange of hydrogen ions secreted by the tubule cells in exchange for sodium ions which are present in the filtrate.

Hydrogen ions are made available in the tubule cells (Equation 1) due to the action of carbonic anhydrase, a zinc-protein enzyme.

In the glomerular filtrate, the hydrogen ions combine with the bicarbonate ions to form carbonic acid, which then reverts to water which is excreted and carbon dioxide which is reabsorbed by the tubule cells. During this time, sodium ions pass from the tubular urine into the tubule cells where they unite with bicarbonate ior s to form sodium bicarbonate (Equation 4). The sodium bicarbonate then passes into the plasma and extracellular water where its concentraiion is maintained.

A similar exchange mechanism occurs between hydrogen ions of the renal tubule cells and disodium phosphate (Na_2HPO_4) which dissociates into sodium ions (Na^+) and monohydrogen phosphate ions ($NaHPO^-_4$) (Equation 2). The sodium ion moves into the tubule cells and a hydrogen ion (H^+) moves from the tubule cells to unite with the monohydrogen phosphate ($NaHPO^-_4$) ion to form a dihydrogen phosphate salt (NaH_2PO_4), removing a hydrogen ion from the body (Equation 3).

CIRCULATORY SYSTEM

The system includes the *heart*, the *blood vessels* and *blood*.

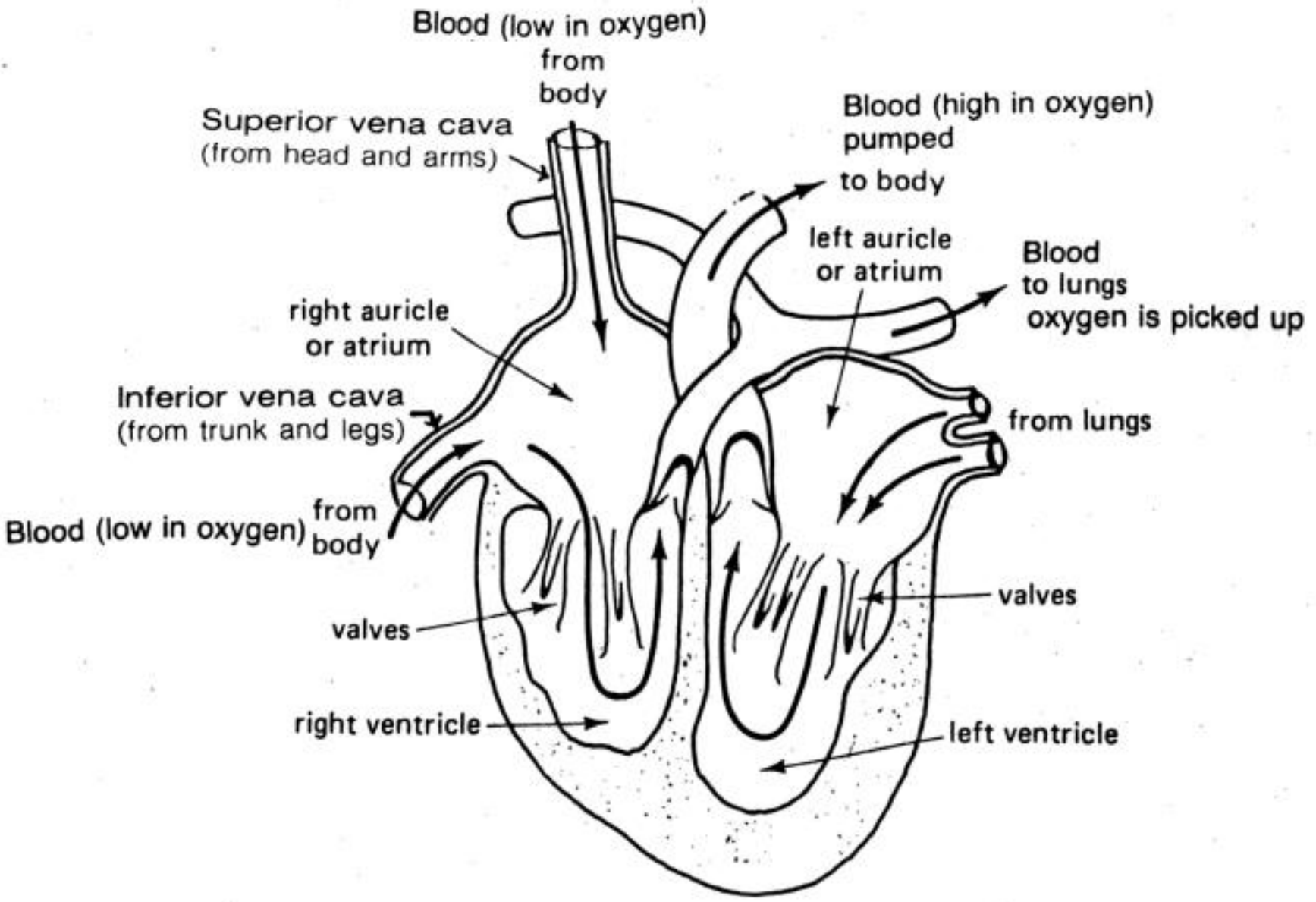
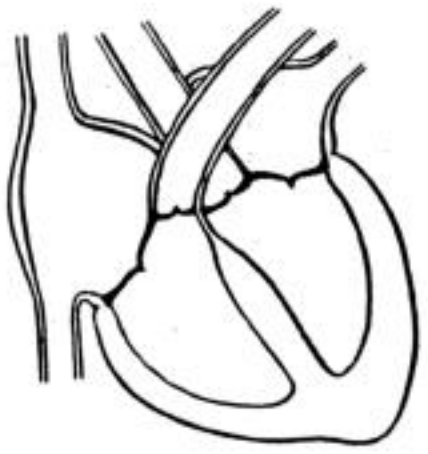


Fig. 3.23 Structure of the Heart. Arrows indicate direction of blood flow.

The Auricles fill and contract. Blood passes through the open Atrio-Ventricular Valves into the Ventricles.



As the filled Ventricles begin to contract the Atrio-Ventricular Valves are forced to close.



As the Ventricle continues to contract the Semilunar Valves open and Blood goes out the Aorta and Pulmonary Artery.



Heart—Blood in the heart's right side returns from the body depleted of oxygen. That in the left chambers has just been cleansed and oxygenated in the lungs. With each heartbeat the two sides simultaneously eject blood. From the right it goes to the lungs. From the left it enters the circulation. This cycle constantly returns clean, oxygen-rich blood to nourish the body.

Fig. 3.24 The cardiac cycle.

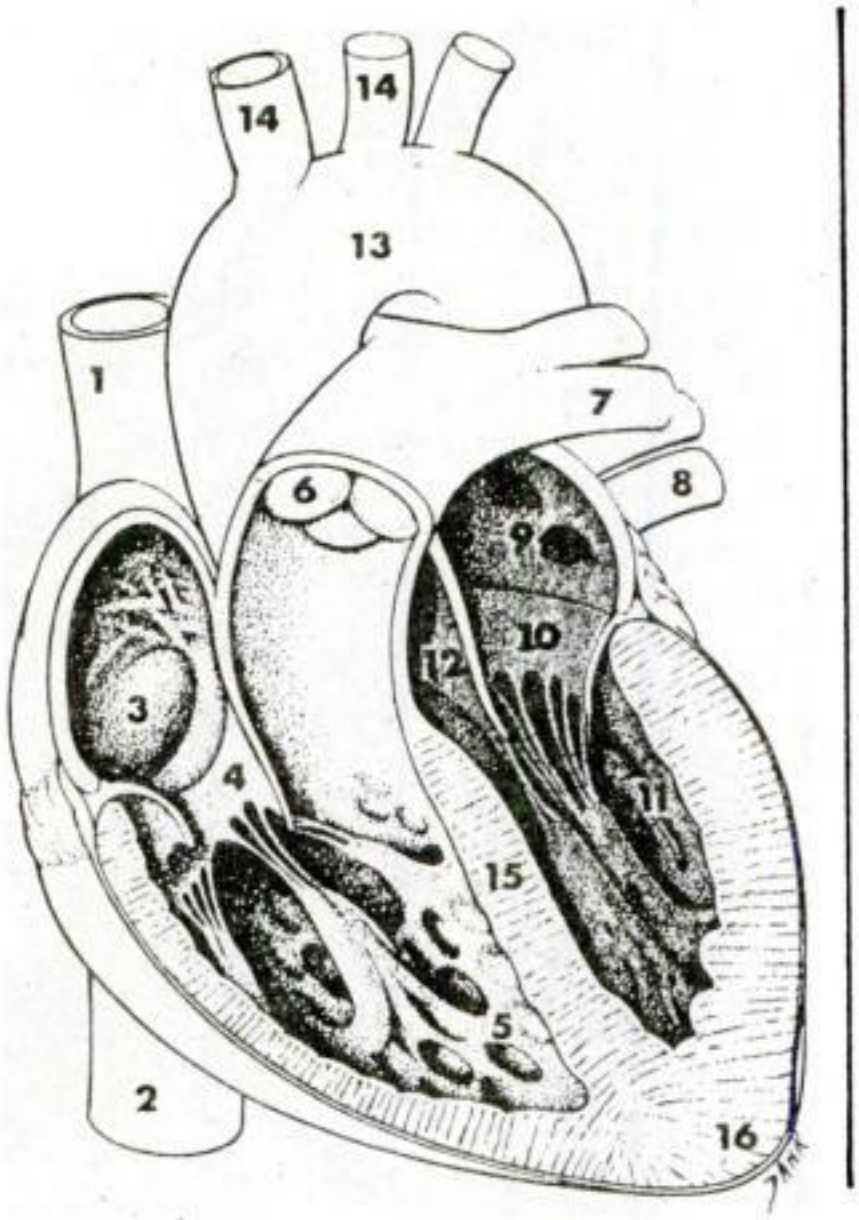
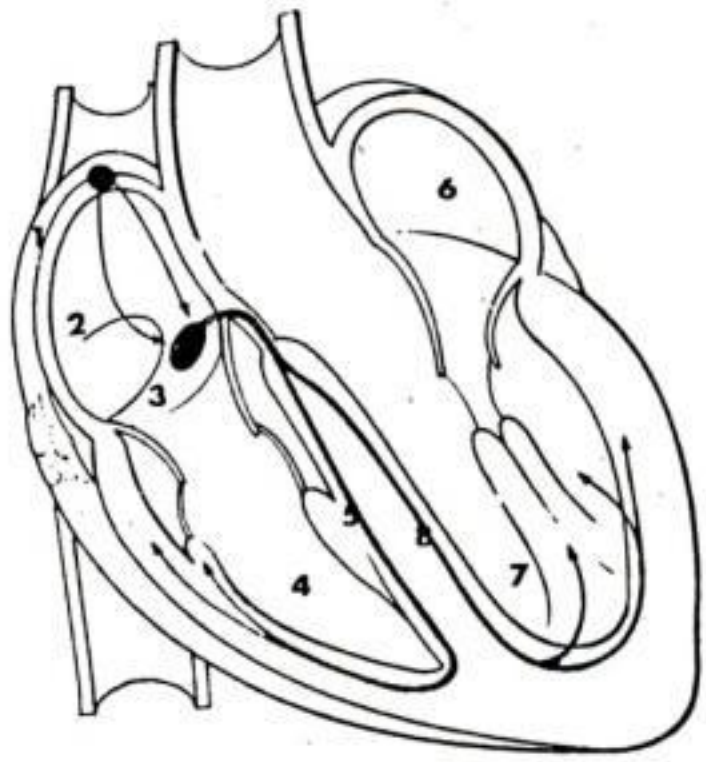


Fig. 3.25 Blood enters the heart by way of the superior vena cava (1) and inferior vena cava (2), into the right atrium (3). The tricuspid valve (4) releases it into the right ventricle (5), which pumps it through the pulmonary valve (6) and pulmonary artery (7) into the lungs for oxygen and release of carbon dioxide. The pulmonary vein (8) then carries the blood into the left atrium (9) and the mitral valve (10) feeds it to the left ventricle (11). Finally it is pumped past the aortic valve (12) into the aorta (13) and back into circulation via branch arteries (14 and others not shown). Dividing the two sides of the heart is the muscular septum (15). The point of the heart (16) is called the apex.

Conduction Pathway



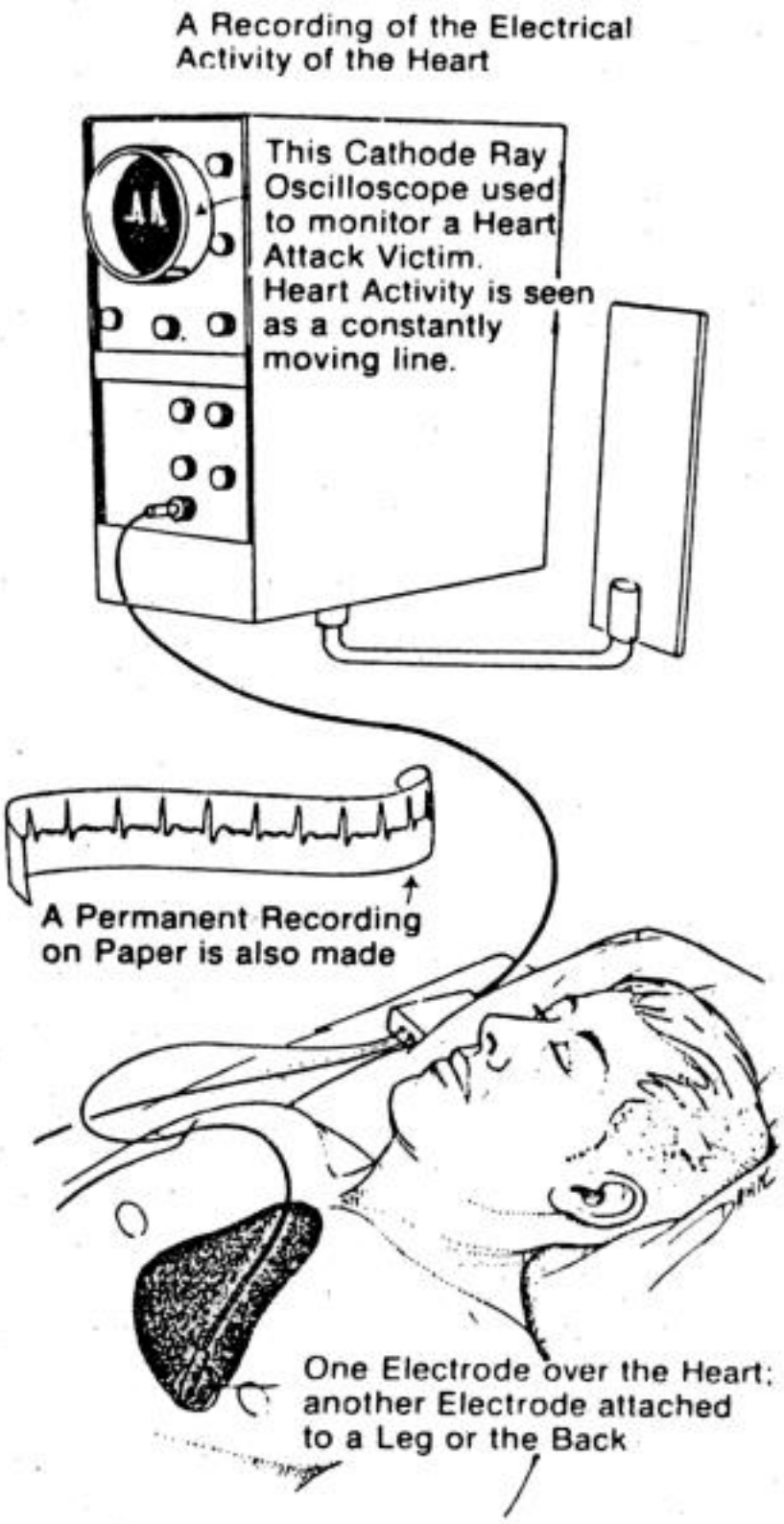
1 Sinoatrial Node (Pacemaker)
2 Right Atrium
3 Atrioventricular Node
4 Right Ventricle
5 Right "Nerve" Branch
6 Left Atrium
7 Left Ventricle
8 Left "Nerve" Branch

This is the pattern of the heartbeat that pumps and circulates the blood. The rhythm of the contractions is established by the sinoatrial node, a mass of specialized muscle fibers in the wall of the right atrium. That impulse travels through both atria, which contract, to the atrioventricular node. These fibers then transmit the impulse via the right and left "nerve" branches causing contraction of the two ventricles. The impulses of the heart increase during activity and diminish during rest.

Fig. 3.26 Conduction system of the Heart. The beat is initiated by the Sinoatrial Node

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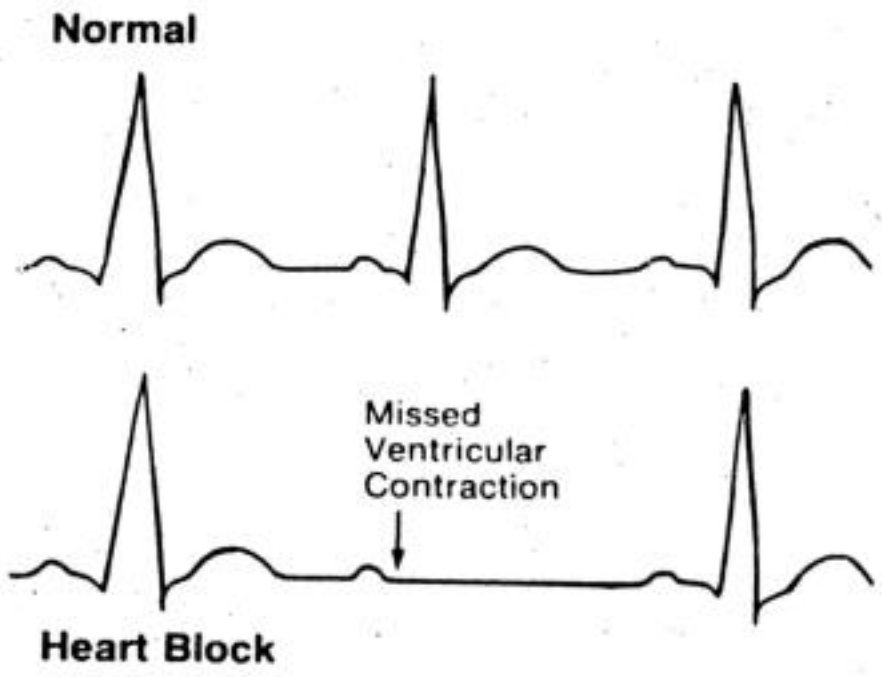
The Electrocardiogram ECG

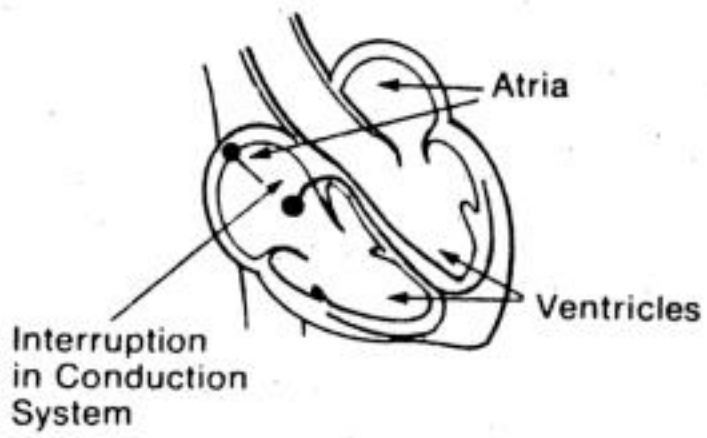


ECG—With electrodes in place on the person's body, the irregular waves produced by the electrical impulses of the beating heart register on the electrocardiograph. Simultaneously the waves' patterns are reproduced by a writing device on moving paper. When read by a physician, these patterns can indicate irregularities of the heart.

Fig. 3.27 The Electrocardiogram.

Electrocardiograms





Heart Block—An electrocardiogram reveals the existence of a heart block. The condition results when the signal for the rhythmical heartbeat fails to reach the ventricles, the lower chambers of the heart. Without this electrical impulse, they contract more slowly than the two atria, the upper chambers, and miss a contraction.

Fig. 3.28

The heart is located in the thoracic cavity between the lobes of the lungs. It is a strong muscular pump, consisting of two distinct sides. The right side accepts blood from the body into the right auricle. The blood then passes through the valves into the right ventricle when

Table 3.10

Heart Rates (beats/minute)*

Animal	Average	Range
Human	70	58–104
Ass	50	40–56
Bat	750	100–970
Camel	30	25–32
Cat	120	110–140
Cow	55	45–70
Dog	–	100–130
Elephant	35	22–53
Giraffe	66	–
Goat	90	70–135
Guinea pig	280	260–400
Horse	44	23–70
Lion	40	–
Monkey	192	165–240
Mouse	534	324–858
Rabbit	205	123–304
Rat	328	261–600
Sheep	75	60–120
Skunk	166	144–192
Squirrel	249	96–378
Swine	–	58–86
Chicken (adult)	–	250–300
Chicken (baby)	–	350–450

*Adapted from *Merck Veterinary Manual*, 5th edition

the heart relaxes. As it contracts, the blood is circulated to the lungs through pulmonary artery to be enriched with oxygen.

The oxygeneted blood then returns from the lungs to the left side of the heart through pulmonary vein into left auricle. From this chamber it passes into the left ventricle, and thence to the dorsal aorta, the main artery of the body. From this numerous arteries convey blood to the capillary systems in the organs and tissues. The closing of the valves between the chambers (auricles and ventricles) is the heart beat. The heart beat can indicate the state of health of the animal. In normal adults it is for cattle: 45 to 60 per minute and for pigs and sheep: 70 to 80 per minute. If excited or stressed, the animals heart rate will rise. The heart undergoes contraction (systole) and relaxation (diastole) rhythmically throughout the animal's life.

Blood vessels

Blood circulates around the body in a network of tubes which vary in diameter from 0.0001 mm to 10.0 mm and form a continuous system. *Arteries* are blood vessels that carries

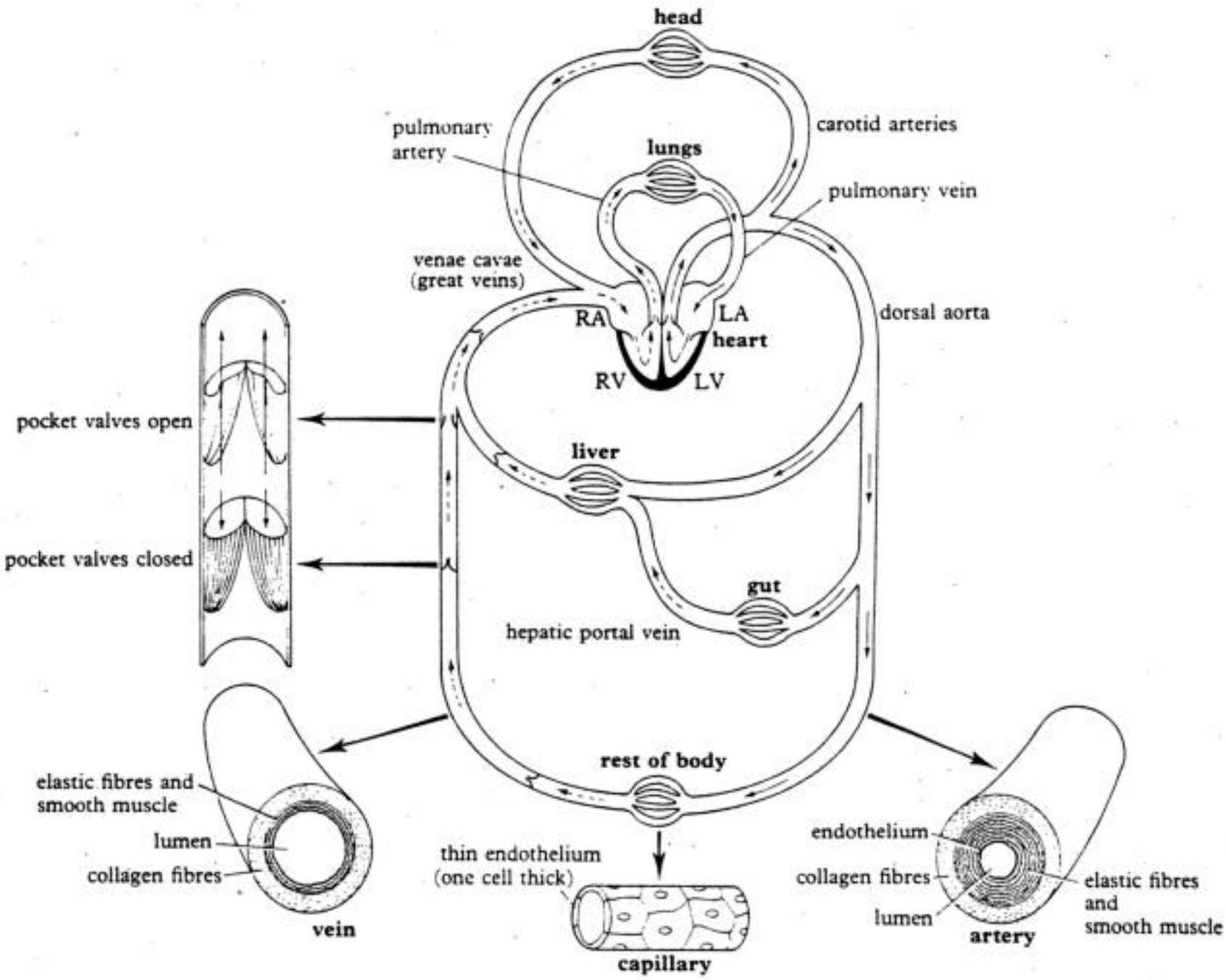


Fig. 3.29 General plan of the mammalian circulation and the detailed structure of some of its component structures. The thick tough walls of the arteries, well endowed with smooth muscle and connective tissue, are admirably suited to withstanding the pressures resulting from the pumping of the heart. The thinner-walled veins, equipped with pocket valves, minimize resistance to the flow of blood back to the heart after it has been through the narrow capillaries. The capillary walls are only one cell thick, thereby facilitating rapid diffusion of respiratory gases and soluble food materials between blood and tissues. **RA**, right atrium; **LA**, left atrium; **RV**, right ventricle; **LV**, left ventricle. Solid arrows, oxygenated blood; broken arrows, deoxygenated blood.

oxygen rich blood from the heart (except Pulmonary artery) to various body tissues. Walls are thick and contain heavy muscle layer that can withstand the blood pressure produced by heart. They branch into smaller and smaller tubes known as arterioles and then capillaries.

Capillaries are minute blood vessels that lie between the arterioles and the beginning of venules and veins. They are very tiny and thin walled (one cell thick) and widely distributed in all tissues. Transfer of nutrients from blood to tissue, and waste products from tissues to blood, occurs in capillaries.

The Veins. These are blood vessels that return blood from throughout the body to the heart and that convey it to the lungs, where carbon dioxide collected from the body and oxygen of the atmosphere are exchanged. Both arteries and veins have valves which prevent 'back flow'.

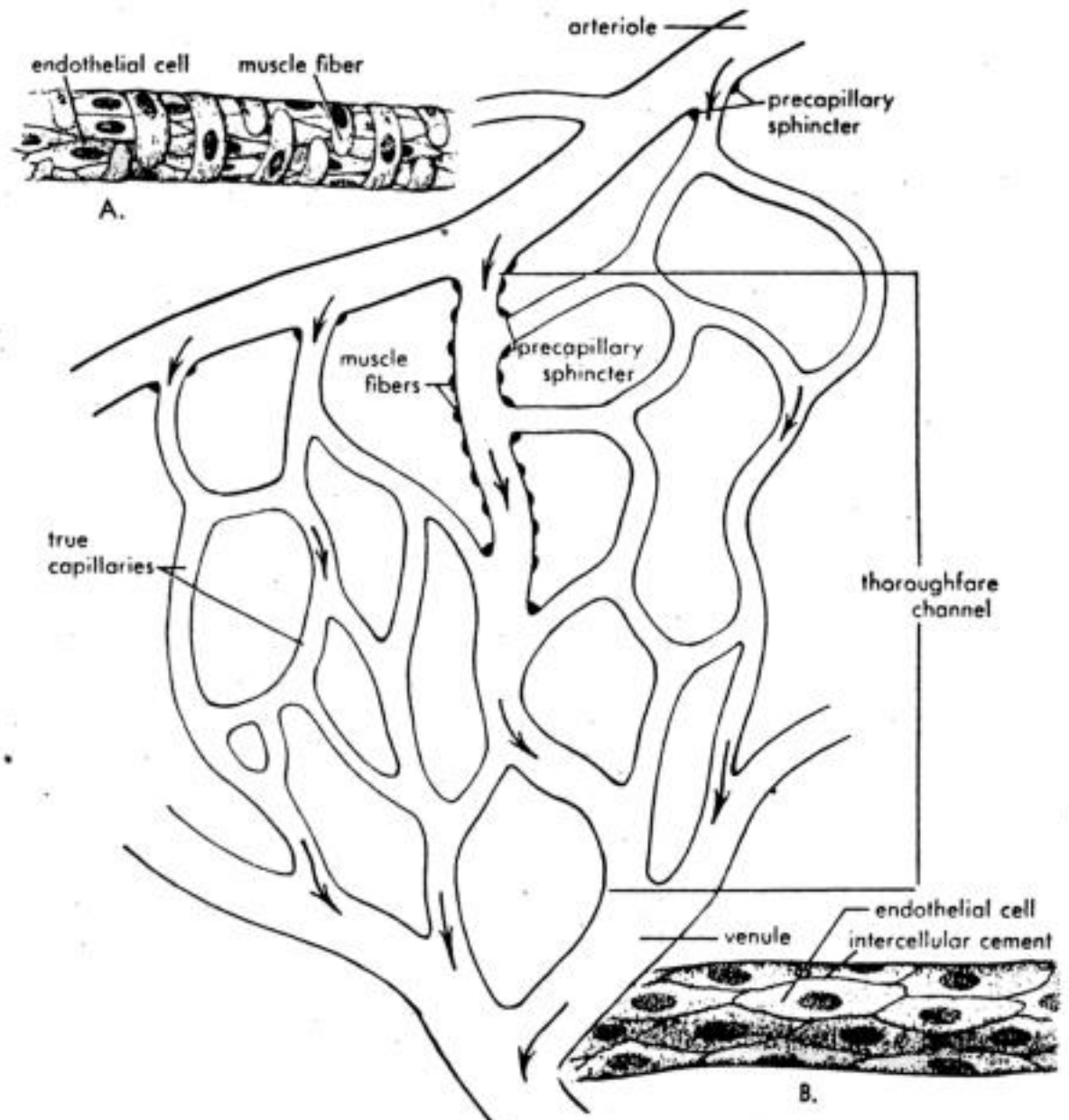


Fig. 3.30 Schematic representation of a capillary bed. Insert A shows some of the muscle fibers of the proximal part of a thoroughfare channel. Insert B shows a part of a true capillary.

Table 3.11 Metabolic Parameters of Selected Species

Common Name	Respiratory Rate (br/min)	Lung Tidal Volume (ml)	Body Temp (°C)	Lower Critical Temperature (°C)	Upper Critical Temperature (°C)	Basal Metabolic Rate (KCal)[a]	Pulse rate per mnt.
Beef cattle	12—20	3450.0	38.5	—21	27	8220	—
Dairy cattle	18—28	3450.0	38.5	—21	27	8220	45—55
Horse	8—16	9000.0	38.0	—	—	6840	30—40
Goat	10—20	310.0	39.0	20	28	—	70—80
Swine	8—18	—	39.0	18	32	3580	70—80
Sheep	10—20	—	39.5	—3	29	1875	70—80
Rabbit	36—56	15.8	38.9	—	—	190	—
Chicken	15—30	40.0	41.7	18	26	110	300
Turkey	25—35	—	—	—	—	—	—

a Calculated as 70 x BW $^{.75}$

Source : *Handbook of Animal Sc.* (1991), Putman, P.A. (ed)., Academic Press, Inc.

Table 3.12

Heart Rate, Blood Pressure, and Other Blood Parameters of Selected Species

Common Name	Heart Rate (Beats/Min)	Blood Pressure (sys/dias mm Hg)	Blood Volume (% live bw)	Blood pH	Hematocrit	Erythrocyte Diameter (μm)	Haemoglobin (g/dl)
Dairy cattle	60—70	134/88	7.70	7.38	32.4	5.6	11.0
Horse	32—44	80/50	9.70	7.35	28—42	5.6	14.5
Goat	70—135	120—84	7.00	—	27—34	4.1	10.0
Swine	60—80	169/108	6.75	—	39.1	6.2	13.0
Sheep	70—80	114/68	8.00	7.44	31.7	5.0	11.5
Rabbit	123—304	110/80	5.50	7.35	41.5	7.5	—
Chicken	178—458	131/95	5.00	7.54	32—45	7.0x12.0	9.0
Turkey	160—288	270/167 235/141	6.00—8.00	7.50	38	15.5x7.5	—

Source : *Handbook of Animal Sc.* (1991), Putman, P.A. (ed)., Academic Press, Inc.

LYMPHATIC SYSTEM

In parallel to blood circulatory system, the mammals have got another lymphatic system. It consists of (a) Lymph vessels—the channels begin in the tissue as blind lymph capillaries like that of blood capillaries but are larger and irregular in size and are situated throughout the body except the brain, spinal cord and eyes, (b) Lymph nodes also called lymph glands are discrete nodular structures scattered along the course of lymphatic vessels, and (c) Lymph, the tissue fluid.

How Lymph Is Produced?

The process of lymph formation is connected with the metabolic interchange between the blood and the tissues. As blood flows through the blood capillaries, part of the plasma nutrients and oxygen passes from the vessels into the surrounding tissues and forms the tissue fluid. The tissue fluid bathes the cells, and a continuous metabolic interchange takes place between the fluid and the cells; nutrients and oxygen enter the cell, and the waste products pass into the fiuid. Part of the tissue fluid containing waste products returns to the blood through the walls of the blood capillaries. At the same time some tissue fluid passes not into the blood capillaries, but into the lymph capillaries and forms the lymph. The process of formation and outflow of lymph intensifies during increased activity of the organs.

Main Roles of the System

The system represents an accessory route by which fluids can flow from the interstitial spaces into the blood. And, most important of all, the lymphatics can carry proteins and even large particulate matter away from the tissue spaces, neither of which can be removed by absorption directly into the blood capillary. It also plays an important role in absorption and transportation of long chain fatty acids and vitamin K from the intestine to the blood. It also acts as a defence mechanism against noxious materials by filtering them out of tissue fluid and phagocytising them, thereby assisting in the control of infection and antibody formation.

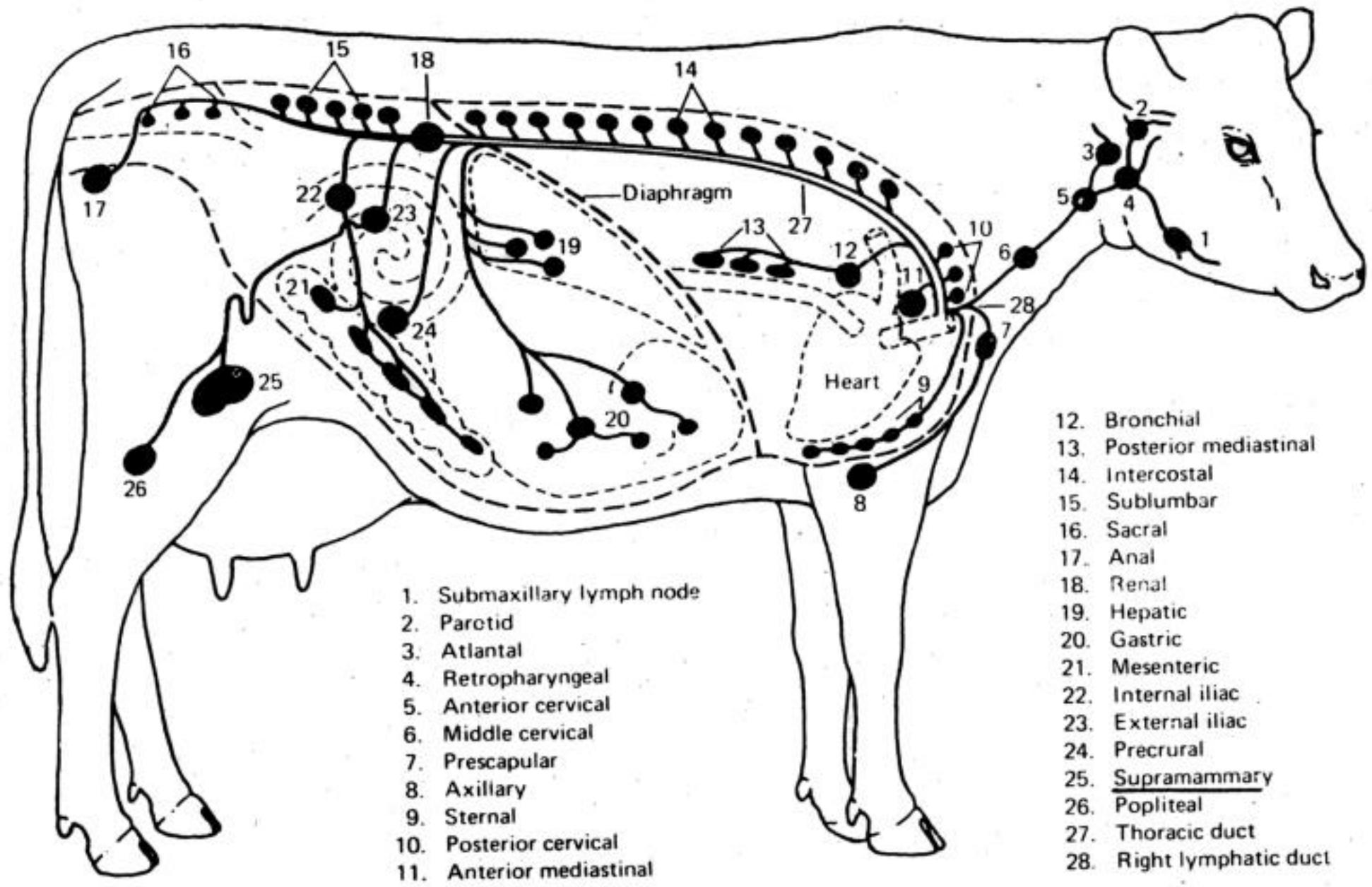


Fig. 3.31 Schematic drawing of the lymphatics of the Cow.

Composition of Lymph

Lymph is a mixture of capillary filtrate and tissue fluid which has entered lymph capillaries. The fluid resembles blood plasma except for a lower concentration of plasma proteins (2.2–3.4 per cent). In plasma it is between 5.5—6.7 per cent. The protein percentage varies depending upon the origin. The composition also varies depending upon the nature of nutrients absorbed. During fat absorption, the colour of the lymph becomes milky-white (the lymph flowing out of other organs is usually colourless). Lymph does contain fibrinogen and prothrombin, and will clot slowly. In general, lymph contains water, gases, proteins, non-protein nitrogenous substances, glucose, inorganic substances, hormones, enzymes, vitamins and immune substances.

Flow of Lymph

The lymph capillaries form more or less complex network throughout most tissues. These network finally combine to form lymph vessels, which in turn unite to form larger and larger lymphatic vessels. All of the lymph collected from the body and flows through lymph vessels are sluggish and in one direction only, from the tissue towards the heart. Ultimate object of the flow is to get an entry to the venous system by way of the *thoracic duct*, *right lymphatic duct* (if present) and *tracheal ducts*. All these ducts enter the cranial vena cava or the jugular veins as they unite to form the vena cava.

The lymph vessels have numerous valves scattered throughout their course. The valves permit the flow of lymph only in the direction toward the heart or great veins just cranial to the heart.

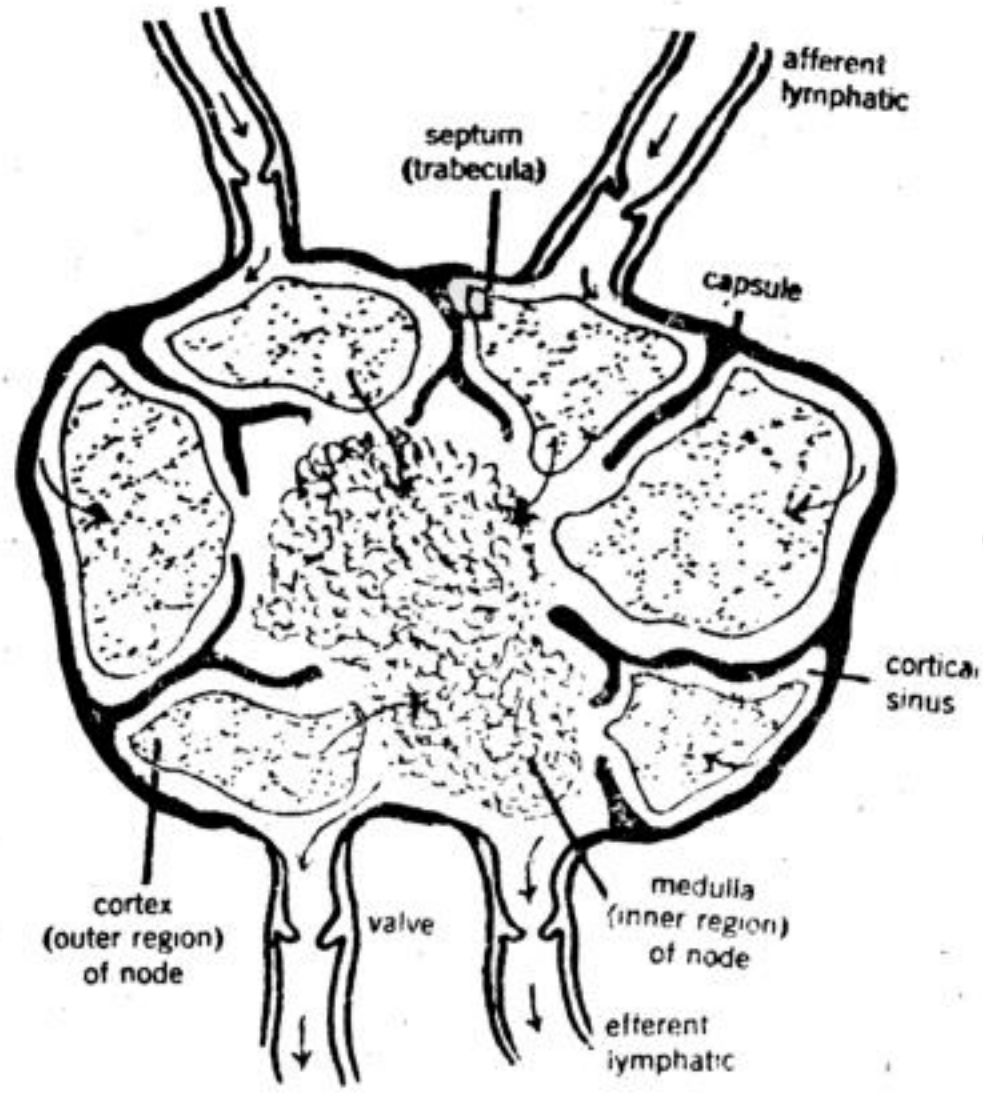


Fig. 3.32 Diagrammatic sketch of lymph node.

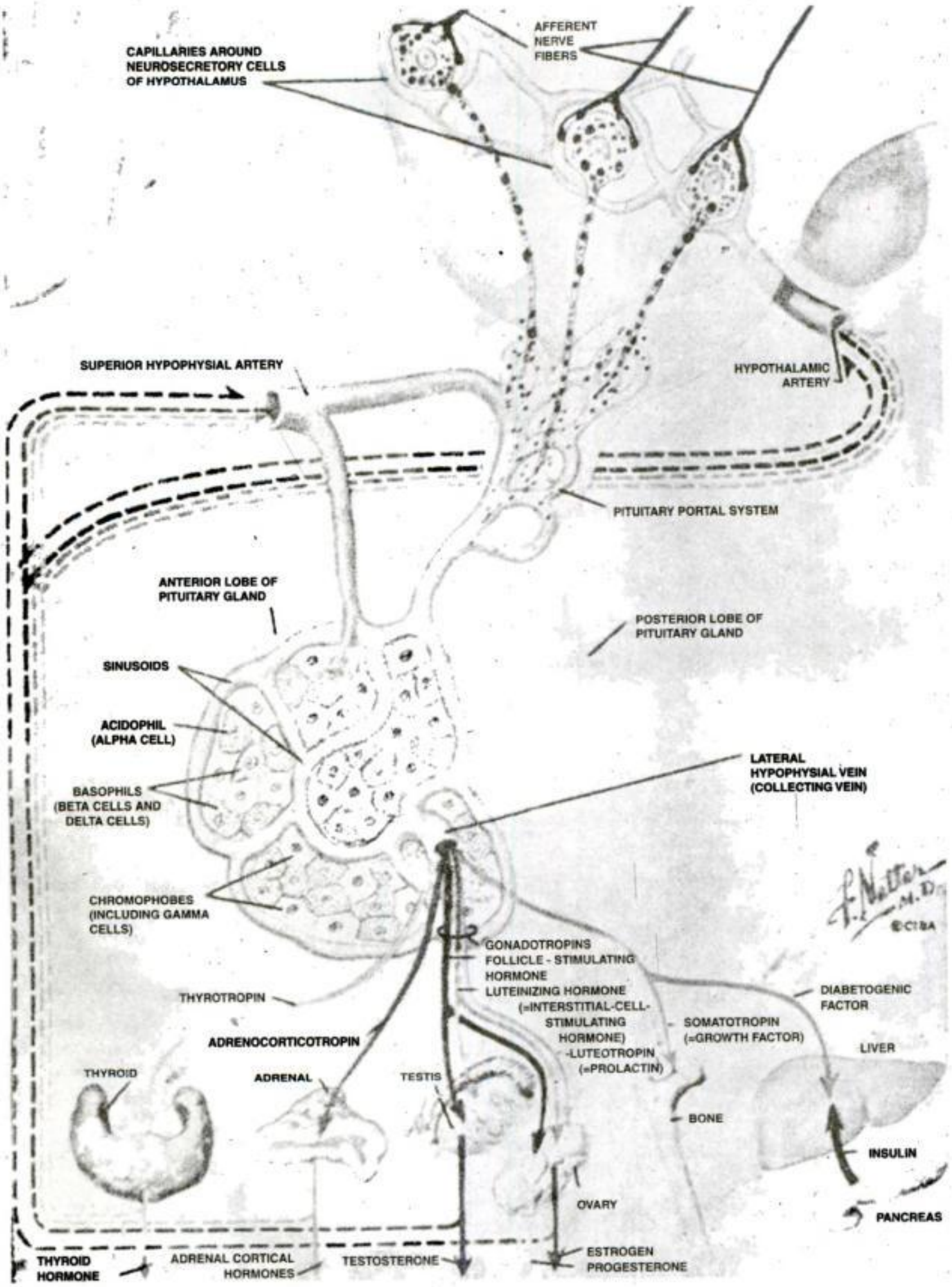


Plate 1. Relation of the hypothalamus to the anterior lobe of the pituitary gland. Note that the humoral substances from neurosecretory cells in the hypothalamus pass to the anterior lobe of the pituitary gland through the portal system (Copyright by CIBA Pharmaceutical Products Inc.).

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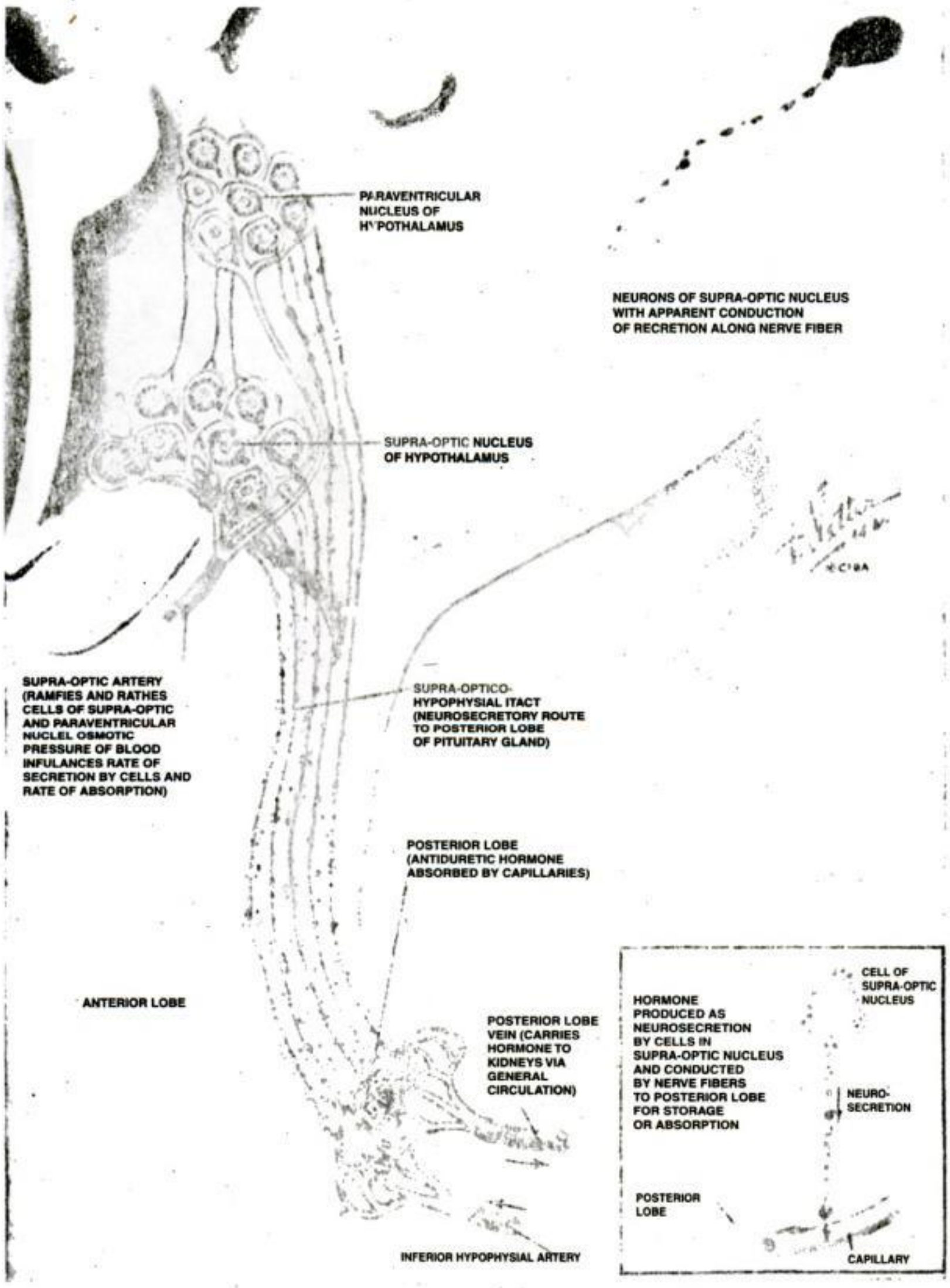


Plate 2. Relation of the hypothalamus to the posterior lobe of the pituitary gland. In contrast to the anterior lobe, the posterior lobe is innervated by the supraopticohypophyseal tract. The secretion products are conducted along the nerve fibers from the hypothalamus to the capillaries.

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The factors affecting the flow are as follows:

1. the difference in pressure at the two ends of the lymph system,
2. the massaging effects of the muscular movements,
3. the presence in the lymph vessels of valves which permit flow in one direction only,
4. the propulsive contractility of lymphatic vessels.

Function of Lymph Nodes

Also called lymph glands, are small roundish or elongated masses of lymphatic tissue. Each node has a connective tissue capsule which gives off trabeculae into the interior. The framework of the lymph nodes consists of reticular tissue. Between the trabeculae are nodules which form lymphocytes. Consequently lymph nodes are haematopoietic organs.

Among functions of lymph nodes, is the production of lymphocytes which are phagocytic cells capable of ingesting foreign particles, thereby removing them from the lymph before it is implied into the blood.

In addition to filtering the lymph, the nodes have the ability to form antibodies. Thus when bacteria and protein antigens arrives at lymph nodes, they are first phagocytised, and then during the following week or more specific antibodies are formed against them and emptied into the circulating body fluids to destroy additional bacteria or bacterial toxins.

NERVOUS SYSTEM

The nervous system, along with the endocrine system, provides the control functions for the body. In general, the nervous system controls the rapid activities of the body, such as muscular contractions, rapidly changing visceral events and even the rates of secretion of some endocrine glands. The endocrine system regulates principally the metabolic functions of the body.

The nervous system is unique in the vast complexity of the control reactions that it can perform. It can receive literally thousands of bits of information from the different sensory organs and then integrate all these to determine the response to be made by the body.

Brain is the supervisory centre of the nervous system in all vertebrates. The brain controls both conscious behaviour (e.g. walking and thinking, and most involuntary behaviour (e.g., heartbeat and breathing). In all higher animals it is also the site of emotions, memory, self awareness and thought. It functions by receiving information via nerve cells (neurons) from every part of the body, evaluating the data, and then sending directives to muscle and glands apart from simply storing the information. A single neuron may receive information from as many as 1,000 other neurons.

Anatomically, the brain occupies the skull cavity and is enveloped by three protective membranes.

Components of the Nervous System

Nervous tissue is composed of three functionally different types of cells: (1) *Neurons* (nerve cells), which transmit impulses; (2) *Schwann cells*, which form a segmented covering around the processes of many of the neurons of the peripheral nervous system; and (3) *Neuroglia* (glial cells), which are specialized to serve as supportive tissues between the neurons in the central nervous system.

Neurons

The neuron (nerve cell) is the basic anatomic and physiologic unit of the nervous system. It has the ability to respond to stimulation by initiating and conducting an impulse. Some other cells such as muscle fibres, are also capable of conducting impulses, but the unique shape of the nerve cell makes it specially well suited to serve as communicator. Neurons possess process that can be quite long. For example, in some cases a single neuron—that is, a single cell—extends from the spinal cord to the tip of a toe!

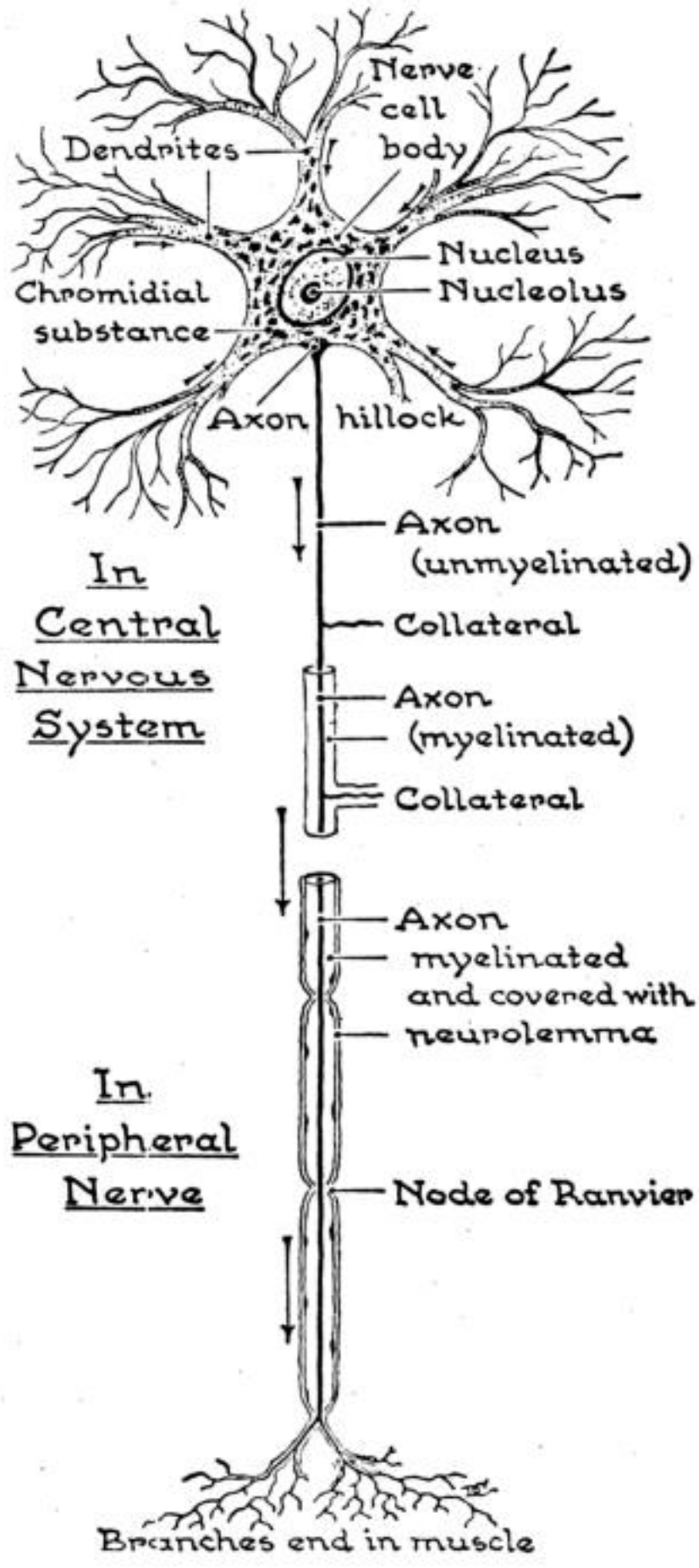


Fig. 3.33 Diagram of a multipolar neuron.

Schwann Cells

In some nerve fibres axons are surrounded by a type of satellite cell called Schwann cells.

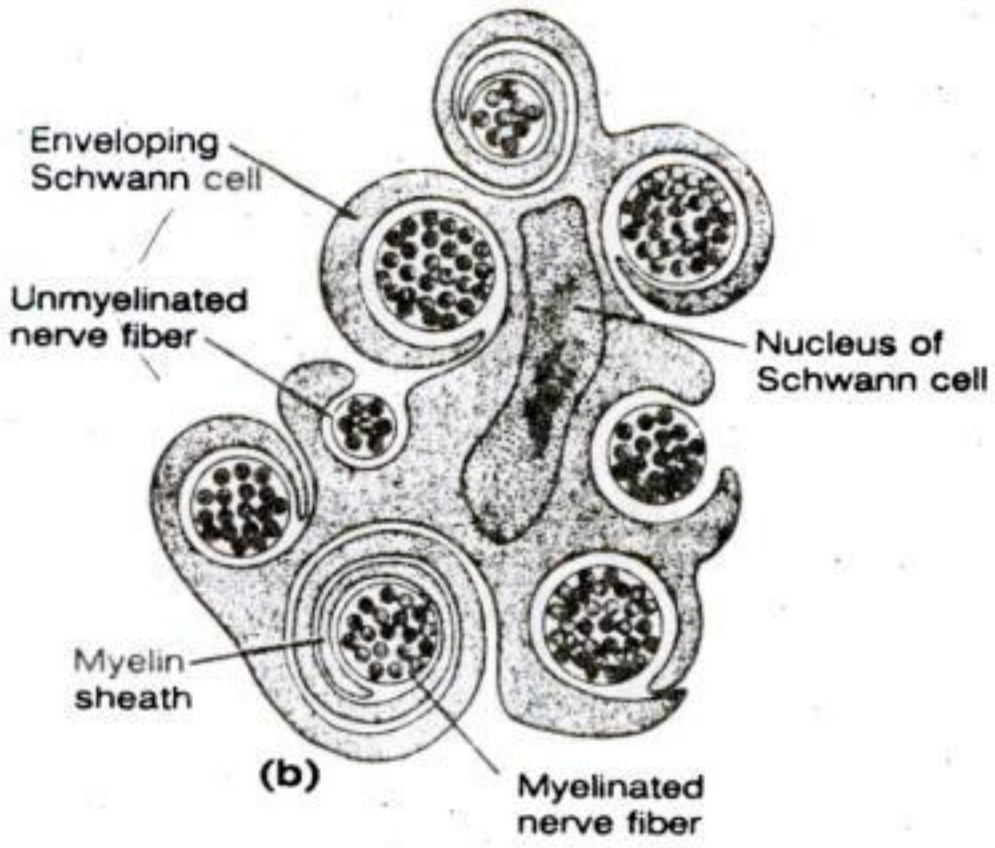


Fig. 3.34 The ultrastructure of myelinated and unmyelinated neurons. **(a)** Diagram of a myelinated nerve fiber. **(b)** A single Schwann cell encompassing eight neurons. The neurons around which the Schwann cell has coiled are myelinated; the neurons thar are simply engulfed by the Schwann cell are unmyelinated.

Neuroglia

There are billions of neurons within the central nervous system, there are even more supportive cells distributed among the neurons. These are neuroglia thought to provide structural support for the neurons, are involved in the transfer of nutrients and assist in the removal of waste products from the neurons.

Organization of Nervous System

Although there is actually only one nervons system, it can be thought of as being separated into various divisions based on either structural locations or unique functional characteristics. It should be kept in mind, however, that these divisions—which are themselves called *nervous systems*—are all integral parts of a single nervous system. Structurally, the nervous system may be

Table 3.13 **Organisation of the Nervous System**

According to location	*According to function*
Central Nervous System	**Somatic Nervous System**
Brain	**Autonomic Nervous System**
Spinal cord	Sympathetic nervous system
Peripheral Nervous System	Parasympathetic nervous system
Cranial nerves and their associated receptors and ganglia	
Spinal nerves and their associated receptors and ganglia	

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divided into two parts (1) *The Central Nervous System* and (2) *peripheral nervous system*. but according to function, (1) Somatic nervous system and (2) Autonomic nervous system as below:

Central Nervous System

The Central nervous system (CNS) consists of the brain and the spinal cord, contains not only components of transmission, but also provides for those functions that we associate with computors such as memory, a central processing unit for solving problems.

DIVISION OF THE CENTRAL NERVOUS SYSTEM

1. BRAIN	Cerebrum; Cerebral hemispheres including Cerebral cortex and basal ganglia	**FOREBRAIN**
	Diencephalon including thalamus and hypothalamus	
	Mid brain	
	Pons	**BRAINSTEM**
	Medulla	
	Cerebellum	

2. SPINAL CORD

The brain is completely encased within 10 bony structures, the cranial cavity of the skull and the spinal cord within the Vertebrate canal of the spinal column.

The Brain

The brain is the part of the CNS that is situated in the cranial cavity. It is developed from three primary vesicles: the prosencephalon (forebrain), mesencephalon (midbrain) and rhombencephalon (hindbrain). By further growth, elongation and bending, the primary vesicles become divided into

Table 3.14

Subdivisions of the Neural Tube and the Major Adult Structures Derived from Each

Primary division	*Subdivision*	*Adult brain structures*	*Neural canal region*
Prosencephalon (forebrain)	Telencephalon	Cerebral hemispheres (cerebrum)	Lateral ventricles and upper portion of the third ventricle
		Cerebral cortex	
		Basal ganglia	
		Olfactory bulbs and tracts	
	Diencephalon	Epithalamus	Most of the third ventricle
		Thalamus	
		Hypothalamus	
Mesencephalon (midbrain)	Mesencephalon	Corpora quadrigemina	Cerebral aqueduct
		Cerebral peduncles	
Rhombencephalon (hindbrain)	Metencephalon	Cerebellum	Fourth ventricle
		Pons	
	Myelencephalon	Medulla oblongata	Part of the fourth ventricle
Spinal cord	Spinal cord	Spinal cord	Central canal

5 secondary vesicles. Further details of the major adult derivatives of the secondary five vesicles as well as the cavities that drain them are given below:

Short description about some major brain structures are given below:

1. *Brainstem*: The brainstem is literally the stalk of the brain: through it passes all the nerve fibres relaying signals of affarent input and efferent output between the spinal cord and higher brain centres. In addition brainstem gives rise to a number of pairs of cranial nerves. It is composed of (i) Midbrain, (ii) Pons, (iii) Medulla oblongata.

Running through the entire brainstem is a core of tissue called the reticular formation, which is composed of small, highly branched neurons.

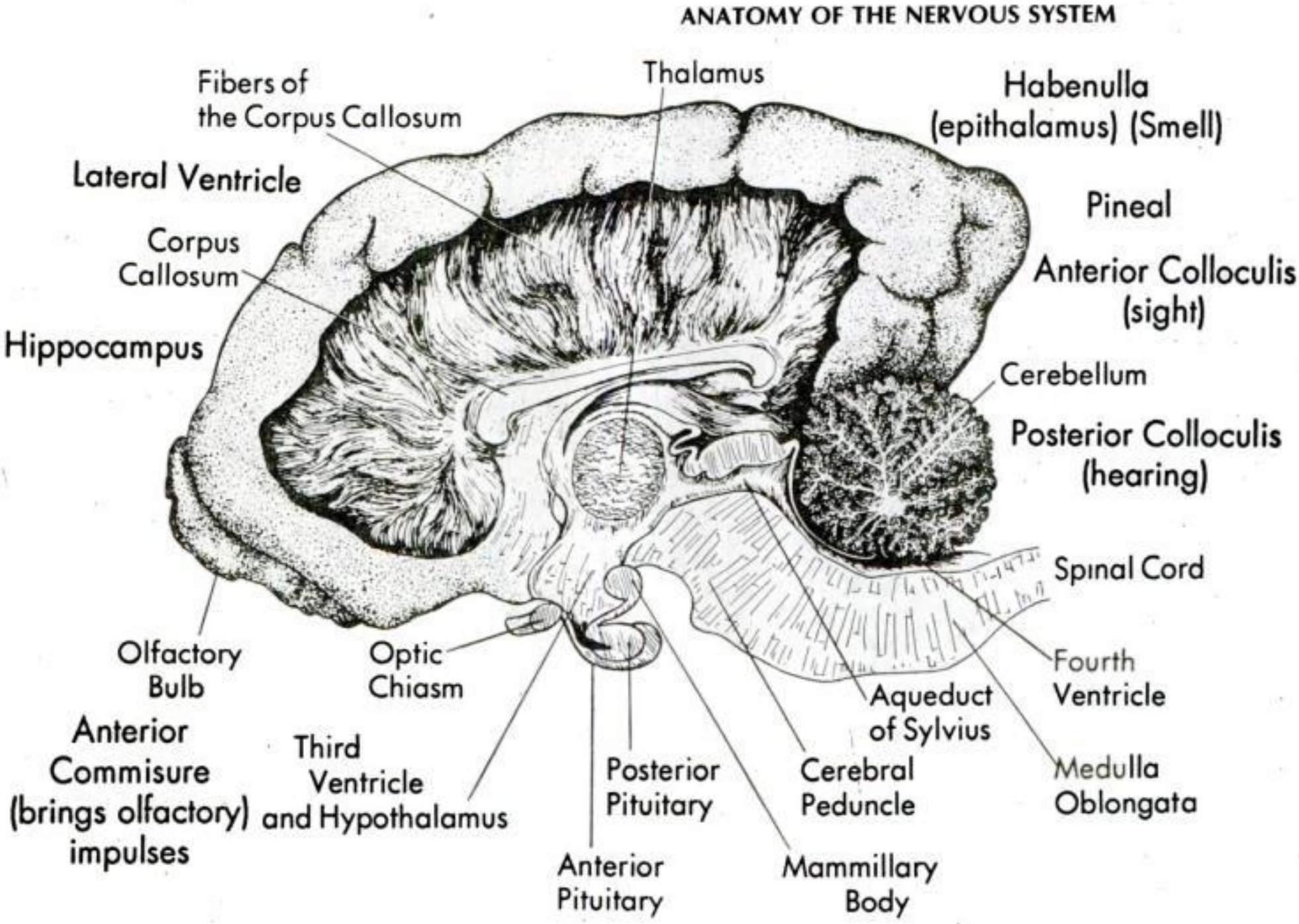


Fig. 3.35 Sagittal section of the brain partially excavated. (After Meyer in Miller, Christensen, and Evans, Anatomy of the Dog, courtesy of W. B. Saunders Co.)

2. *Cerebellum*: The *Cerebellum* functions as a coordinator (maintaining balance) of the brain's other centres and is a mediator between them and the body. It functions chiefly as a coordinator of *muscular activity* in eating, talking, running and walking. Damage to the cerebellum results in incoordination, which interferes with voluntary muscular action, but it does not cause paralysis. Farm animals have a large cerebellum, although elephants and whales probably have the largest

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to body size. The location of the cerebellum relative to the brainstem and forebrain can be seen (Fig.3.36).

3. *Forebrain*: The large part of the brain remaining when the brainstem and cerebellum have been excluded in the forebrain. It consists of a central core (the diencephalon) and the right and left *cerebral hemisphere* (the cerebrum). The hemispheres, although largely separated by a longitudinal divisions are connected to each other by axon bundles known as *Commissures*, the *Corpus callosum* being the largest.

The outer part of the cerebral hemispheres, the cerebral cortex, is a cellular shell about 3 mm thick. The cortex is divided into several parts, or lobes (the frontal, parietal, occipital and temporal lobes. (Fig. 3.36).

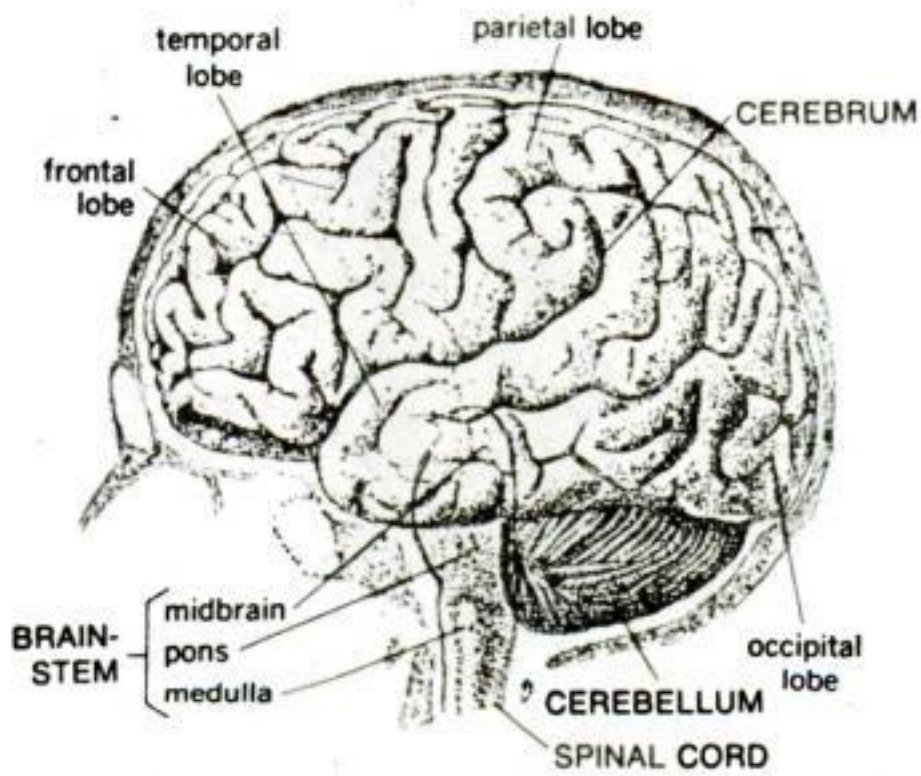


Fig. 3.36 The three major divisions of the brain: the brainstem, cerebellum, and forebrain. The outer layer of the forebrain (the cerebrum) consists of four lobes, as shown. The diencephalon, which is an extension of the brainstem and lies deep within the brain, is not shown.

The cortex is an area of grey matter. In other parts of the forebrain, nerve fibre tracts predominate, their whitish myelin coating distinguishing them as white matter.

4. The *thalamus*, part of the diencephalon, is a relay station and important integrating centre for sensory input on its way to the cortex and is also important in motor control. Like the brainstem, it contains a central cone that is part of the reticular formation. The *hypothalamus*, which lies below the thalamus is a tiny region. It appears to be the single most important control area for the regulation of the internal environment.

5. The pons and *medulla oblongata* control reflex action such as breathing, swallowing, vomiting and blinking of the eyelids. They usually act independently of the cerebrum and cerebellum.

Spinal Cord

The spinal cord is a slender cylinder about as big around as the little figer in adult cattle and buffaloes.

Fig(3.37)shows the basic division of a cross section of the spinal cord. The central butterfly—

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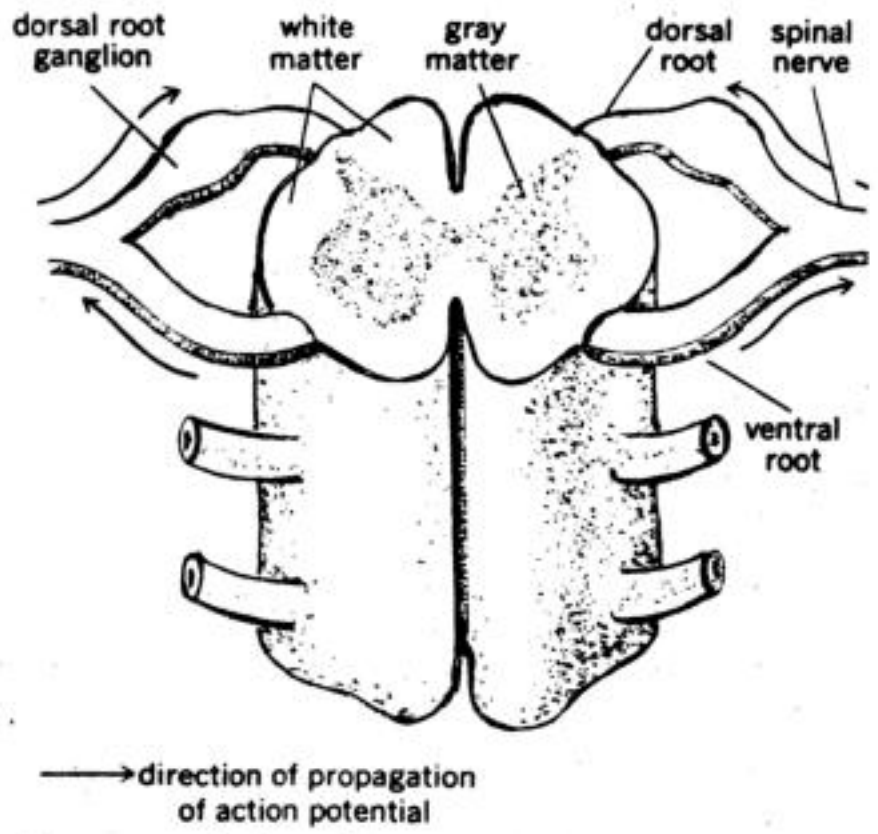


Fig. 3.37. Section of the spinal cord (ventral view i.e., fror the front).

shaped area is called the *grey matter*; it is filled with interneurons, the entering fibres of affarent neurons, and glial cells. The grey region is surrounded by *white matter*, which consists largely of myelinated axons. These axons are organized into groups called tracts and pathways, which run longitudinally through the cord, some descending to convey information from the brain to the spinal cord (or from upper to lower levels of the cord), other ascending to transmit in the opposite direction.

Groups of affarent fibres (from peripheral receptors) enter the spinal cord on the dorsal side (the side toward the back of the body); these groups form the *dorsal roots* and contain the *dorsal*

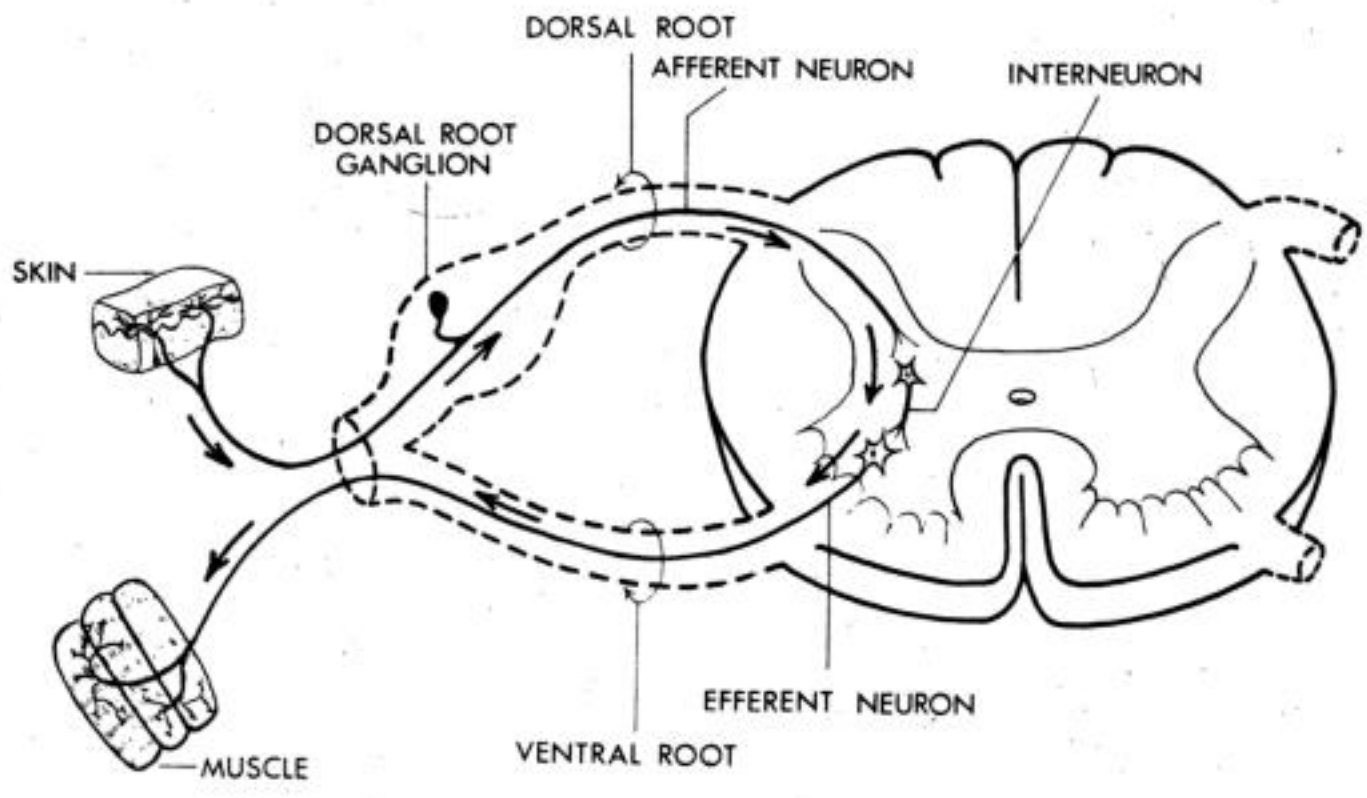


Fig. 3.38—Diagrammatic cross-section of the spinal cord. (Kitchell in Miller, Christensen, and Evans. *Anatomy of the Dog*, courtesy of W. B. Saunders Co.)

root ganglia (the cell bodies of the affarent neurons). Efferent fibres (to effector cells) leave the spinal cord on the ventral side (the side toward the front of the body) via the *ventral roots*.

Dorsal and ventral roots combine to form a pair of spinal nerves one on each side of the spinal cord. (The spinal nerves are discussed with the peripheral nervous system).

Peripheral Nervous System (PNS)

The peripheral nervous system is composed of nerves that connect the more outlying parts of the body with the central nervous system and the ganglia (groups of nerve cell bodies) associated with the nerves. The peripheral nervous system includes 12 pairs of cranial nerves, which arise from the brain and the brainstem. Pairs of spinal nerves arise from the spinal cord, which itself extends from the region of the occipital bone to the level of the lumber and sacral vertebra, depending on species. For example, the spinal cord ends at the level of the first sacral vertebrae (S1) in the bovine (S3 in calf); S1 or S2 in the horse, S2 in pig, S1 in sheep and goat.

Spinal Nerves (Somatic Components)

The somatic division also known as voluntary nervous system and is made up of all the fibres going from the central nervous system to skeletal muscle cells. The cell bodies of these neurons are located in groups in the brain or spinal cord; their large diameter, myelinated axons leave the central nervous system and pass directly (i.e. without any synapse) to skeletal muscle cells. The neurotransmitter substance released by these neurons is *acetylcholine*.

With the exception of cervical nerves and coccygeal nerves, there is a pair of spinal nerves (one right and one left which emerge behind the vertebra of the same serial number and name).

Almost as soon as the spinal nerve emerges from the vertebral canal it divides into a dorsal branch and a ventral branch. Both of these branches are mixed nerves, because it contains both sensory and motor fibres.

Cranial Nerves

There are 12 pairs of cranial nerves with a right and left nerve comprising each pair. Most of the cranial nerves emerge from the basal surface of the brainstem and have their nuclei of origin in the brainstem. After emerging from the brainstem, the cranial nerves usually leave from the cranial cavity through holes (foramina) in the skull. The cranial nerves usually supply innervation to structures in the head and neck. The vagus nerve is an exception. In addition to its sensory and motor supply to the pharynx and larynx it also supplies parasympathetic fibres to visceral structures in the thorax and abdomen. Some cranial nerves are strictly motor (efferent), some are strictly sensory (affarent), and some are mixed (both sensory and motor). The cranial nerves are designed both by number and by name. The cranial nerves are listed by number, name and distribution as listed below.

Somatic Nervous System

It is also called the voluntary nervous system. It includes somatic *motor nerve* cells or efferent neurons that carry impulses from the central nervous system to the skeletal muscle, thus produces contraction of the skeletal muscle. This may be under the conscious control of the individual or

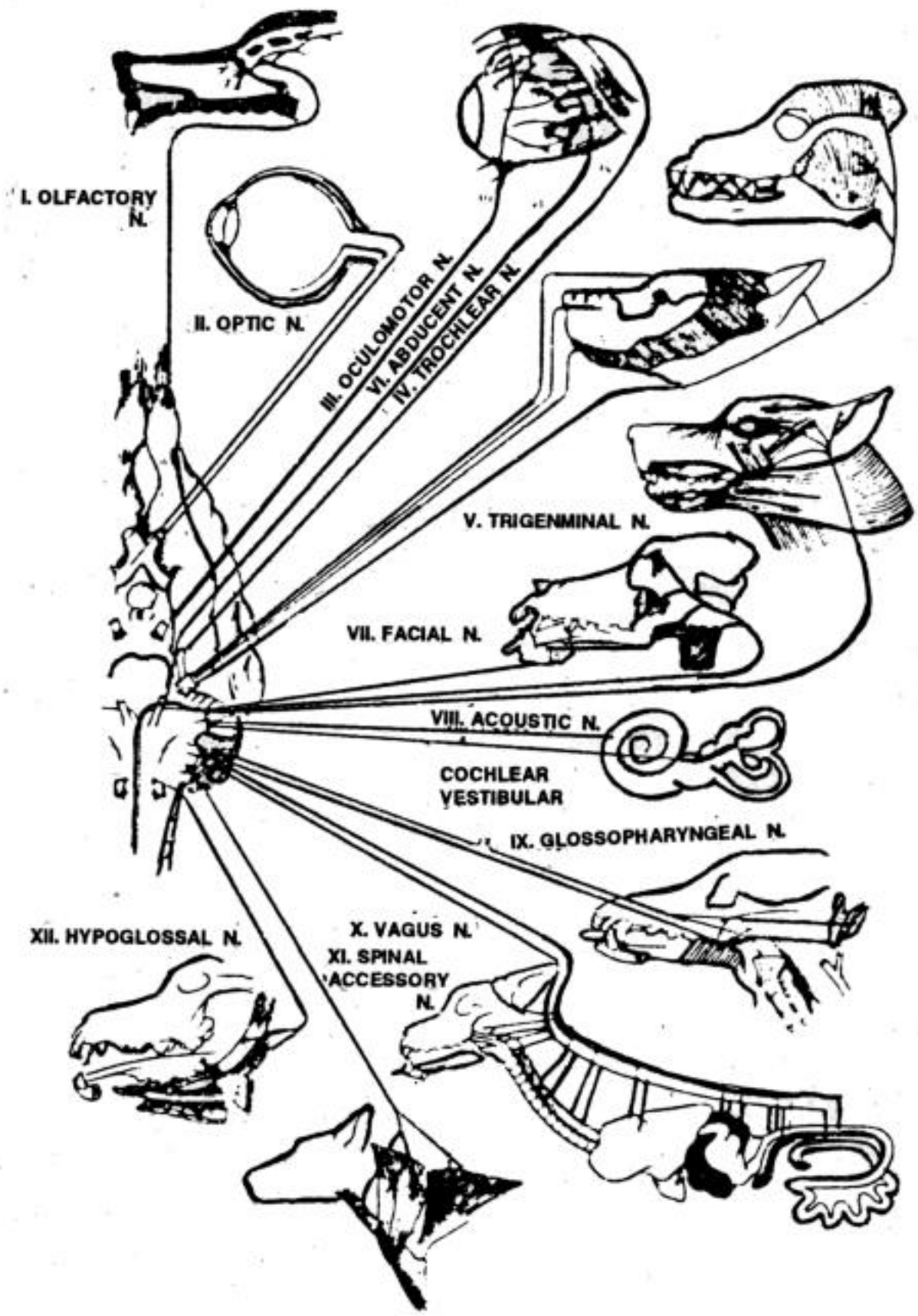


Fig. 3.39 Origin and distribution of cranial nerves in dog.

in the case of reflex response which may not be conciously controlled.

Somatic *sensory nerve cells* or *affarent neurons* carry impulses from the sense organs like skin, the fascia and around the joint to the central nervous system.

Autonomic Nervous System

The autonomic nervous system differs anatomically from the somatic motor mechanism. The chief difference lies in the fact that the autonomic fibres which originate in the spinal cord do not innervate muscle or gland directly. It may be seen that the fibre ends in synaptic union with a

Table 3.15

Cranial Nerves

No.	Name	Type	Distribution
I	Olfactory	Sensory	Nasal mucous membrane (sense of smell)
II	Optic	Sensory	Retina of eye (sight)
III	Oculomotor	Motor	Most muscles of eye
			Parasympathetic to ciliary muscle and circular muscle of iris
IV	Trochlear	Motor	Dorsal oblique muscle of eye
V	Trigeminal	Mixed	Sensory-to eye and face; motor-to muscles of mastication.
VI	Abducens	Motor	Retractor and lateral rectus muscles of eye
VII	Facial	Mixed	Sensory-region of ear and taste to cranial two-thirds of tongue; motor-to muscles of facial expression; parasympathetic-to mandibular and sublingual salivary glands.
VIII	Vestibulocochlear	Sensory	Cochlea (hearing); semicircular canals (equilibrium)
IX	Glossopharyngeal	Mixed	Sensory-to pharynx and taste to caudal third of tongue; motor -to parotid salivary glands
X	Vagus	Mixed	Sensory-to pharynx and larynx; motor -to muscles of larynx; parasympathetic-to visceral structures in the thorax and addomen
XI	Spinal accessory	Motor	Motor- to muscles of shoulder and neck
XII	Hypoglossal	Motor	Motor-to muscles of tongue

Modified from Frandson, R.D. : Anatomy and Physiology of Farm Animals. 4th Ed. Philadelphia, Lea & Febiger, 1986, p 84.

second neuron which does innervate a muscle or gland. This is in direct contradistinction to the somatic fibre which connects the spinal cord directly with an effector organ. Thus, in considering the autonomic nervous system, we speak of *preganglionic* and *postganglionic* fibres. The preganglionic fibres terminate in the ganglion consisting of cell bodies which give rise to postganglionic fibres. These later fibres innervate smooth muscles and glands.

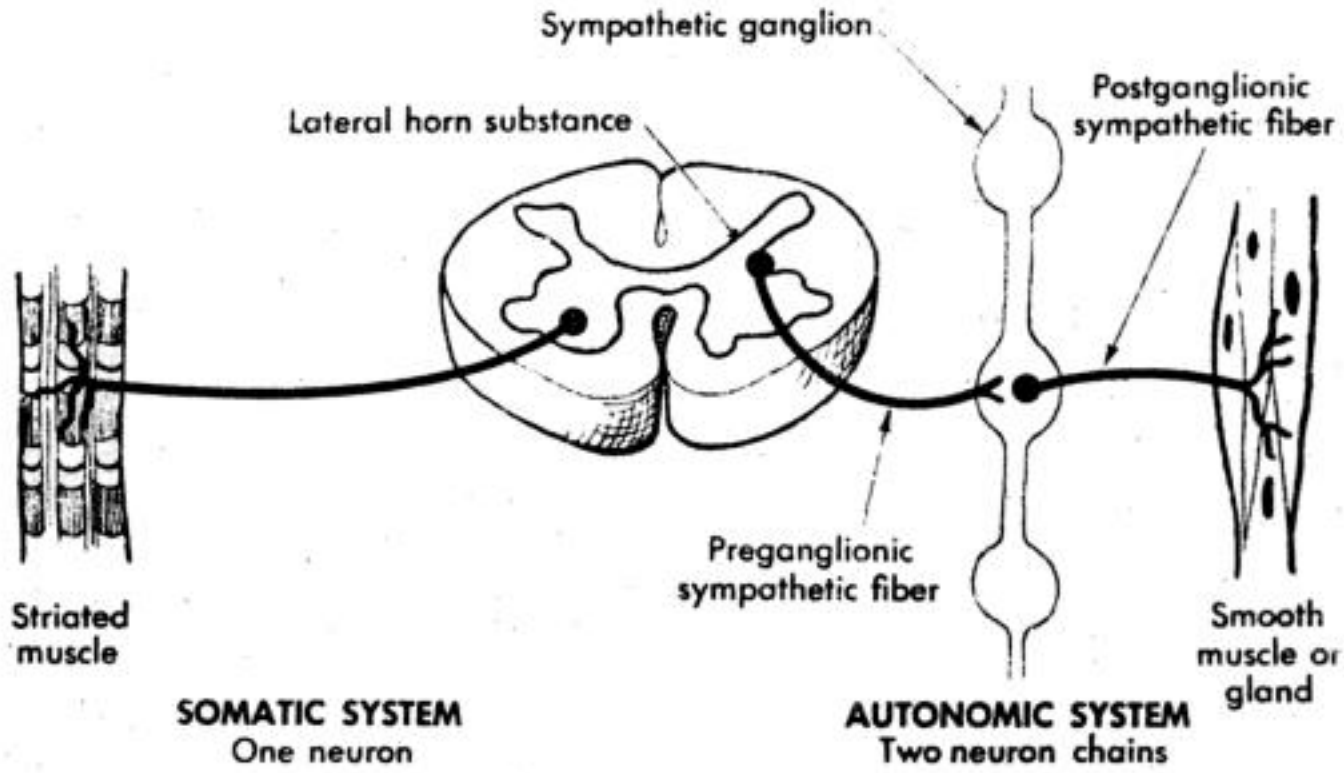


Fig. 3.40 Comparison of the somatic and autonomic nervous systems. Note that in the somatic system there is only one neuron; in the autonomic system there are always two.

The autonomic nervous system is composed of two parts: (1) *the sympathetic* and (2) *the parasympathetic* divisions. Both are parts of peripheral nervous system that innervates smooth muscle, cardiac muscle and glands, i.e., these are associated with visceral structures, while the remainder of the peripheral nervous system is associated with somatic structures.

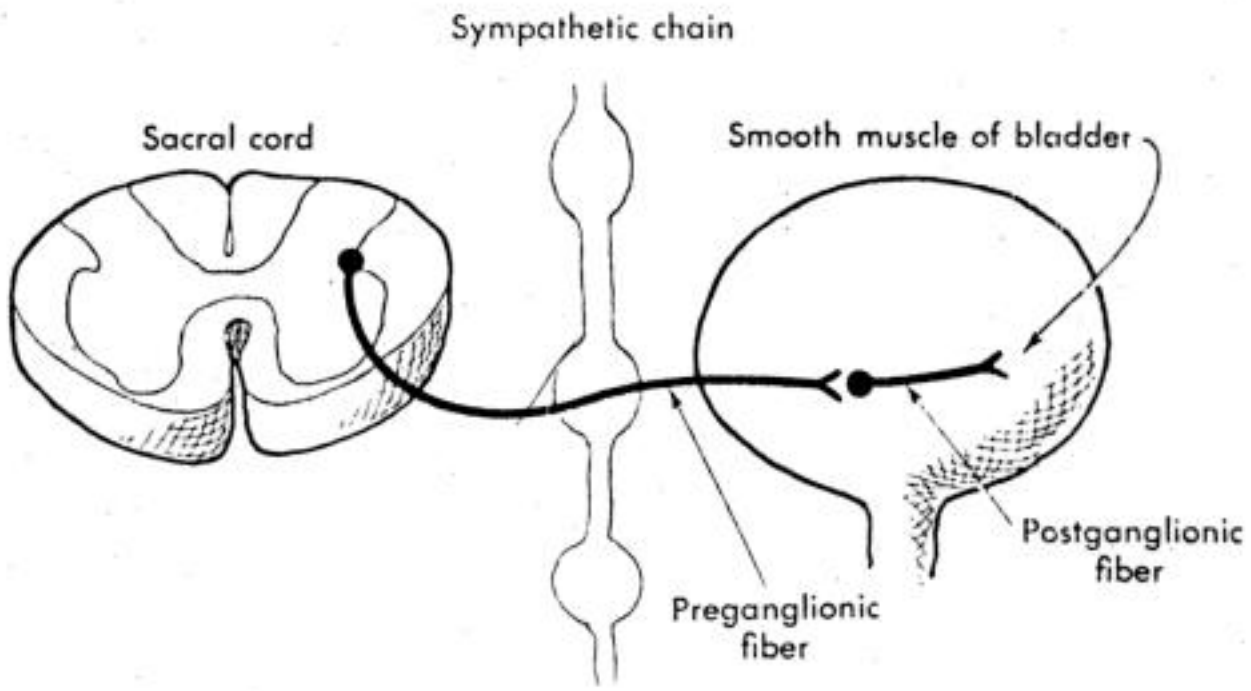


Fig. 3.41 Parasympathetic relationships. The preganglionic fiber extends from the central nervous system to the organ to be innervated, or to a special ganglion. The postganglionic fiber is generally very short.

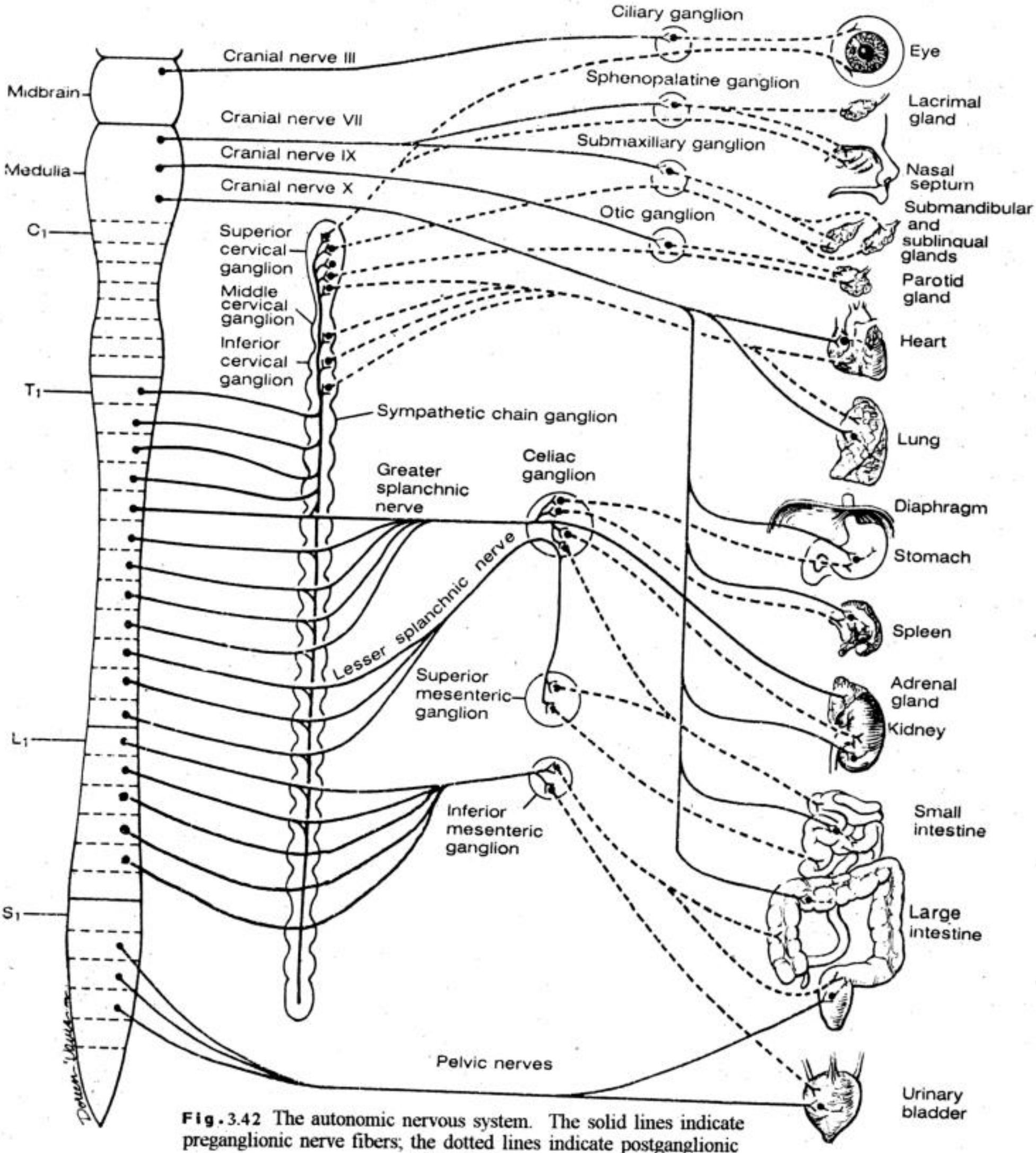


Fig. 3.42 The autonomic nervous system. The solid lines indicate preganglionic nerve fibers; the dotted lines indicate postganglionic nerve fibers.

Table 3.16
Some effects of autonomic nervous system activity

Effectors	*Effect of sympathetic nervous system*	*Effect of parasympathetic nervous system*
EYES		
Muscles of the iris	Contraction of radial muscle (widens pupil)	Contraction of sphincter muscle (makes pupil smaller)
Ciliary muscle	Relaxation (tightens suspensory ligaments thus flattening lens for far vision)	Contraction (relaxes ligament, allowing lens to become more convex for near vision)
HEART		
S-A node	Increase in heart rate	Decrease in heart rate
Atria	Increase in contracility	Decrease in contractility
A-V node	Increase in conduction velocity	Decrease in conduction velocity
Ventricles	Increase in contractility	Decrease in contractility
ARTERIOLES		
Coronary	Constriction	Dilation
Skin and mucous membrane	Constriction	‡
Skeletal muscle	Constriction or dilation	‡
Abdominal viscera and kidneys	Constriction	‡
Salivary glands	Constriction	‡
Penis or clitoris	Constriction	Dilation (causes erection)
VEINS	Constriction	‡
LUNGS		
Bronchial muscle	Relaxation	Contraction
Bronchial glands	Inhibition of secretion	Stimulation of secretion
SALIVARY GLANDS	Stimulation of secretion	Stimulation of secretion
STOMACH		
Motility	Decréase	Increase
Sphincters	Contraction	Relaxation
Secretion	Inhibition	Stimulation
GALLBLADDER AND DUCTS	Relaxation	Contraction
LIVER	Glycogenolysis, gluconeogenesis	‡
PANCREAS		
Exocrine glands	Decrease in secretion	Stimulation of secretion
Endocrine glands (islets)	Inhibition of insulin secretion, stimulation of glucagon secretion	Stimulation of insulin secretion
FAT CELLS	Stimulation of lipid breakdown	‡
URINARY BLADDER	Relaxation	Contraction
UTERUS	Pregnant; contraction Nonpregnant; relaxation	Variable
REPRODUCTIVE TRACT (male)	Ejaculation	‡
SKIN		
Muscles causing hair to stand erect	Contraction	‡
Sweat glands	Stimulation of secretion	Stimulation of secretion
LACRIMAL GLANDS	‡	Stimulation of secretion

‡ means that these cells are not innervated by this branch of the autonomic nervous system.



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bloodstream or tissue fluids, eliciting changes in their specific target cells which may be the same cell that produced them or situated anywhere in the body in minute amounts.

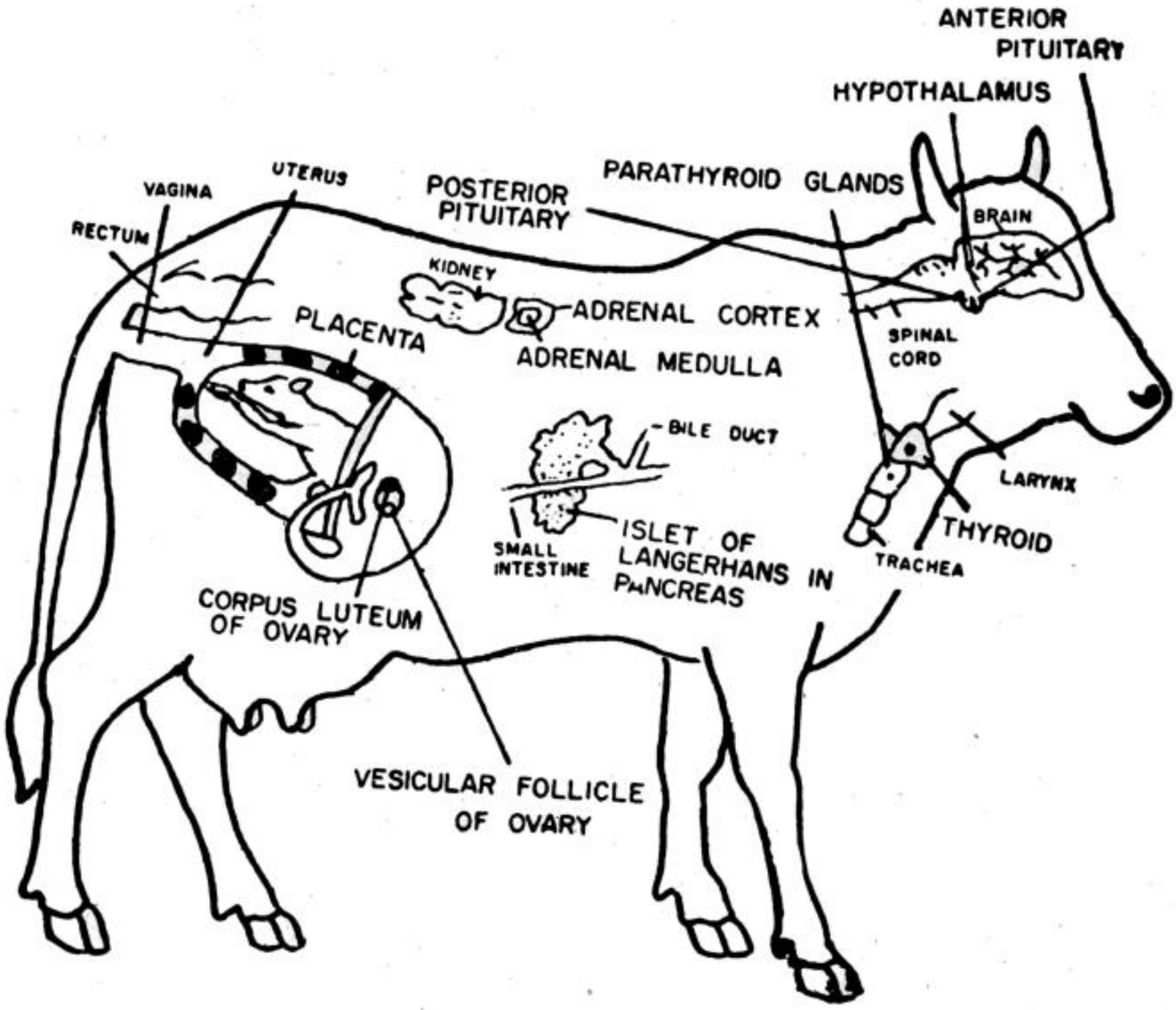


Fig. 3.45 Hormonal glands in Animal body.

Mode of Transmission

The concept of the restriction of hormone transmission to blood circulation only, must be abandoned and recognition be given to other means of transmission. Hormonal communications are classified according to the distance over which the signal acts.

1. Autocrine hormones act on the same cell that released them.
2. Paracrine hormones act only on cells close to the cell that released them. Prostaglandins and polypeptide growth factors of the hypothalamus are examples of this group.
3. Endocrine hormones act on cells distant from the site of their release. Endocrine hormones, for example, insulin and epinephrene, are synthesized and released in the bloodstream by specialized ductless endocrine glands. This is typical of most hormones.



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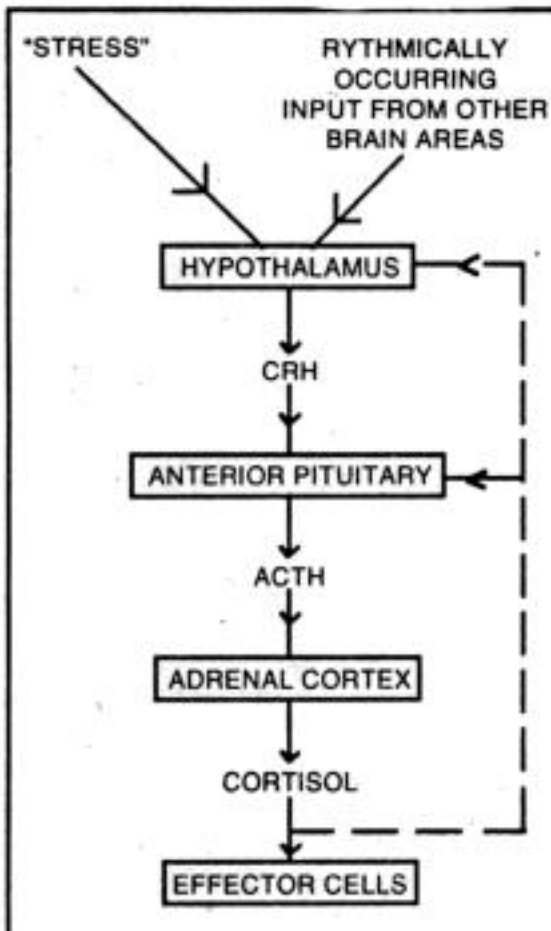
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Neuronal Input

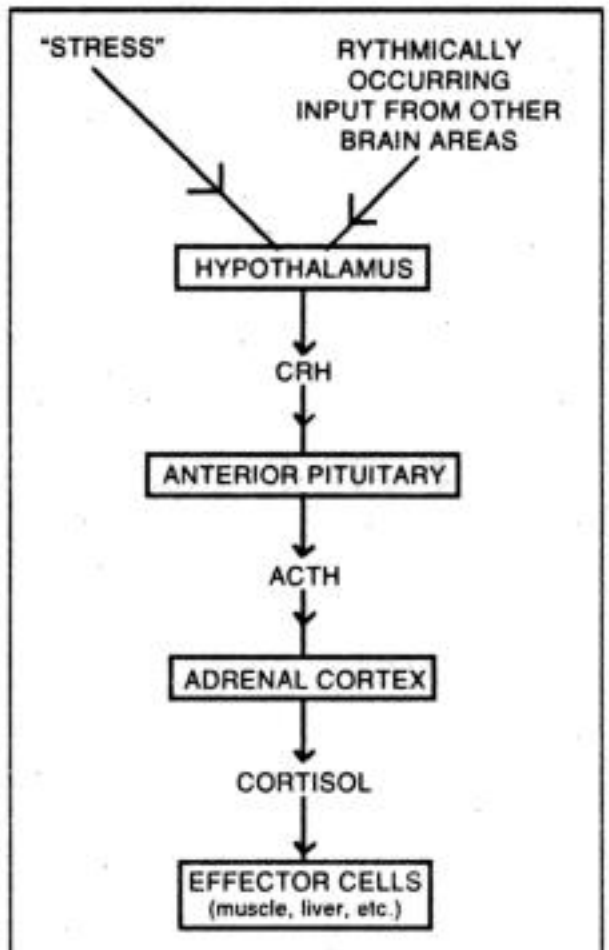
The hypothalamus receives synaptic input, both stimulatory and inhibitory, from virtually all areas of the central nervous system. Figure illustrates these points for the CRH-ACTH-Cortisol system: Corticotropin releasing hormone, secreted by the hypothalamus, stimulates the anterior pituitary to secrete ACTH, which in turn stimulates the adrenal cortex to secrete the hormone cortisol. A wide variety of stresses, both physical (an injury, severe blood loss, etc.) and emotional (fright, for example) act, via neuronal pathways to the hypothalamus, to increase CRH secretion (and hence, that of ACTH and cortisol) markedly above its basal value. But even in a completely unstressed person, the secretion of cortisol varies in a highly stereotyped manner during a 24 hour period. This is because endogenous neural rhythms within the central nervous system impinge upon the hypothalamic neurons which secrete CRH.

Hormonal Feedback

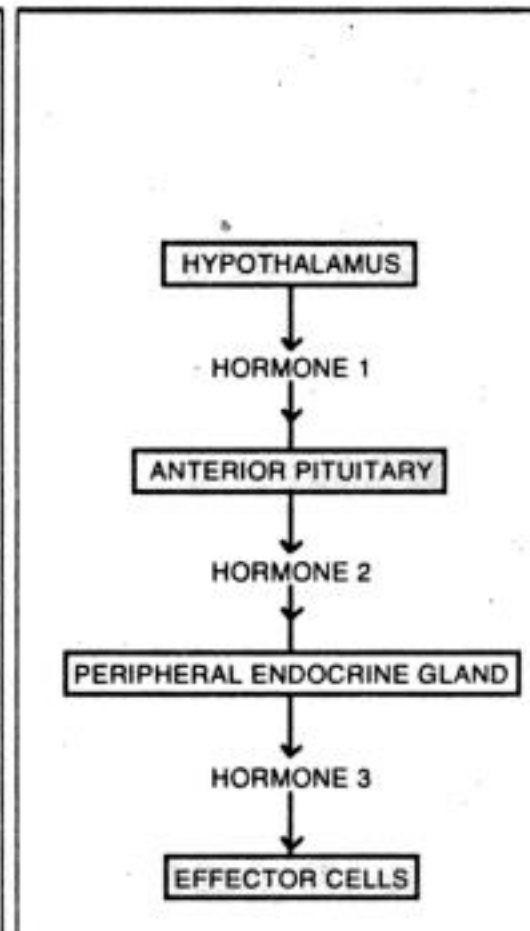
A prominent feature of each of the hormonal sequences initiated by the hypothalamic releasing hormones is negative feedback exerted upon the hypothalamic—pituitary system by one or more of the very hormones in the sequence. For example, in the CRH—ACTH-Cortisol sequence (Fig.3.51) the final hormone—cortisol—acts upon the hypothalamus to reduce secretion of CRH (by causing a decrease in the frequency of action-potentials in the neurons secreting CRH). In addition, cortisol acts directly on the anterior pituitary to reduce the sensitivity of the ACTH—secreting cells to CRH. Thus by a double-barreled action, cortisol exerts a negative feedback control over its own secretion.



Negative feedback effects of cortisol. Cortisol not only acts on the hypothalamus to inhibit CRH secretion but acts on the anterior pituitary to reduce its responsiveness to CRH. The net effect is to reduce ACTH secretion. Thus, when the overall system is stimulated by stress, not as much additional cortisol is secreted as would be if the negative feedback did not exist.



CRH–ACTH–Cortisol hormonal sequence. The stress input to the hypothalamus is a via neural pathways from other brain areas. CRH corticotropin releasing hormone. ACTH = adrenocorticotrophin.



Typical sequential pattern by which a hypothalamic hormone controls the secretion of an anterior pituitary hormone, which in turn controls the secretion of a hormone by a peripheral endocrine gland.

Fig. 3.51



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When a sample of blood is treated to prevent clotting and permitted to stand undisturbed, the cells gradually settle to the bottom of the container, leaving a straw coloured fluid. This fluid portion of the blood, called *Plasma* and is made up of about 92% water and 8% other substances. The kidneys are responsible for maintaining constant proportions of water and other constituents of the plasma by selective filtration and resorption of water and other substances from the blood plasma. These substances include about 90% proteins and 0.9% inorganic matter; the remainder is non-protein organic matter.

The substances other than water that comprise 8% of the plasma can be subdivided on the basis of their molecular weights (MW). Those having a MW greater than 50,000 gm/mole are the proteins, which comprise 7/8 of this plasma fraction (7 gm/100 ml). Those having a MW less than 50,000 gm/mole include glucose, lipids, amino acids, vitamins, hormones, NaCl and other electrolytes, inorganic mineral salts and metabolic waste products, such as urea, uric acid and creatinine. These make up the other 1/8 fraction of the plasma. Normally, plasma comprises 50 ± 10 percent of the blood in mammals. Changes in colour of the plasma may occur under normal physiological condition : horses and cows fed on green forage typically have bright yellow plasma. After a fatty meal the plasma in most animals is milky white. However pathological changes may change the colour of the plasma. A red-coloured plasma results from increased fragility and rupture of red blood cells.

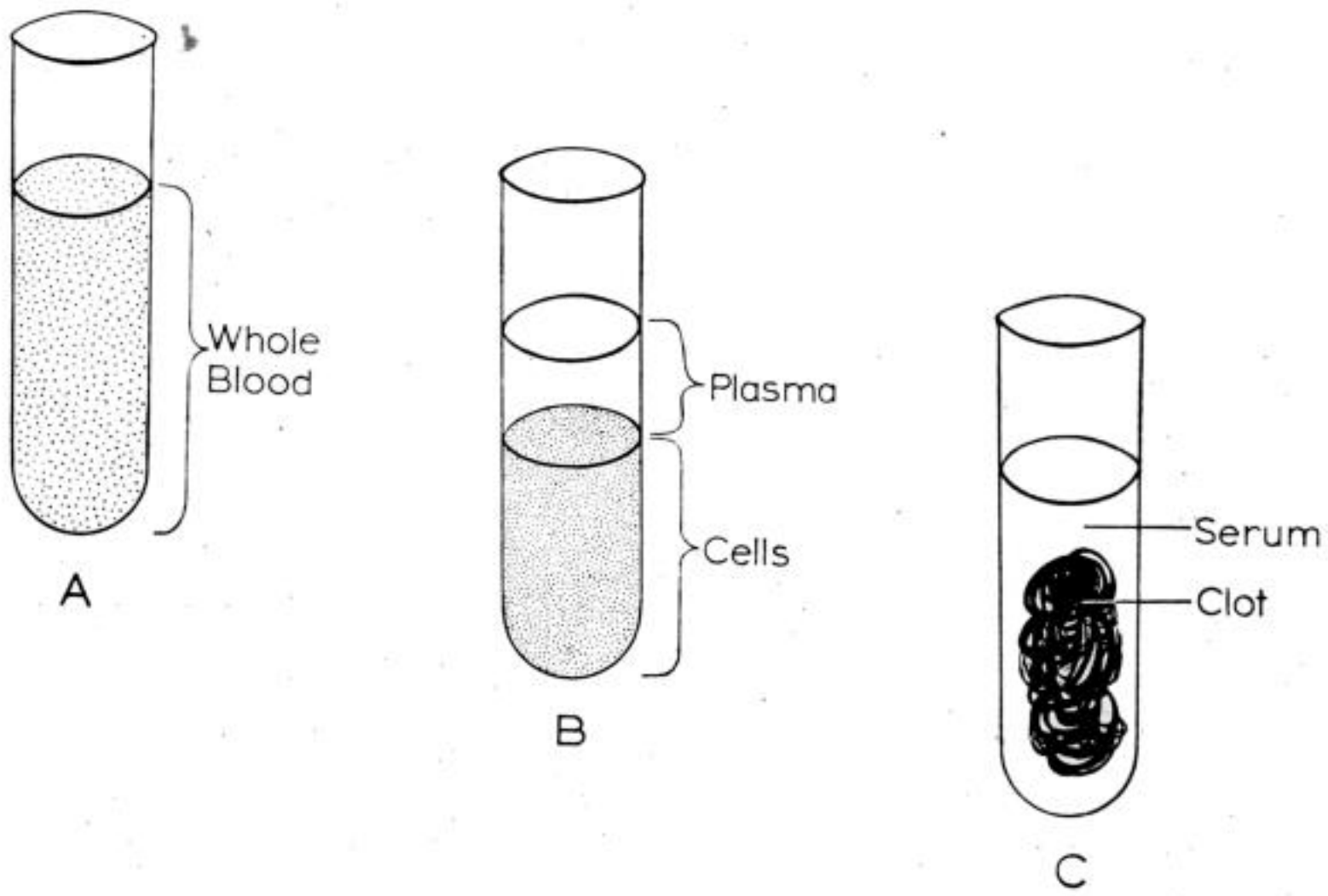


Fig 4.1 **Blood. Diagram illustrating different physical states of blood. *A*, Unclotted blood, cells dispersed uniformly throughout; *B*, blood treated with anticoagulant. Cells permitted to settle, leaving clear plasma. *C*, Clotted blood. Serum separated from clot.**



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Red Blood Cells (RBC) or Erythrocytes

Erythrocytes constitute about 32 per cent of the total amount of the blood. Seen under the microscope they appear as biconcave discs, circular in shape, flexible and they possess no nucleus; having lost it before entering the circulation. It may be noted that the RBC of birds including chicken, ducks, turkeys etc., fish and reptiles including any of a group of cold-blooded vertebrates that crawl on their bellies, viz. snakes, lizards, crocodiles, alligators and turtles possess a nucleus, while those of camel erythrocytes are oval in outline and biconvex.

The depth and size of the concavity vary with the species. The dog RBC is a distinct biconcave disc, those in horse and cat have a shallow concavity and the pig and ruminants have RBC similar to a flattened disc.

The largest size erythrocyte is found in dog (7.0/μm) and the smallest in goat (4.1/μm). The total number of RBC not only varies for a given species, but wide variations occur with different breeds, nutritional state, physical activity and age.

Erythrocytes are formed in the red bone marrow of the proximal ends of certain long bones and also in ribs, the sternum, vertebrae and in pelvis.

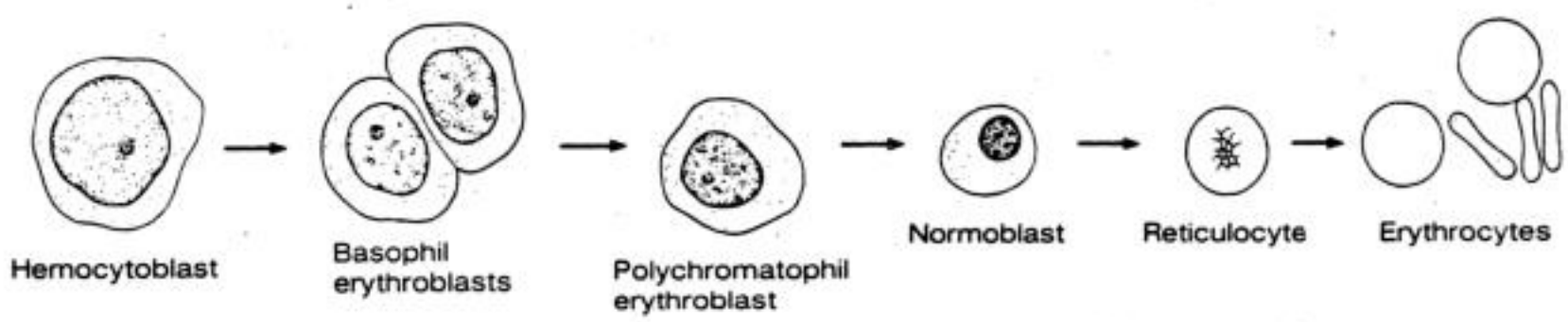


Fig 4.2. Erythrocyte formation from hemocytoblast cells in red bone marrow. The hemocytoblasts are formed from stem cells located in the bone marrow.

During formation, stem cell, inside the marrow give rise to cells called *hemocytoblasts* which in turn form cells called *basophil erythroblasts*. At this stage cells begin to synthesize a special organic compound known as *hemoglobin*. The basophil erythroblasts give rise to cells called *polychromatophil erythroblasts*. As hemoglobin synthesis continues, the nuclei of the cells shrinks, and the cells become *normoblast*. When the normoblast cytoplasm attains a hemoglobin concentration of about 34 per cent, the nuclear disappears, although the remains of some endoplasmic reticulum are still evident. These non-nucleated cells are called *reticulocytes*. Finally the reticular material itself disappears and the cells become fully formed erythrocytes.

Erythrocytes function in the transport of gases by the blood at pressures sufficient to permit rapid diffusion of oxygen from the blood to the metabolizing cells and also CO_2 from these cells to the blood. It is the hemoglobin within the erythrocyte that is responsible for this activity and is present in various domestic animals from 8 to 16 gm per 100 ml blood. Hemoglobin (Hb) consists of a protein called *globin* united with four non-protein groups called *hemes*. Each heme group contains an iron atom which is able to combine reversibly with one oxygen molecule. Thus each hemoglobin molecule can potentially associate with four oxygen molecules. When hemoglobin is combined with oxygen, it is called *Oxyhemoglobin* (HbO_2);



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Platelets

Blood platelets, also called *thrombocytes*, are fragments of protoplasm found in the blood. Platelets function chiefly to reduce loss of blood from injured vessels. By adhering to vessel walls and to each other in the area of the injury, platelets may form a white thrombus (clot) that can occlude the vessel and prevent further loss of blood.

Blood cell formation

Unlike many other cell-types blood cells are short-lived. They survived for days or months and then are destroyed. Thus they are produced and removed continuously. For the most part, cell formation, *haemopoiesis* and cell destruction occur in the same tissues. Many of the tissues where these processes go on, also contribute to antibody production, clean the blood by filtration and remove many kinds of foreign pathogens.

In the embryo, blood cells first form in conjunction with blood vessels. Later, blood cells form in the tissues of the digestive tract, thymus, kidneys and liver. In the adult mammal, red blood cells and granulocytes are formed mainly in the bone marrow, while lymphoid cells are produced in lymphoid organs such as the spleen and lymph nodes. In phylogenetically more primitive, adult animals all cellular elements of the blood may be produced in the spleen.

Erythrocytes of adult mammals are in fact formed in the red bone marrow of the proximal ends of certain long bones and also in ribs, the sternum, vertebrae and in

Table 4.4

Tissue or Organ	*Function in Hematopoiesis*
Bone marrow	Produces erythrocytes, granulocytes, thrombocytes and hemoglobin; stores iron.
Lymph nodes and follicles	Produce lymphocytes and participate in antibody production.
Liver	Stores B_{12}, folic acid, and iron. Produces prothrombin and fibrinogen. Converts free bilirubin to bilirubin glucuronide for excretion via the bile. Retains its embryonic potential for hematopoiesis.
Spleen	Produces lymphocytes, stores erythrocytes and iron, retains embryonic potential for hematopoiesis. Destroys erythrocytes and hemoglobin through its extensive R.E. system.
Stomach	Produces HCl for release of iron from complex organic molecules. Produces intrinsic factor which functions in preparing B_{12} for absorption by the intestinal mucosa.
Reticuloendothelial system	Produces monocytes. Destroys erythrocytes and converts hemoglobin to iron, globin and free bilirubin. Stores iron.
Kidney	Presumptive organ for production of erythropoietin.
Thymus	Probable origin of antibody-producing cells for distribution to lymphocytic tissues throughout the body. Removal of the thymus in the very young leads to loss of ability to respond to antigen.



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Table 4.6

	Total Leukocytes thousands per mm³	Lymphocytes	Heterophils	Eosinophils	Basophils	Monocytes	Thrombocytes thousands per mm³
Chicken	20.0	59.0	27.2	2.0	1.7	10.2	25.4
*Chicken	30.4	73.3	15.1	—	2.7	6.3	—
Chick	29.4	66.0	20.9	1.9	3.1	8.1	26.5
Duck	23.4	61.7	24.3	2.1	1.5	10.8	23.4

(Partly from Kolb, Lehrbuch der Physiologie der Haustiere)

**Source*: Cook, S.F. (1937). A study of blood picture of poultry and its diagnostic significance. Poultry Science, *16*, 291.

1. *Heterophils*: This type of leucocyte is sometimes designated as a polymorphonuclear—pseudo eosinophilic granulocyte, but for the sake of brevity it is usually designated "heterophii". In chickens these are generally round and have a diameter of about 10 to 15 μm. The characteristic feature of these cells is the presence of many rod or spindle-shaped acidophilic crystalline bodies in the cytoplasm. The nucleus is polymorphic with varying degrees of lobulation.

2. *Eosinophils*: Polymorphonuclear eosinophilic granulocytes are of about the same size as the heterophils. The nucleus is often bilobed and is of richer blue than that of the heterophil, giving the impression of a sharper differentiation between chromatin and parachromatin than in the nucleus of the latter.

The question has arisen as to the correctness of distinguishing between the heterophil and the eosinophil in avian blood. Some workers believe that the two cell types represent modified forms of the same group, but others think that the heterophil and eosinophil have different lineages.

3. *Basophils*: Polymorphonuclear basophilic granulocytes are of about the same size and shape as the heterophils. The nucleus is weakly basophilic in reaction and round or oval in shape; at times it may be lobulated. The cytoplasm is abundant and devoid of colour. Electron microscopy reveals that granules of basophils are variable in size and are fibrillar in nature.

4. *Monocytes*: In birds monocytes are difficult to identify or to distinguish from large lymphocyte because there are transitional forms between the two. In general, the monocytes are large cells with relatively more cytoplasm than the large lymphocytes. The cytoplasm of these cells has a blue-grey tint. The nucleus is usually irregular in outline. The nuclear pattern in monocyte is of a more delicate composition than is that in the lymphocyte.

5. *Lymphocytes*: Lymphocytes consititutes the majority of the leukocytes in the blood of the fowl. There is a wide range in the size and shape of these cells The cytoplasm is usually weakly basophilic. The nucleus is usually round and may have a small indentation.

Thrombocytes (Platelets)

Avian thrombocytes show considerable variation in size, and their shape may vary from oval to round. However, the typical one is oval, unlike mammals the cells are provided *with a round nucleus in the center* of a clear cytoplasm. A constant feature is the one or more brightly



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Table 4.11

Some Differential Characteristics in Blood Morphology of Domestic Animals

	The Erythrocytes					*The Leukocytes*	
Animal	*Rouleaux*	*Central Pallor*	*Mean Diameter (μm)*	*Reticulocytes in Peripheral Blood in Health (%)*	*Special Features*	*Approximate Neutrophil: Lymphocyte Ratio*	*Speical Features*
Dog	+	++	7.0	± 1.0	Essentially uniform in size. Crenation does not occur readily.	70:20	Basophils rare. Eosinophil granules do not fill cell; granules variable in size and stain lightly. Cytoplasm shows through and takes pale blue stain.
Cat	++	+	5.8	± 0.5	Crenation with few blunt processes. Slight anisocytosis. Eccentric blue body in 1% of cells.	60:30	Basophils rare. Eosinophil granules rod-like and stain dull grayish-orange. Majority of lymphocytes of small size. Few band neutrophils are normally present.
Cow	—	+	5.5	0	Anisocytosis is common. Giant forms may occur. Thrombocytes usually are numerous.	28:58	Eosinophil granules small, round, intensely stained, and fill cell. Azurophil granules of large size may occur in lymphocytes. Vacuoles common in monocytes.
Sheep	±	+	4.5	0	Regular in size and shape with small central pale spot. Compact groups of thrombocytes.	30:60	Neutrophil nucleus usually multilobed. Eosinophil granules well-stained, ovoid and fill cell. Frequent large azurophil granules in lymphocytes. Monocyte nucleus amoeboid.
Horse	+++	±	5.7	0	Marked rouleaux, a consistent finding. Cells uniform in size. Occasional H-J-like body. Immature RBC almost never in peripheral blood.	cold-blooded, 55:35 hot-blooded, 50:45	Eosinophil very characteristic; granules very large and fill cell. Majority of lymphocytes are small. Monocytes usually have kidney-bean nucleus.
Pig	++	±	6.0	± 1.0	Crenation with sharp points is a characteristic feature. Slight anisocytosis. Occasional polychromatophilia.	35:50	Eosinophil granules ovoid, pale pink-orange, fill cell. Band neutrophils occur in health (ave. 1%). Lymphocytes vary from small to large.

Source : Jain, Nemi. C : Schalm's Veterinary Haematology, 4th edition (1986); Lea and Febiger, U.S.A.



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Table 4.16 **Normal Blood Values for the Goat**

	Erythrocytic Series		*Leukocytic Series*		
	Range	*Ave.*		*Range*	*Ave*
Erythrocytes (x10⁶/µl)	8.0 - 18.0	13.0	Leukocytes/µl	4,000-13,000	9,000
Hemoglobin (g/dl)	8.0 - 12.0	10.0	Neutrophil (band)	Rare	--
PVC (%)			Neutrophil (mature)	1,200 - 7,200	3,250
Wintrobe			Lymphocyte	2,000 - 9,000	5,000
(2,250 G x 30 min)	24.0 - 48.0	35.0	Monocyte	0 - 550	250
Microhematocrit			Eosinophil	50 - 650	450
(14,000 G x 10 min)	22 - 38	28.0	Basophil	0 - 120	50
MCV (fl)					
(Wintrobe)	19.5 - 37	27	Percentage Distribution		
(Microhematocrit)	16 - 25	19.5	Neutrophil	30 - 48	36.0
MCHC (%)			Lymphocyte	50 - 70	56.0
(Wintrobe)	28 - 34	31.5	Monocyte	0 - 4	2.5
(Microhematocrit)	30 - 36	33	Eosinophil	1 - 8	5.0
MCH (pg) (Microhematocrit)	5.2 - 8.0	6.5	Basophil	0 - 1	0.5
Reticulocytes (%)	None	--			
ESR (mm)	None	--			
RBC diameter (µm)	2.5 - 3.9	3.2			
Resistance to hypotonic salaine (%)					
Min.	0.74	--			
Max.	0.44	--			
Myeloid : erythroid ratio	0.69 : 1.0				
Other Data					
Thrombocytes (x10⁵/µl)	3.0 - 6.0	4.5			
Icterus index (units)	2 - 5				
Plasma proteins (g/dl)	6.0 - 7.5				
Fibrinogen (g/dl)	0.1 - 0.4				
Eythrocyte life span (days)	125				

Table 4.17 **Normal Blood Values for the Pig**

	Erythrocytic Series		*Leukocytic Series*		
	Range	*Ave*		*Range*	*Ave.*
Erythrocytes (x10⁶ µl)	5.0 - 8.0	6.5	Leukocytes/µl	11,000 - 22,000	16,000
Hemoglobin (g/dl)	10.0 - 16.0	13.0	Percentage Distribution		
PCV (%)	32.0 - 50.0	42.0	Neutrophil (band)	0 - 4	1.0
MCV (fl)	50 - 68	60	Neutrophil (mature)	28 - 47	37.0
MCH (pg)	17.0 - 21	19.0	Lymphocyte	39 - 62	53.0
MCHC (%)	30.0 - 34.0	32.0	Monocyte	2 - 10	5.0
Reticulocytes (%)	0.0 - 1.0	0.4	Eosinophil	0.5 - 11	3.5
ESR (mm in 1 hr.)	Variable		Basophil	0 - 2	0.5
RBC diameter (µm)	4.0 - 8.0	6.0			
RBC life span (days)	86 ± 11.5		***Other Data***		
Resistance to hypotonic			Thrombocytes (1 x 10⁵/µl)	5.2 ± 1.95	
Saline (%)			Icterus index (units)	< 5	
Min		0.70	Plasma proteins (g/dl)	6.0 - 8.0	
Max.		0.45	Fibrinogen (g/dl)	0.1 - 0.5	
Myeloid:erythroid ratio	1.77 ± 0.52 : 1 (Lahey et al., 1952)				



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from which it is derived, but has less protein, glucose and K^+. It probably serves partly as a nutritive medium for the brain and spinal cord as well as cushioning these structures against shock.

Synovial Fluid

Synovial fluid is a thick, tenacious liquid found in joint cavities, tendon sheaths, and bursae. It ows its physical properties and lubricating ability due to the presence of mucopolysaccharides and possibly hyaluronic acid. Besides reducing friction in joints, synovial fluid probably helps to nourish the articular cartilages.

Fundamentals of Terminology

Medical terms generally have Greek or Latin origin. The meaning of many commonly used terms in hematology can be readily understood by learning the following word parts :

Prefix or Stem			*Prefix or Stem.*		
a	=	without	mega	=	large
aniso	=	not equal	meta	=	change
baso	=	base	micro	=	small
eosin	=	red	mono	=	one
erythro	=	red	morpho	=	form
granulo	=	granule	myelo	=	marrow
hem or hemat	=	blood	neutro	=	neutral, neither
hyper	=	excessive	normo	=	nor
hypo	=	deficient	oligo	=	scanty, few
hetero	=	denoting relationship to another	pan	=	all
karyo	=	nucleus or nut	poikilo	=	irregular
leuk	=	white	poly	=	many
lympho	=	water, relating to lymph	pro	=	before
macro	=	large	reticulo	=	net
			thrombo	=	clot

Stem or suffix			*Stem or suffix*		
blast	=	germ	osis	=	a process
chrome	=	color	penia	=	poverty
crit	=	to separate	philia	=	love
cyte	=	cell	plasia	=	to form (tissue)
meter	=	to measure	poiesis	=	making
ology	=	study of	rubri	=	red

Terminology

Anemia. A decrease in the hemoglobin value, the packed cell volume, or the erythrocyte count of more than two standard deviations below the mean normal determined by the same method on the bloods of healthy animals of the species concerned.

Basophilia and Basophilic. Terms which when applied to a cell or cells of the erythrocytic



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caput and a highly concentrated sperm is left in the tail, (3) Maturation—while migration takes place sperm cells get matured as a result of secretion from the epididymal cells, (4) Storage—

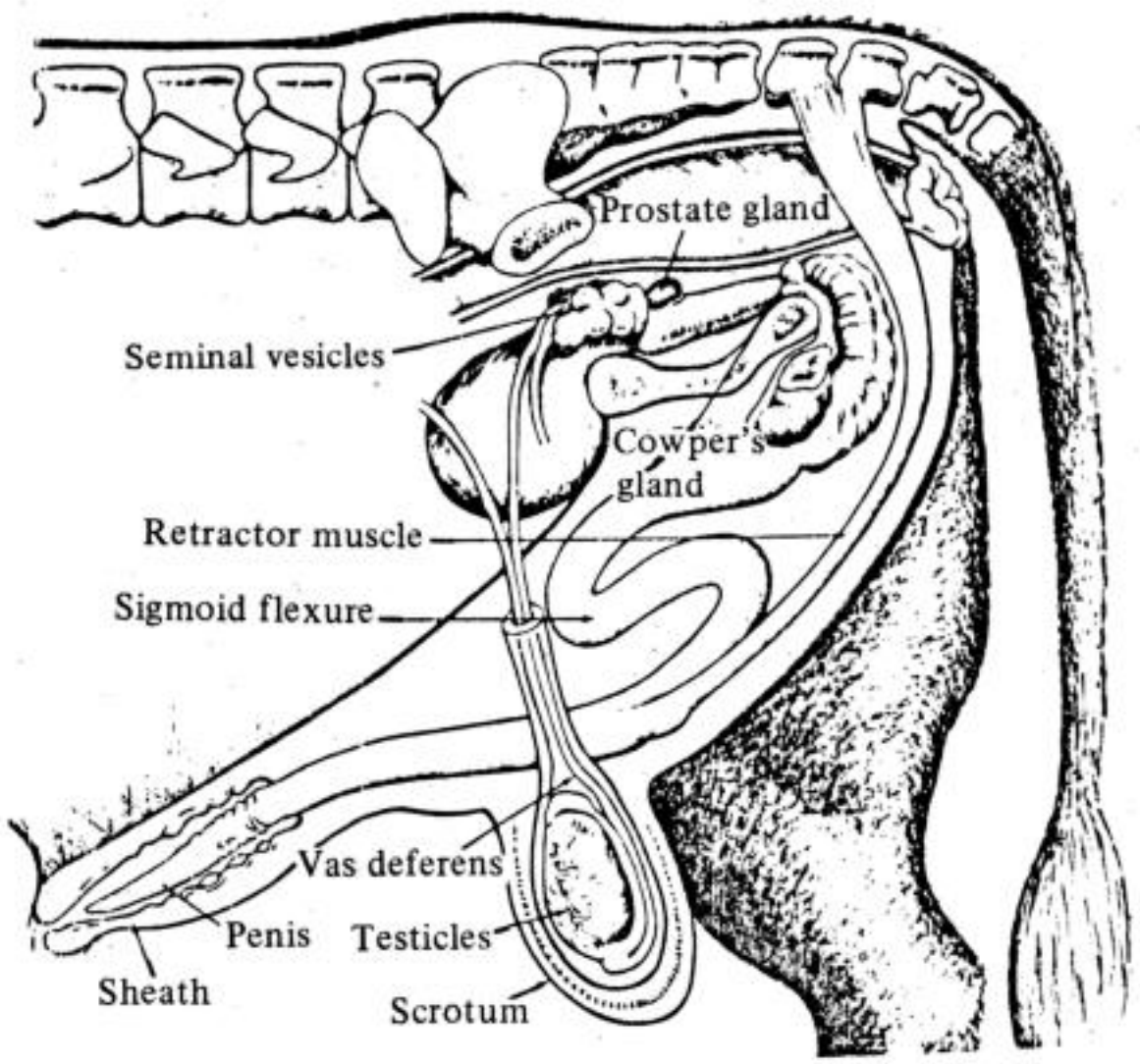


Fig. 5.1 Genitalia of the bull.

the tail of the epididymis is the sperm depot. If the epididymis in the bull is ligated, the sperm will remain alive and fertile in the epididymis upto about 60 days.

Vas deferens. The tail of the epididymis leads into the vas deferens which is a slender tube with a thick cord like wall. Like the epididymis and the testes, the vas deferens is paired and the two along with the spermatic arteries, veins, nerves and cremester muscle surrounded by tunica vaginalis (a paritonial layer) are sometimes known as the spermatic cords. Each vas deferens goes through the inguinal ring and lies very close to the vas deferens from the other testis in the pelvic cavity and finally empties into the urethra. The vas deferens is abundantly supplied with nerves and by involuntary contractions of the musculature, the vas deferens is involved in ejaculation.

The urethra. The urethra is a common passage way for the products of the testes, accessory glands and for the excretion of the urine. It extends through the pelvic area and the penis and end at the tip of the glans penis as the external urethral orifice.

The accessory organs. The accessory sex organs provide the bulk of the seminal plasma. This is rich in carbohydrate, salts of citric acid, proteins, amino acids, enzymes, water soluble vitamins and being relatively high in buffer capacity. There are three accessory organs: (1) The seminal vesicles—the two seminal vesicles are located one on either side of an ampulla.



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and the inner Mucosa. The inner mucosa of the body and the horn is thrown out into a number of raised spots called caurancles which develop into cotyledons during pregnancy, and is provided with uterine glands to secrete uterine milk for early nutrition of the embryo. In the non-pregnant animals the uterus lies in the pelvic cavity which descends into the abdomen during pregnancy. This can be palpated per rectum and forms a basis of pregnancy diagnosis by rectal palpation method. It is the uterus to which the foetus becomes attached, and develops inside it until the time of birth.

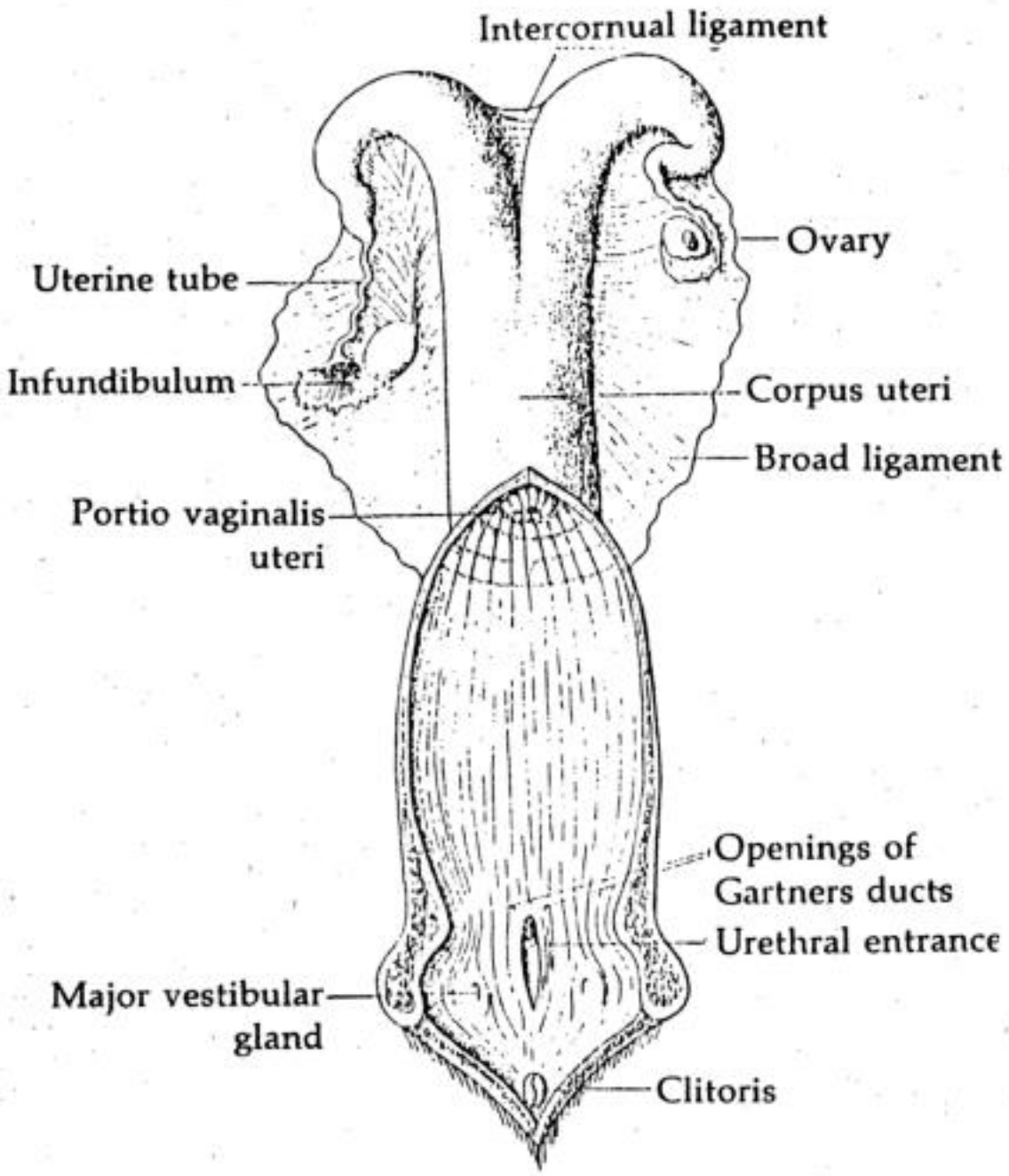


Fig. 5.4 ***Reproductive tract of the cow (dorsal aspect).*** The vulva, vestibule, and vagina have been laid open and the left ovary withdrawn from the bursa. The portio vaginalis uteri is an interlocking circular fold that assists closure of the cervical lumen.

The Cervix

The cervix is also known as the neck of the womb. It is a thick walled portion of the reproductive tract and lies between the uterus and vagina. It also has the usual three layers but the muscle layers are very thick and the mucosa has longitudinal folds and transverse constrictions forming a spiral passage way through it. It is tightly closed during pregnancy and anoestrus period and relaxes only during oesttrus (heat) and parturition. It is rich in mucus secreting goblet cells which secrete the slimy antiseptic discharge generally seen as coming out of the



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stage of primordial follicle growth starts at puberty (defined as the beginning of reproductive life). This involves growth of the oocyte and an increase in the number of granulosa cells for several primordial follicles each day during the reproductive life of the animal.

During proestrous stage FSH as secreted by the anterior lobe of the pituitary gland stimulates the development of the Graafian follicles and is further responsible for maturation of the ovum and also controls secretion of estrogen from ovary. High levels of ovarian steroid hormones, mainly estradiol stimulates the growth and secretion by the uterus and the other genitalia resulting estrus signs.

Hormones of Ovulation

Except some species like cat, rabbit, camel where ovulation occurs following copulation, in other domestic animals it is spontaneous and usually occurs towards the end of estrus. An exception to this are cattle and buffaloes where ovulation occurs after the end of oestrous, i.e., during metoestrous.

The essential endocrine stimulus for ovulation is a sharp increase of LH. Under the stimulus of this hormone, cells in the wall of the follicle begin a change called luteinisation; during this change there is an increase in the amount of cytoplasm and a shift from the secretion of estrogen to the secretion of progesterone. At the same time, the connective tissue barrier between the follicle and the ovarian surface is gradually thinned. The role of progesterone is to stimulate collagenase activity in the follicular wall. The role of estrogen might be to give proper signal for the release of two prostaglandin compounds, viz., $PGF_{2\alpha}$ and PGE_2. The $PGF_{2\alpha}$ is involved in follicular rupture and PGE_2 in the remodelling of the follicular layers. Finally the connective tissue barrier between the follicle and the ovarian surface is gradually thinned. An increased intrafollicular pressure causes the follicle to rupture, this is ovulation.

Hormones of Corpus Luteum (CL) Formation and Maintenance

Formation of CL involves luteinization of the granulosa, by which the granulosa is converted from estrogen secretion to progesterone secretion. The process is initiated by the pre-ovulatory LH surge. The cavity of the ruptured follicle and the fibrin clot within serve as the framework on which the granulosa cells develop. Blood vessels from the theca externa invade the developing CL, so that it becomes vascularised. Maintenance of the CL is provided for by LH. Over 4 to 5 days the *corpus haemorrhagicum** is transformed into a solid yellow body, the corpus luteum. The entire process is known as luteinisation.

The CL secretes the female sex hormone, progesterone. Progesterone prepares the uterus for acceptance of a fertilised ovum or embryo. If the animal fails to conceive, the CL decreases in size, becomes pale in colour and the tissue inside become fibrous, known as *Corpus albicans*. However, if the ovum is properly fertilized and pregnancy ensues, the CL may last throughout the gestation period and functions as an endocrine gland which produces progesterone, a hormone essential for maintenance of prognancy by blocking myometrial contractions. In the cow the level of which declines rapidly during the last 48 hours prior to parturition.

In addition the placenta also assumes the main role of progsterone production at between 150 to 200 days of gestation. Towards the termination of pregnancy direct effect of glucocorticoids or the direct effect of placental estrogen may be responsible for luteal regression, but it is most likely that regression is initiated by the action of $PGF_{2\alpha}$. The latter is released as a result of the effect of placental estrogens acting upon the fetal cotyledons.

Hormones of Parturition

The most dramatic changes in the levels of hormones during pregnancy occur shortly before par-



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altered. Evidence to date implicates an increase in the amount of ACTH being released from the anterior pituitary of the fetus and thereby produces enough cortisone to cause the placenta to change progesterone to estradiol. The estradiol then stimulates the uterus to produce relaxin, which softens and dilates the cervix. Corticosteroids also cause an increase in the release of a prostaglandin ($PGF_{2\alpha}$) from the maternal uterine wall. The prostaglandin may then start the myometrial contractions, after the progesterone levels have decreased.

The prostaglandin may also stimulate the release of oxytocin, secreted mainly from posterior pituitary store and additionally from ovary just before to parturition, causing uterine muscle contraction and thereby completes the parturition process.

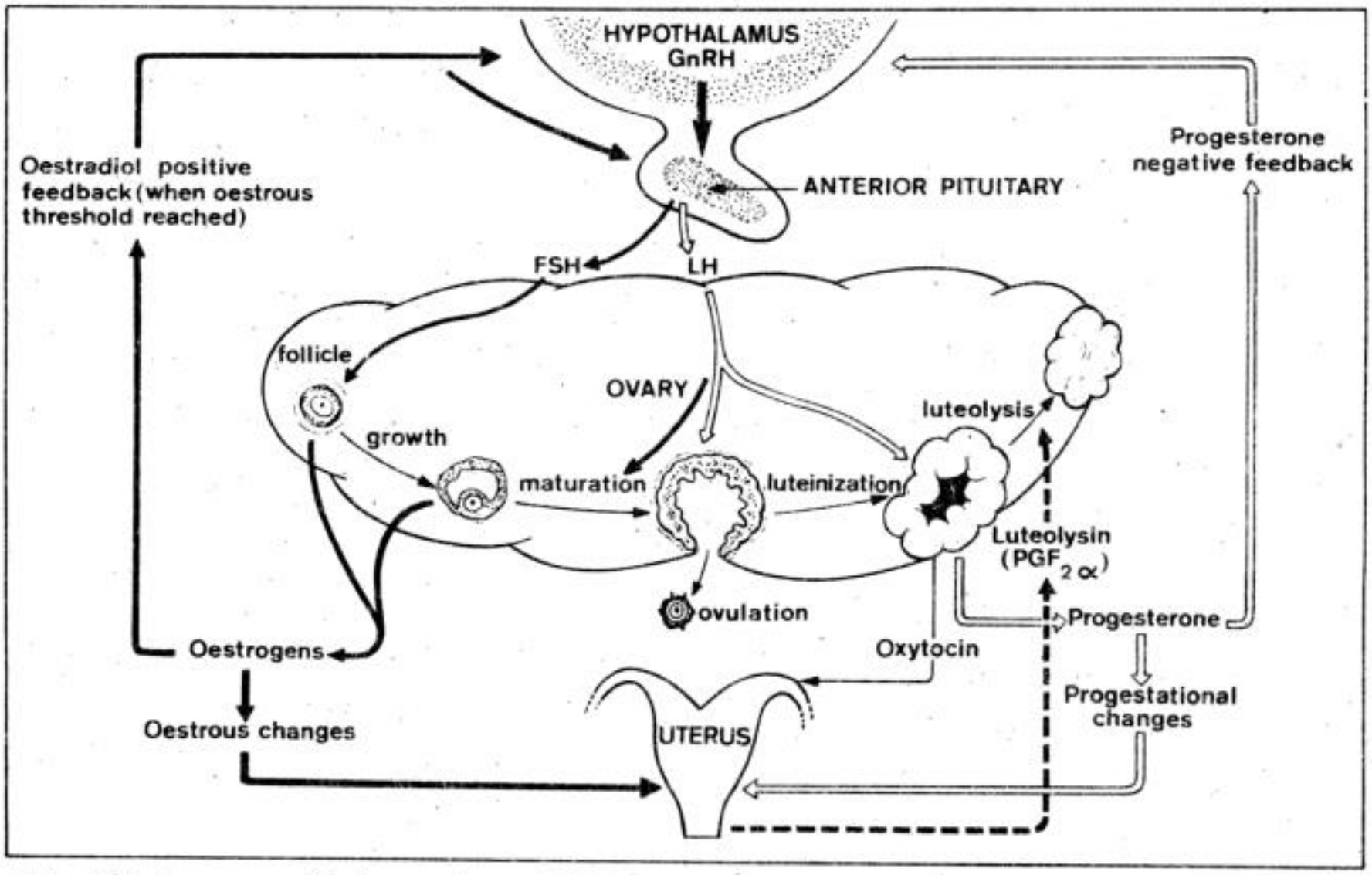


Fig. 5.8 A summary of the hormonal control of the ovarian cycle.

GAMETOGENESIS

The process by which gametes are formed is known as gametogenesis. When an individual becomes sexually mature, production of mature germ cells begins. The gonia first undergo a period of rapid growth, after which they are known as Auxocytes or Meocytes. In the male they are called spermatocyte and in the female oocytes. So we have spermatogenesis in the male and oogenesis in the female. By this process ultimately each auxocyte gives rise to 4 daughter cells.

Oogenesis

The female auxocyte or primary oocyte is very much like the primary spermatocyte. But



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occur twisting of the tetrad which allows for the exchange of chromatin material between the members of the tetrad, i.e., crossing over.

The secondary spermatocyte after its formation goes through a second meiotic division. This process involves homotypic or equational division and the separation of the earlier-formed diads. This results in the formation of spermatids, which are smaller than either the spermatogonia or primary spermatocytes and differ from them in having half the original number of chromosomes.

The newly formed spermatid then enters a series of morphological changes by which it becomes converted into an elongated element with the chromatin material packed in the head, followed by a slender middle piece and behind the middle piece is a whip like tail (Fig. 5.11).

Spermiogenesis. The term is also known as spermateliosis and is used in reference to the final maturation of the spermatids into spermatozoa. The changes involve both nucleus and cytoplasm but no divisions of the cells occur. The process begins in the seminiferous tubules and is completed in the epididymis.

The nuclear envelope of the spermatid is double and the entire nucleus is localised in the anterior area of the cell. It contains several granules of DNA of various sizes.

The Golgi complex is composed of numerous small vacuoles, congregate at the anterior nuclear pole and then flatten and form a cap over the pole. The acrosome of the spermatozoon is formed from these structures and the fluid within the vacuole.

After formation of the vacuole, the Golgl bodies migrate into the cytoplasm near the neck area, the centrioles appear. The larger of the two, the proximal centriole remains ttached to the proximate poles of the nucleus, and the other, the distal centriole, migrates posteriorly to become the end of the spermatozoon middle piece.

In the meantime mitochondria have become concentrated in the posterior area of the cell and looks like a membrane. This membrane known as the *manchetta* or *caudal tube* is the cytoplasmic area to be included in the mitochondrial sheath covering the axial filaments. The cytoplasm outside the caudal tube is later lost and the membrane of the manchetta forms the future outer boundary of the middle piece. Throughout this period the acrosome is growing from the proacrosome. Due to the development of acrosome, mitochondrial sheath, axial filament—the spermatid elongates. The tail originates from the centriole when the latter is moving towards the posterior part of the nucleus. It is initially formed of 9 fibrils arranged in circle around one central fibril and surrounded by a tubular membrane. At the neck of the fully formed spermatozoon the granular Golgi bodies remain, and after elimination of excess cytoplasm, a residual protoplasmic droplet remains there as ring centriole. The bead is not usually lost until the spermatozoon has completed at least a part of its journey through the epididymis. Thus the mature spermatozoon consists of three principal parts: the head, the neck and the tail.

Spermeation. After spermatogenesis the spermatozoa stays for about 5 to 7 days within the seminiferous tubule and gets attached to Sertoli cells for some physiological and biochemical change. The detachment of spermatozoa from the Sertoli cell takes place as they move to epididymis for further biochemical maturation. This movement of spermatozoa from the Sertoli cells is known as *spermeation*.

THE SEXUAL CYCLE

Within the breeding season, heat appears in the normal female for the most part in quite regular cycles. The cycle of heat is made up of four distinct phase which have been desig-



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Table 5.3

Symptoms of Heat in Cows and Buffaloes

Symptoms at early stages of heat are not pronounced in cattle but they show activities like smelling other cows, attempting to mount on them and bellowing. They become restless and their vulva gets moist, red and slightly swollen. After a lapse of six to eight hours the heat becomes more pronounced. The cow stands still to be mounted by other cows or bulls. Due to this, this period is termed as "standing heat" . This extends for 12-18 hours and shows other symptoms like bellowing, nervousness, anorexia, reduction in milk yield, moist and red vulva and clear mucus discharge.

Symptoms	*Early heat (Mounting) 0-8 hours*	*Mid-heat(Standing) 12-18 hours*	*Late heat 24 hours*
	COWS		
Social behaviour	Restless, tries to get isolated from other cows	Mixes with other cows in the herd	Normal behaviour with other cows in the herd
Excitement	Shows sign	More pronounced	Absent; calm
Appetite	Depressed	More depressed	Normal
Bellowing	Sometimes	Frequent	Very seldom
Milk yield	Falls	Further falls	Starts increasing
Licking other animals	Moderate	High	Seldom
Rise of body temperature	Slight rise	Sharp rise	Comes back to normal
Mucus discharge from vulva	Clear, watery and copious break while falling down form vulva and flows	Turbid, opaque or cloudy viscous and ropy; in reduced quantity; does not break while falling; rather hangs right from vulva down to the ground.	Seldom seen
Vulva	Wrinkles on vulva lips start disappearing; lips starts swelling	Pronounced swelling	Swelling recedes
Vaginal Mucus discharge	Clear and ropy	Pronounced	Difficult to detect
Mounting other animals	Rarely seen	Frequently observed in the first half of mid heat	Seldom seen
Standing still when other cows or bulls try to mount	Sometimes seen	Very common during the second-half of mid heat and indicate right time for insemination	Seldom seen
Urination	Frequent	More frequent	Normal
Uterine tone	Tight and turgid	Becomes more turgid	Comes down to moderate tone
	BUFFALOES		
Appetite	Normal	Depressed	Normal
Excitement	Very much	Less excited	Does not show
Bellowing	Occasional	Frequent	Absent
Swollen vulva	Slight	Moderate	Absent
Frequency of urination within 30 minutes	Occasional to two times	More frequent	Less frequent
Uterine tone	Intense(tight & turgid)	More intense (tight and turgid)	Moderate
Opening of cervix	Partial or fully open	Fully open	Almost closed
Mounting by teaser bull	Present (70% cases)	Present (90% cases)	Present (40% cases)

Source : Dairy India 1992



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The Entry of Sperm into Ovum. To enter the ovum the sperm has first to penetrate (1) the cumulus mass, (2) the zona pellucida, and (3) the vitelline membrane.

The sperm makes its way through the cumulus mass due to its own motility. Cumulus oophorus consists of a large number of follicle cells embedded in a jelly-like matrix composed of a hyaluronic acid-protein complex. The spermatozoon carries in the acrosome an enzyme, *hyaluronidase* capable of depolymerising the hyaluronic acid-protein matrix of the cumulus oophorus. Spermatozoa thus make an entry by dissolving a tunnel through the hyaluronic acid matrix reach upto zona pellucida—which is the next obstacle to sperm entry. The ovum is said to produce a substance *fertilizin*, which reacts with the sperm and specifically agglutinates it. Sperm cells also carries another enzyme known as "*Zona lysin*", that acts upon the substance of the zona, permitting the spermatozoon to make its way through. Thus by the action of sperm motility and enzymatic reaction sperm enters through the cumulus oophorus and zona pellucida and makes contact with the surface of the vitellus. The last stage in the penetration of ovum involves the attachment of the sperm head to the surface of

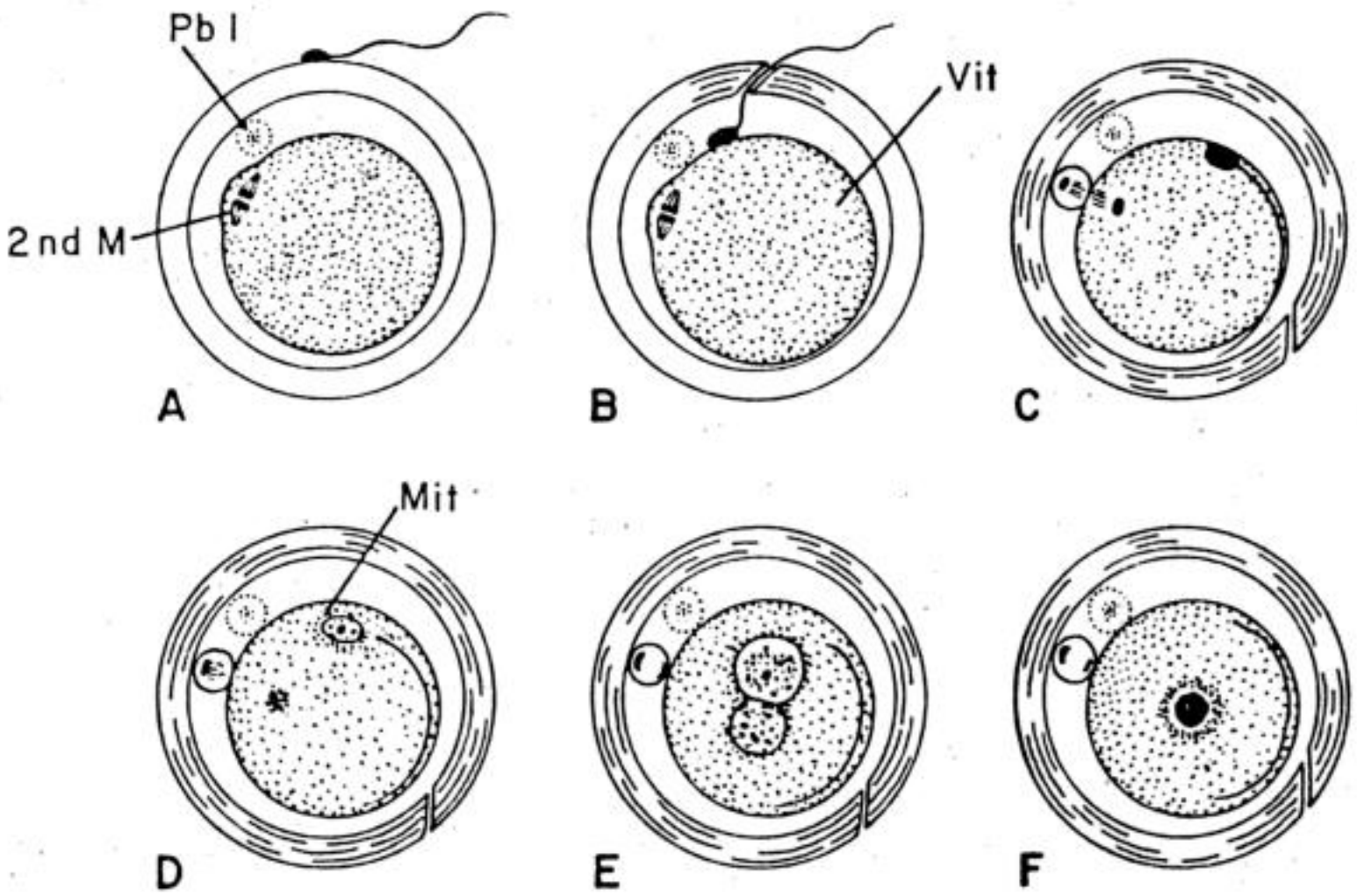


Fig. 5.15 ***Processes occurring during fertilization in swine.*** **A.** The sperm is in contact with the zona pellucida. The first polar body (*Pb1*) has been extruded; the nucleus of the ovum is undergoing its second meiotic division (*2nd M*). **B.** The sperm has penetrated the zona pellucida and is now attached to the vitellus (*Vit*). This evokes the zona reaction, which is indicated by shading as it passes around the zona pellucida. **C.** The sperm has now been taken almost entirely within the vitellus. The head is swollen. The vitellus has decreased in volume and the second polar body has been extruded. The zona has rotated relative to the vitellus. **D.** Male and female pronuclei develop. Mitochondria (*Mit*) gather around the pronuclei. **E.** The pronuclei are fully developed and contain many nucleoli. The male pronucleus is larger than that of the female. **F.** Fertilization is complete. The pronuclei have disappeared and been replaced by chromosome groups, which have united in the prophase of the first cleavage division. From Hafez, E.S.E.: Reproduction in Farm Animals. 4th Ed. Philadelphia, Lea & Febiger, 1980.



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pass through the membrane of the placenta. The food materials leave the maternal placenta and enter the fetal circulation by diffusion through the maternal and fetal placentae, after which they enter the blood vessels of the allantois which terminate in the umbilical cord. Wastes are carried back to the maternal circulation by the same system.

Table 5.6

PERIODS OF DEVELOPMENT DURING PREGNANCY

State of pregnancy		Mare	Cow	Ewe and goat	Sow	Bitch
I	Duration of period	14 days	14 days	14 days	14 days	10 days
	Length of fetus	Ovum $\frac{1}{12}$ in	Ovum $\frac{1}{12}$ in	Ovum $\frac{1}{15}$ in to $\frac{1}{20}$ in	Ovum $\frac{1}{15}$ in to $\frac{1}{20}$ in	Ovum $\frac{1}{15}$ in to $\frac{1}{20}$ in
	Stages in development	Fertilised ovum has reached uterus from oviduct				
II	Duration	3 to 4 weeks	3 to 4 weeks	3 to 4 weeks	3 to 4 weeks	10 days to 3 weeks
	Length of fetus	$\frac{1}{2}$ in	$\frac{1}{3}$ in	$\frac{1}{8}$ in	$\frac{1}{2}$ in	$\frac{1}{8}$ in
	Stages	Traces of fetus appear; head, body and limbs are discernible by end of this period				
III	Duration	5 to 8 weeks	5 to 8 weeks	5 to 7 weeks	4 to 6 weeks	3 to 4 weeks
	Length of fetus	$2\frac{1}{8}$ in	$1\frac{3}{4}$ in	$1\frac{1}{4}$ in	$1\frac{3}{4}$ in	1 in
	Stages	First indications of hoofs and claws visible as little pale elevations at ends of digits				
IV	Duration	9 to 13 weeks	9 to 12 weeks	7 to 9 weeks	6 to 8 weeks	5th week
	Length of fetus	6 in	$5\frac{1}{2}$ in	$3\frac{1}{2}$ in	3 in	$2\frac{1}{2}$ in
	Stages	Stomach well defined in foal, pig, and puppy; differentiation of four stomachs in ruminants at end of this period				
V	Duration	14 to 22 weeks	13 to 20 weeks	10 to 13 weeks	8 to 10 weeks	6th week
	Length of fetus	13 in	12 in	6 in	5 in	$3\frac{1}{2}$ in
	Stages	Large tactile hairs appear on lips, upper eye-lids, and above eye. Teats visible in female fetuses				
VI	Duration	23 to 24 weeks	21 to 32 weeks	13 to 18 weeks	11 to 15 weeks	7 to 8 weeks
	Length of fetus	2 ft 3 in	2 ft	1 ft 2 in	7 in	5 in
	Stages	Eye-lashes well developed. A few hairs appear on tail, head and extremities of limbs				
VII	Duration	35 to 48 weeks	33 to 40 weeks	19 to 21 weeks	15 to 17 weeks	9th week (8th in cat)
	Length	$3\frac{1}{2}$ ft	3 ft	$1\frac{1}{2}$ ft	9 to 10 in	6 to 8 in (kitten 5 in)
	Stages	Fetus attains full size. Body becomes gradually covered with hair, hoofs and claws complete, but soft				

There are two general types of placentae among farm animals. The sow and the mare have a *diffuse placenta*; the entire chorion is beset with finger-like villi which fit into corresponding depressions in the uterine mucosa. The cow and the ewe have a cotyledonary placenta; the villi are localised in a hundred or so rosettes, or cotyledons, over the surface of the chorion. These are separated by areas of smooth chorion. The villi of the cotyledons fit into pits in the spongy button-like cotyledons of the uterus. At parturition, the chorionic villi of both types are merely withdrawn, and there is no extensive destruction of the uterine tissue.

The extent to which a foetus grows in the latter stages of pregnancy is demonstrated by the actual weights obtained by the late Sir John Hammond in one of his investigations carried out on Shorthorn heifers.

Correct feeding is important throughout pregnancy, but it is even more important during the last stages, when the foetus is making very rapid growth.



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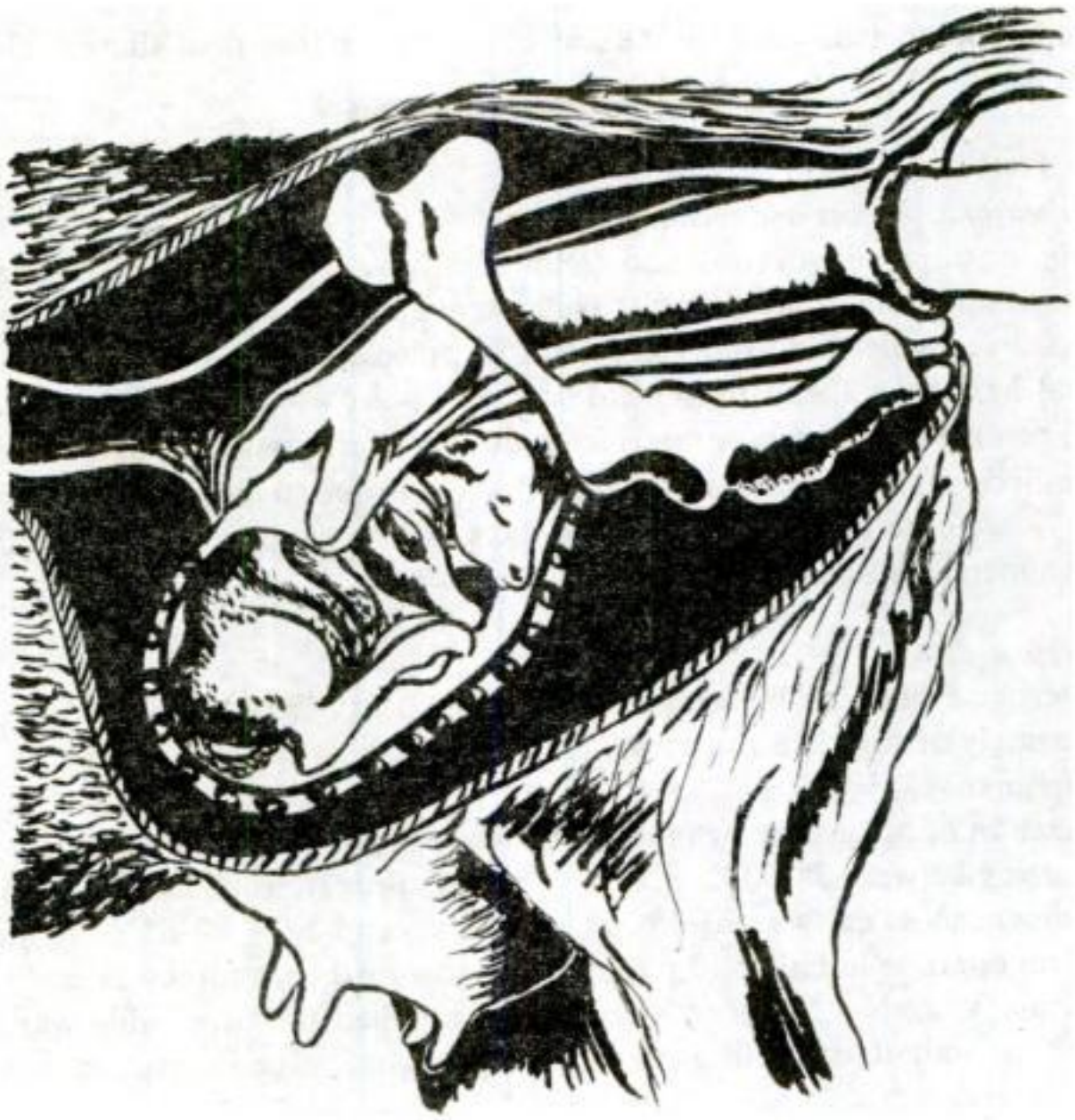


Fig. 5.19 Pregnancy diagnosis by rectal palpation method.

they grow larger as pregnancy advances. By the end of the 4th month, uterine arteries start enlarging. The middle uterine artery can be felt as a tense chord. At this time if the artery be slightly compressed between the finger and the thumb, a continuous vibrating fremitus (uterine thrill) can be detected which later changes to pulsation.

3. *From 5th Month Onwards*

From the 5th month onwards, the uterus sinks below the pelvic brim until the middle of the 6th month, but the foetus can still be felt in 50% of cases.

From the middle of the 6th month to the middle of 7th month, pregnancy can be detected from condition of the uterus, its blood vessels, the cotyledons and from the tension of the cervix.

From this period to the end of the pregnancy the presence of calf can be detected from external signs.

Differential diagnosis. In many cases pregnancy may be confused with some of the uterine abnormalities. One such case is pyometra of uterus. In case of pyometra, the uterus enlarges in both the sides, there will be no cotyledons, no double layers of the uterus, fremitus absent. Also in case of pyometra, pus will be present in vagina.

Per vaginum examination. If the vagina is examined during pregnancy by means of a speculum, the vaginal wall appears dry and wrinkled. During pregnancy the secretion of the cervical glands becomes gelatinous and tough forming a plug for sealing the canal. The seal is

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1. *Bruising, Laceration and Inflammation of Genital Organs.* It is common in case of horses and asses which get kicked by the oestrus female if not properly secured. This may hurt the animals on testes, penis, etc. Jumping over barbed wire while running behind the females may also lead to similar injuries. Sometimes false entry of the penis during copulation leads to the bruising of the penis and rectum.

2. *Perforation of the Uterine and Vaginal Walls.* A variety of complications of this sort may arise due to abnormal parturition or service by a large and vigorous male. Under abnormal conditions the penis may be caught by the urethral orifice or enlarged Gartner's ducts and the fistulae may be formed.

3. *Prolapse of Uterus and Vagina.* This condition is generally faced during advanced pregnancy or when approaching parturition. Generally the vagina and at times also the uterus gets reversed and protrudes out through the vulva and makes parturition difficult. This condition is also known as Ballooned Vagina.

PHYSIOLOGICAL. Probably this is one of the most widespread form of sterility or reduced fertility. It is mainly due to disturbed coordination, equilibrium and imbalance among the various hormones of the body.

1. *Impaired Sexual Maturity.* It may be due to pituitary dysfunction with regard to the gonadotrophic hormones (GTH). This may lead to underdeveloped or undeveloped condition of the gonads and the accessary genitalia in both the sexes. Other hormones like thyroxin, somatotrophic, etc., which affect the general growth of the animal body may also affect sexual maturity.

2. *Lack of Gametogenesis and Libido.* Both these processes controlled by the FSH and LH components of the GTH stimulate both spermatogenesis and oogenesis in the testes and ovaries respectively. The LH on the other hand stimulates the interstitial cells of the testes in males to produce androgen which in turn induce the animal to exhibit its sex or sex drive otherwise called libido. The deficiency of any of these hormones may limit or retard reproduction in either sex.

3. *Anoestrus Condition.* The anoestrus condition of the females may be due to a variety of causes of which the main ones are noted below:

(a) *Infantile ovaries.* It may be due to genetic or nutritional causes. In these cases there will be no follicular development and the level of estrogen will be reduced so much that there hardly will be any oestrus.

(b) *Persistent corpus luteum.* The corpus luteum that remains functional beyond the normal period goes on producing progesterone which keeps the pituitary suppressed for the GTH activity. The absence of the FSH, therefore, does not stimulate the ovary to develop follicles which produce estrogens responsible for heat.

4. *Silent or Quiescent Estrous.* Frequently females go through the normal ovarian changes in the estrous cycle but do not show the signs of heat and receptivity to males. Such cows and buffaloes are also known as silent or shy breeders. This is quite common in sheep which do not exhibit any sign of their first heat after the long anestrous period. Most probably the deficiency of the progesterone due to completely regressed corpus luteum may be the reason.

5. *Short Cycles and Retarded Implantation.* This condition may be due to unhealthy or deficient C.L. This leads to the deficiency of the progesterone and frees the pituitary for GTH activity, thus stimulating the ovary for oogenesis and bringing the animal into heat even



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RECENT RESEARCH FINDINGS IN THE PHYSIOLOGY OF REPRODUCTION

Synchronization of Oestrus & Ovulation

Oestrous synchronization involves manipulating the reproductive processes so that females can be bred during a short, predefined interval with normal fertility. This application of technology facilitates breeding in two inportant ways: (1) it reduces and in some cases eliminates, the botheration of oestrous detection; and (2) it enables the producer to schedule the time of breeding. For example, if all the animals in a herd can be induced to exhibit oestrous at about the same time, the producer can arrange for a few days of intensive artificial insemination. Other advantages of this procedure includes: (1) it creates a more uniform group of offspring, (2) a selected male may be used for breeding purposes to a number of females, (3) the breeding and thereby parturition takes place at a particular time of the season which facilitates necessary planning in a economic way, (4) females with certain compounds can be bred without oestrus detection. Various compounds or methods used for synchronization are as follows:

1. *Prostaglandins*: Prostaglandin F_2 and its synthetic analogues induce oestrous and ovulation in cattle, horses, and sheep by terminating the functional activity of the corpus luteum. Intramuscular injection of these compounds 6 days after ovulation will induce oestorus within 2-3 days after treatment.

Table 5.8

Classes of Compounds used for Synchronization of Estrus of Farm Animals

Class of compound	Route and length of administration	Class of animal
Progestogen	Oral, intravaginal pessary, injection, subcutaneous implant; 12–21 days (approximately one estrous cycle)	Cattle, sheep, goat, swine (generally effective in acyclic as well as cycling females)
Prostaglandin F_2 or analog	Intramuscular injection, once during luteal phase of estrous cycle	Cattle, sheep, goat, horse
Progestogen with estrogen	Progestogen as above, 9–12 days; estrogen by intramuscular injection at beginning of treatment to shorten life of corpus luteum	Cattle
Progestogen and prostglandin F_2	Progestogen by intravaginal pessary, 5–7 days; prostaglandin near last day to regress corpus luteum	Cattle

[a]Primarily from Hafez, 1980 (chap. 27); Hawk, 1979 (chap. 8).

2. *Progestogen*: Progestin will also synchronize oestrus in farm mammals. These



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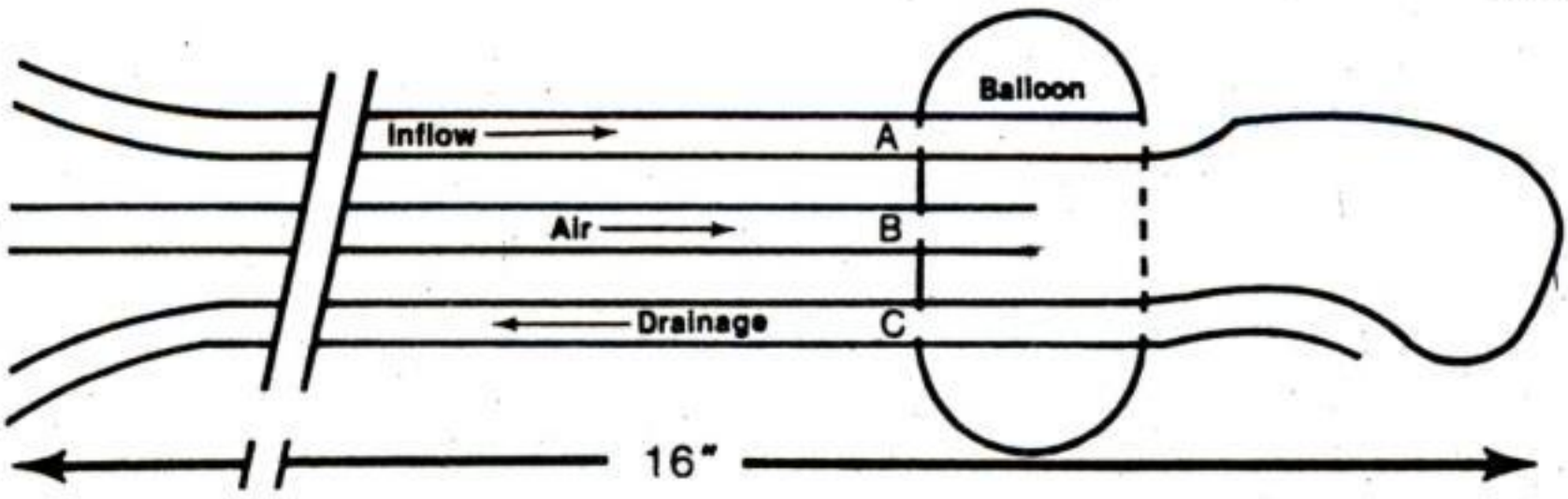


Fig.5.22 Diagrammatic depiction of a three way Foley catheter.

ET is not aimed at creation of high yielding animals for the milk producers directly. It provides only the seed stock – supply of superior bulls for the National AI network and for natural service where AI is not available.

Freezing Embryos

The freezing of viable embryos has been more difficult in comparison to freezing of bovine semen, since embryos are composed of masses of cells, rather than being a single cell as is the case with spermatozoa. When embryos are frozen and thawed, external cells are exposed to the environment before internal ones. This can result in becoming weak and lead to disaggregation of the cell mass, leading to embryonic dealth.

Recently embryos 6–7 days of age (0.2 mm in diameter) are recovered from superovulated donor cows using non-surgical collection methods. The embryos are pooled in a suitable growth medium viz., (i) Dulbecco's Phosphate—Buffered Saline (PBS), or (ii) Ham's F-10 supplemented with blood serum, or (iii) Bovine serum albumin. Other protective agents like Dimethyl sulfoxide (DMSO), glycerol, and 1,2—Propanediol are used to reduce the damage of freezing to embryos.

With this technique, embryos can be recovered, stored and transported almost anywhere in the world. However, the present technology of freezing, thawing and transferring the frozen embryos to recipients results 50% success when compared to fresh unfrozen embryos.



Fig.5.23 The Holstein Cow (upper right) is the genetic mother of 10 calves shown above. She was superovulated and the embryos were recovered from her uterus 7 days after conception, which were transferred to 10 recipient cows (left) for gestation to term. Colorado State University, U.S.A..

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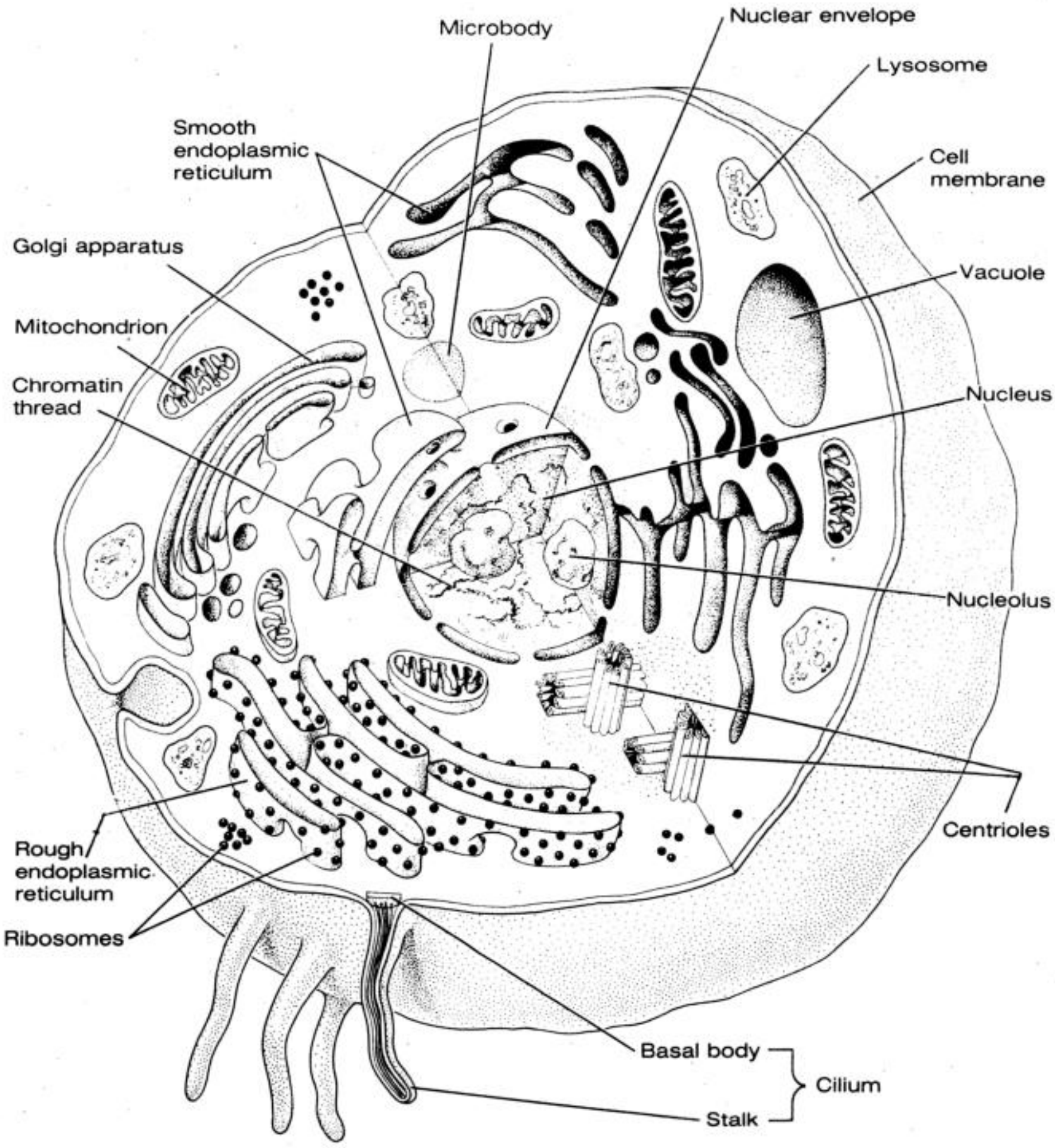


Fig 6.1 Diagram of a typical cell based on what is seen in electron micrographs.

of lipids has non-polar carbon chains at the centre of the membrane with the polar ends pointing outwards. This entire membrane is referred to as a unit membrane. The plasma membrane also has a number of pores, leading to the interior, which are lined with protein molecules. The endoplasmic reticulum and the Golgi apparatus of the cytoplasm are continuous with the pores of the plasma membrane. The cell membrane itself produces an almost impermeable barrier between the aqueous portion of the cytoplasm and the aqueous solution



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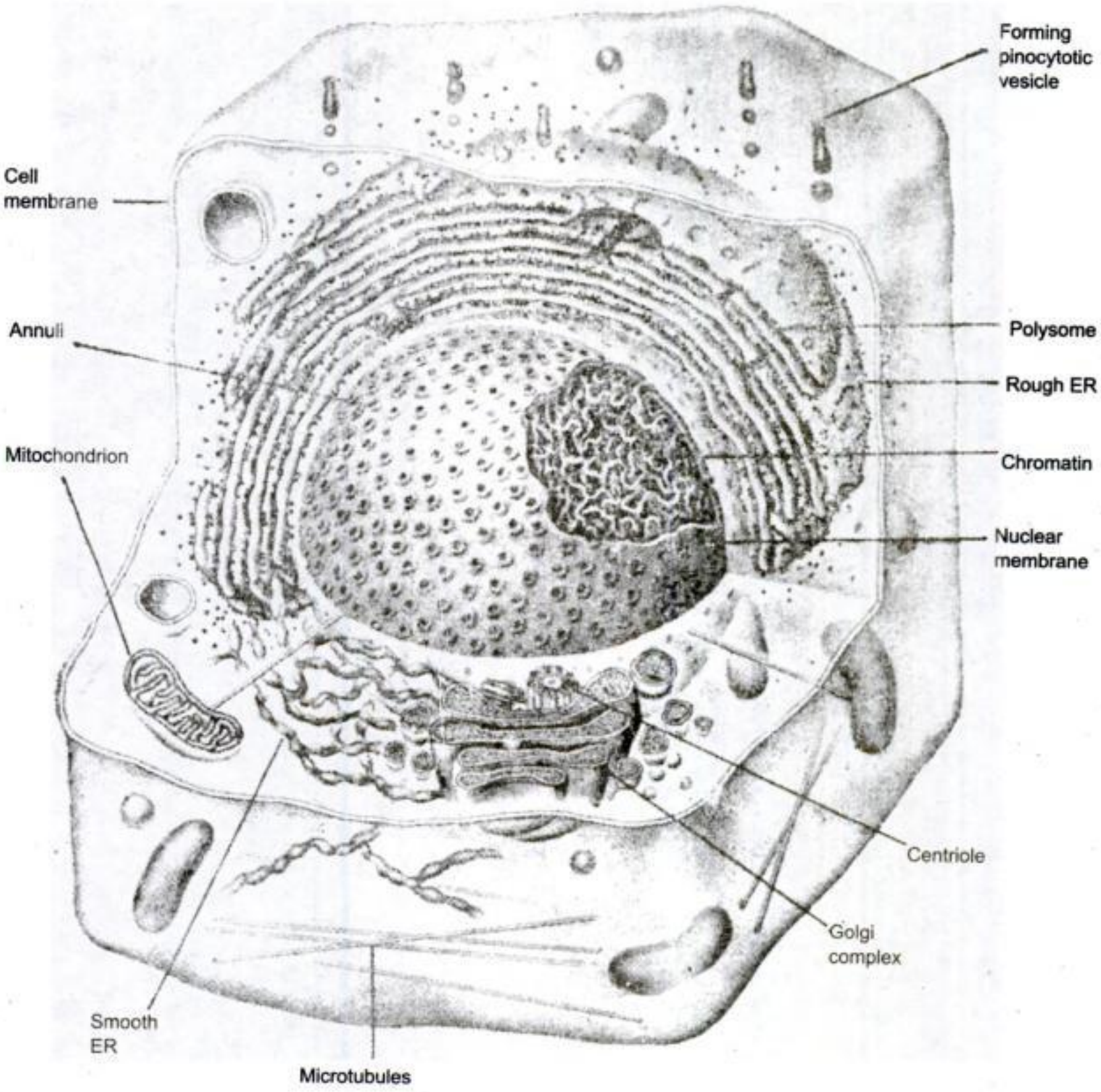


Plate 4. Animal cell showing internal features (Chapter 6).

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at some other stage of the life cycle. Such reduction is brought about by a single chromosomal replication followed by two successive nuclear divisions. The process is known as meiosis or reduction division and occurs during the gametogenesis of animals.

Meiosis is divided into division I and division II. In division I, the prophase is subdivided into five consecutive stages: leptonema, zygonema, pachynema, diplonema and diakinesis.

Leptonema. During this stage the chromosomes are highly stretched and bead like structures, chromomeres are often visible. The chromosomes may remain attached with one of their ends by a portion of nuclear membrane, forming the so-called bouquet configuration.

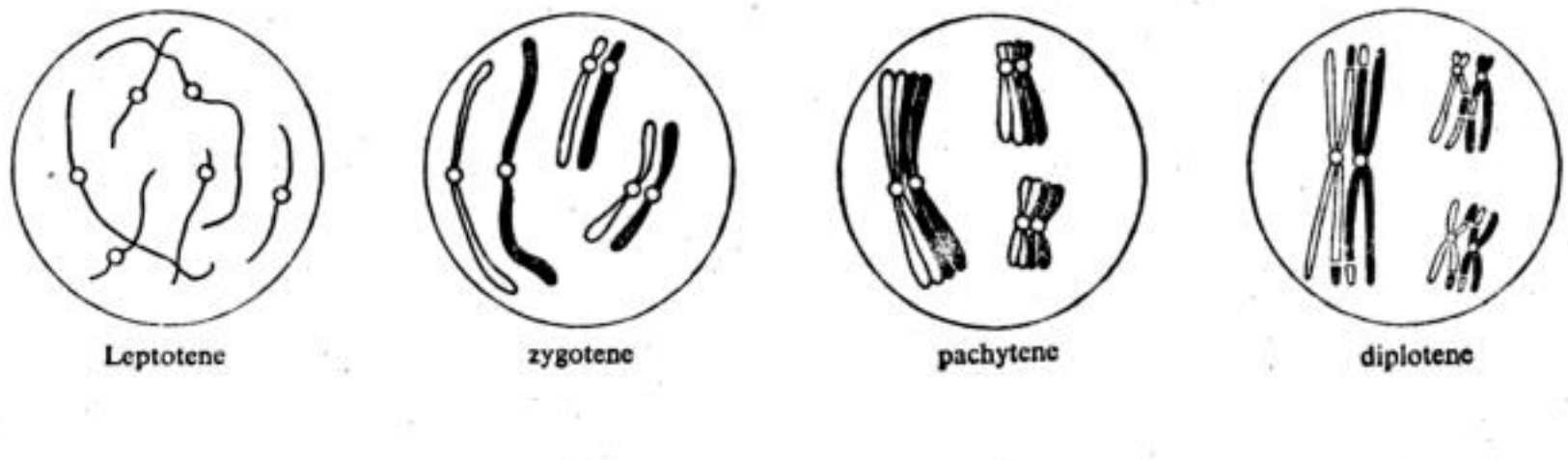


Fig. 6.7 Stages in heterotypic division of meiosis.



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Filial The Latin word meaning "progeny". Used in genetics to represent the generation or progeny resulting from intermating succeeding generations originating from the cross of two inbred lines. Filial is generally denoted by F with the subscript 1 to denote the generation after crossing.

Gene A portion of a DNA molecule (occupy a specific locus on the chromosome) through which inheritable characteristics are transmitted to succeeding generations in all living organisms. They provide information for the synthesis of various enzymes and each and every type of proteinous compounds of the body. Genes are basic units of inheritance. There are at least two alleles for a gene, one of which may be dominant over the expression of the recessive allele.

Genetics The branch of biology concerned with the physical basis of the transmission of inherited characters, i.e. about the heredity and variation of organisms.

Genetic recombination The reshuffling of gene combinations caused by breakage of DNA and its reunion at a different chromosomal point.

Genotype An individual's genetic make up (composition).

Heredity The passage of genetic traits to offspring which consequently are similar or identical to the parent(s).

Hereditary The transmission of qualities from parent to offspring by processes which occur first in the nuclei of germ cells. The words genetic and hereditary are often used interchangeably.

Heretability The strength of inheritance of the trait. Denoted by h^2. A technical term used to describe what fraction of the differences in a trait is due to differences in genetic value rather than environmental factors.

Heterosis The increased level of performance as compared to the average of the parental types is known as hetirosis or hybrid vigour.

Heterozygous A term applied to organisms that posses two different alleles for a trait. Often, one allele (A) is dominant, masking the presence of the other (a), the recessive.

Homologous Members of a chromosome pair, which have a similar shape and the same sequence of genes along their length.

Homologous chromosome From the Greek **homo**, meaning "like", and "logus" meaning "proportion". Homologus refers to chromosomes that are structurally alike. Two chromosomes, one inherited from the sire and the other from the dam, which pair and synapse at meiosis, have the same morphology, and contain genes governing the same characteristics.



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Parents—→♂ Tall (TT) X Dwarf ♀ (tt)

↓

Tall (Tt) . . . . . F_1

F_2 gametes→♂ T t

♀↓

	T	t
T	TT Tall	Tt Tall
t	Tt Tall	tt Dwarf

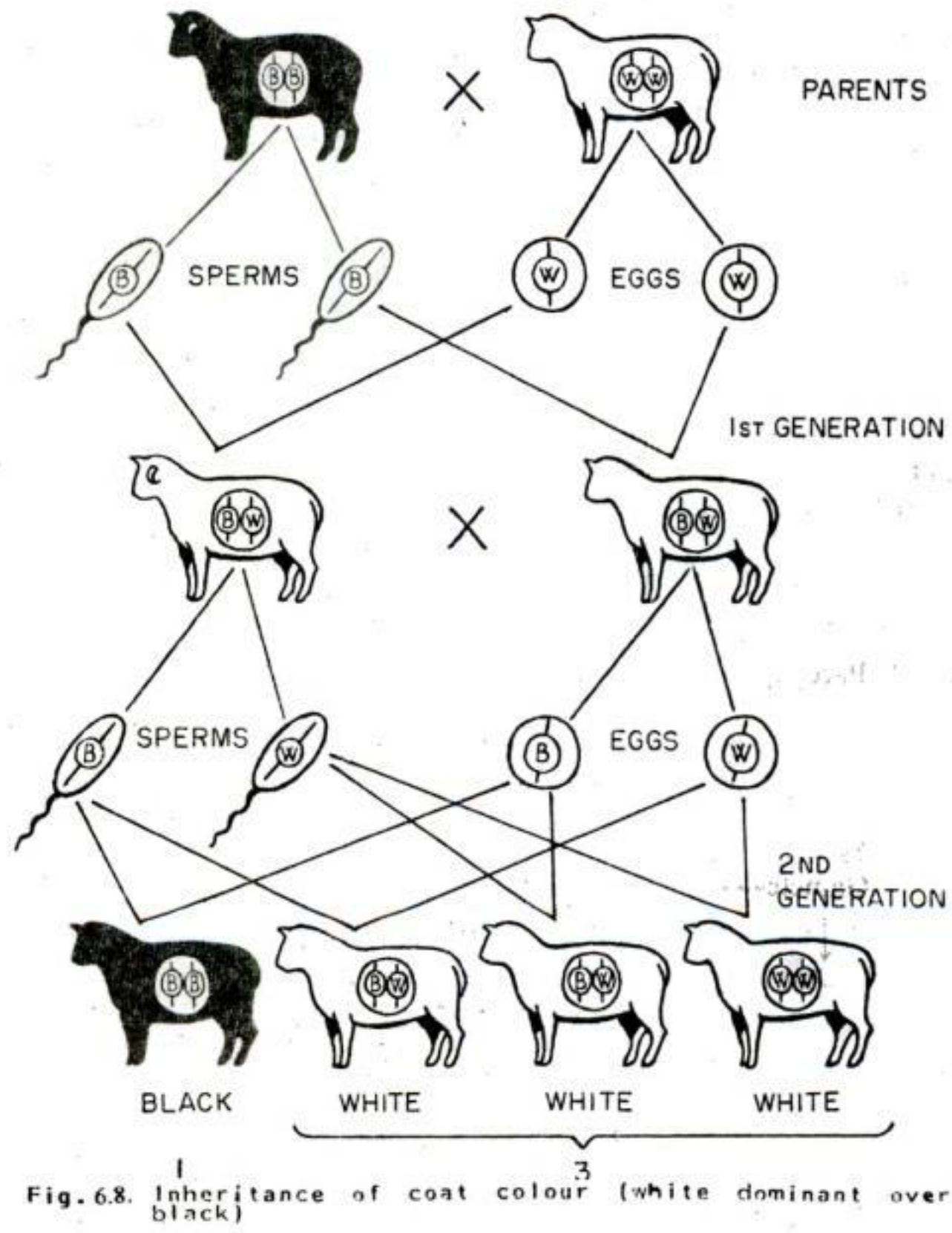


Fig. 6.8. Inheritance of coat colour (white dominant over black)

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Mendel explained these results with the assumption that the two characters, i.e., colour of cotyledon and shape of seed, segregated independently of each other. The F_1 (Yy) will produce two types of gametes Y and y with regard to colour of cotyledons; and R and r types with regard to shape of seeds. When two characters are considered at a time, the gametes produced by F_1 will be of the four possible types YR, Yr, yR, and yr. Mendel tested this assumption with a test-cross, involving the F_1 and the double recessive parents, i.e., green wrinkled.

The double recessive parent produces only one type of gamete carrying two recessive heredity units and hence they will not interfere with the expression of the genotypes of gametes produced by F_1 hybrid. The four different phenotypes observed in equal proportions in the testcross of Mendel were due to four types of gametes produced by F_1 plants. This testcross justifies the basic assumption of independent assortment. The law of independent assortment can be enunciated as follows—if two pairs of unrelated contrasting characters are combined in a hybrid they group themselves independently of each other during gamete formation.

CYTOLOGICAL BASIS OF MENDELIAN INHERITANCE

Cytologists uncovered the secrets of metosis, meiosis, and fertilisation between the time Mendel's paper was published and its rediscovery in 1900. Mendel's main contributions were:

1. To demonstrate that hereditary factors are discrete entities which are constant from generation to generation.
2. To demonstrate that hereditary factors occur in pairs in each individual.
3. To demonstrate that each hereditary pair of each progeny contains one factor from each parent.

Rediscovery of Mendel's paper caused great excitement among cytologists because the Mendelian factors paralleled, in phenotypic response, many of their observations about chromosome behaviour during cell division. Sutton and Boveri (1902-1904) summarised the cytological basis for Mendel's laws in the following ways:

1. Fertilisation in plants and animals is effected by the union of egg and sperm. These two gametes form the physical link between the parents and offspring. The hereditary factors must be transmitted through these gametes.
2. Only the nucleus of the sperm takes part in fertilisation, thus the nucleus must contain the male hereditary factors. It may be concluded that the nucleus is the vesicle for all hereditary factors.
3. The chromosomes are the only elements which divide exactly and are distributed equally to the daughter nuclei during cell division. Hence the chromosomes must carry the hereditary factors.
4. The chromosomes occur in pairs of somatic cells. In each pair one chromosome is paternal in origin and the other is maternal. The hereditary factors also occur in pairs as demonstrated by Mendel.
5. The members of a chromosome pair segregate during meiosis and, as a result, each



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patterns. The genes which are responsible for these two conditions are said to be allelic with one another. They are located on the same position in homologous chromosomes and in the reduction division they regularly go to different cells. Each gamete receives only one. These two genes are known as allelomorphs or alleles. Allelic genes always segregate in monohybrid ratio. Monohybrid segregation is the standard test of allelism.

A gene can have more than two alternative forms. These different forms of the same gene are called multiple alleles. The members of a multiple allele series will show monohybrid segregation crossing with each other. Multiple alleles arise due to mutation.

The Albino series of coat colour in rabbit. In rabbit, albinos with white coat and pink eyes are recessive to wild type with grey coat colour. Albinos are also recessive to Himalayan type with white coat but black nose, ears and feet. In these two cases the F_2 generation shows typical 3:1 segregation. This indicates that genes at a single locus govern coat colour, which has five alternative expressions—Albinos, Himalayan, Wild, Chinchilla and Light grey. Chinchilla is recessive to wild but incompletely dominant over Himalayan and albino. Light grey type is produced in F_1 of the crosses of segregation ratio is 1:2:1. In this series of coat colour the Albino is recessive to all other expressions while Wild type is dominant. The genotypes of the different expressions can be represented as follows:

Wild type	CC
	Cc^{ch}, Cc^{h}, Cc^{a}
Chinchilla	$c^{ch}\,c^{ch}$
Light grey	$c^{ch}\,c^{ah}$, $c^{ah}\,c^{a}$
Himalayan	$c^{h}\,c^{h}$
	$c^{h}\,c^{a}$
Albino	$c^{a}\,c^{a}$

Multiple alleles exist in many other cases. There are 12 different alleles in the white eyes series of Drosophila. The genes or blood groups and Rh factor in man have multiple alleles. The cellular antigens in cattle have a long series of multiples, numbering about 300. In plants, self-sterility is controlled usually by a long series of multiple alleles.

MODIFIED DIHYBRID RATIO DUE TO INTERACTION OF GENES

The classical Mendelian dihybrid ratio is 9 : 3 : 3 : 1. However, there are cases where this dihybrid ratio is modified phenotypically in various ways. It has been found that in these cases the fundamental laws of transmission of heredity remain the same. These apparent exceptions are due to the fact that the two pairs of genes influence in the expression of the same character and the modification is due to the interaction between these two pairs. The only deviation in this case is that more than one pair of factors are responsible for each single character while Mendel supposed that each pair of factors is responsible for one character.

The type of comb in poultry is a classical example of two genes influencing the same character, the birds with 'rose comb' in Wyandotte, 'pea-comb' in Brahamas and 'single comb' in Leghorn can breed true. Crosses between rose-combed and single combed varieties showed that rose is dominant over single and in F_2 a segregation of 3 : 1 appeared. The same result is obtained in crossing between pea-combed and single-combed varieties and it



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this inhibitor by (I) and the colour gene by (C), the homozygous White Leghorn is (IICC) and the white silky is (ii cc). The presence of the least one (I) will mask the expression of the colour gene. It can be explained on a checker board as given below.

In F_2 generation the white and coloured types appear in 13: 3 ratio. Here the combinations (II CC), (CII Cc), (Ii CC), or (Ii CC) are white due to the presence of inhibiting action of (I) over colour gene (C), while combination (II cc), (Ii cc) and (ii cc) are white due to the absence of any colour gene.

II CC
White Leghorn

X

ii cc
White silky

↓

Ii Cc. . . . . .F_1
White.

F_2
Gametes→♂

↓
♀

	IC	Ic	iC	ic
IC	II CC White	II cc White	Ii CC White	Ii Cc White
Ic	iI Cc White	II cc White	Ii Cc White	Ii cc White
iC	Ii CC White	Ii Cc White	ii CC Coloured	ii Cc Coloured
ic	Ii Cc White	Ii cc White	ii Cc Coloured	ii cc White

Other modified dihybrid ratio where two pairs of factors acting on the expression of same character are also found such as:

(a) 9 : 3 : 4 ratio due to recessive epistasis.
(b) 12 : 3 : 1 ratio due to dominant epistasis.

Pleiotrophy

When a gene is studied carefully it is usually found to produce several effects. Many examples could be cited but perhaps the most extreme is the gene, "polymorph", in Drosophila which has been demonstrated to affect eye colour, growth rate, fertility, wing size, body hair, viability, wing vein arrangement and several other characters. A gene which produces several superficially unrelated effects is said to be pleiotrophic.

The chemical nature of the gene and its guidance of development through production of proteins, enzymes, and hormones provides some insight into the phenomenon of pleiotrophy. Although the chemical reaction catalysed by a specific enzyme or hormone usually produces a specific chemical product, this chemical can enter into many other reactions. The appearance of the same chemical in many biochemical pathways which produce different end products would suggest that pleiotrophy is the rule rather than the exception.



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in F_2 is known as linkage. This is due to the location of genes on the same chromosome. In such cases Mendel's law of Independent Assortment does not hold good.

Bateson and Punnet (1906) first reported an exception to Mendel's Law of independent assortment in *Lathyrus odoratus*, the sweet pea. On crossing a homozygous type with purple flower and long pollen with another homozygous type with red flower and round pollen the following results were obtained:

Purple long (PL/PL) × Red round (pl/pl)

PL/pl.....F_1
Purple long

The F_2 results were as follows:

Segregates	*Observed frequency*	*Ratio*	*Expected frequency*	*Ratio*
Purple long	4,831	11	3,910.5	9
Purple round	390	1	1,303.5	3
Red long	393	1	1,303.5	3
Red round	1.338	3	434.5	1
	6,952		6.952.0	

Here it is observed that parental combinations, viz., purple long and red round are in great excess while the recombination or new combination, viz., purple round and red long are less than expected. So, it is clear that these two characters of flower colour and pollen shape did not assort in all the possible combinations in an independent fashion. Purple and long from one grand parent and red and round from the other, tend to hold together, so that more of these combinations are obtained than the expected ratio in the F_2 whereas the new combinations are observed in lesser quantity. Since the parental characters tend to stay together, this feature of heredity is called linkage.

Bateson and Punnet pointed out that when the dominants entered from the same parents they tend to remain together and did not assort themselves freely so that recombinations were fewer, while in the second cross when the dominants entered from different parents they tend to keep apart. The former was termed as coupling and the latter as repulsion. No satisfactory explanation of coupling and repulsion was developed until Morgan in 1910 found similar situation in Drosophila. Morgan said that coupling and repulsion are but two aspects of a single phenomenon called linkage. He showed that this tendency of linked genes to remain in their original combination was due to their presence in the same chromosome. Furthermore, he advanced the basic idea that the degree of strength of linkage depends upon the distance between the linked genes on the chromosomes. This proved to be a very fruitful idea, for it soon developed into the theory of the linear arrangement of genes in the chromosomes, and has led to the construction of genetic or linkage maps of chromosomes.

An example of linkage in poultry. Screbrousky in 1928 reported a case of linkage of comb shape and leg length in chickens. Rose comb (R) is dominant to single comb (r), and the creeper (C) is dominant to normal leg length (c). Creeper chickens have short legs that cause them to take very short steps, so that they appear to creep when they walk. Individuals homozygous for the creeper gene die early in life, and thus this gene is a semilethal gene.



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Still other genes do not cause death, but definitely reduce vigour. These will be referred to as detrimental genes.

A lethal gene may have its effect any time from the formation of the gamete until birth or shortly afterward. In a strain of horses, a sex linked recessive lethal has been reported that kills approximately one-half of the male offsprings of carrier female, so there are approximately twice as many females as males at birth. It is possible that such genetic defect may also be present in other species of farm animals. Frequently when a cow is mated and apparently conceives, she does not show signs of oestrus at a later date. Possibly conception takes place, but the zygote or embryo dies because of lethal gene effects; it is reabsorbed, and the female resumes the normal oestrus cycle. There is good evidence that lethal genes may cause losses in swine during pregnancy, because inbreeding increases embryonic death losses whereas cross breeding decreases them. This suggests that genes with non-additive effects are involved.

Semilethal genes are responsible for some death losses in farm animals. Dwarfism in Herefords, resulting from the mating of Comprest with Comprest is such an example. The dwarfs are born alive, as a general rule, but almost invariably they die before they are one year of age.

Most detrimental and lethal genes are either recessive or partially dominant and must be present in the homozygous state to have their full effect.

Detrimental recessive genes are generally present at low frequencies in a population.

Typical Illustration of Lethals in Cattle

Achondroplasia 1. Affected calves have short vertebral columns, inguinal hernia, rounded and bulging forehead, cleft palates and very short legs. The homozygous dominants are bulldog, the heterozygous are Dexters. About one fourth of the bulldog calves are aborted after their death in the sixth to eighth month of pregnancy following accumulation of amniotic fluid in the dam. The mode of inheritance is dominant, requiring to genes to have the lethal effect.

Achondroplasia 2. This condition has been described in the Telemark cattle of Norway and is similar to bulldog calf. Affected calves are carried to full term but die within a few days after birth due to respiration obstruction. The mode of inheritance appears to be recessive.

Achondroplasia 3. Described in Jersey breed, the defect is quite variable in the expression and is usually, but not always, lethal. Both the axial and appendicular skeleton may be affected. The head is deformed, being short and the legs are slightly reduced in length. In extreme cases, the calves are stillborn or die soon after birth. A recessive gene seems to be involved.

Agnatha. This lethal condition has been reported in Angus and Jersey cattle. The lower aw is several inches shorter than the upper, and it has been observed only in male calves, so it may be a sex linked recessive.

Cerebral hernia. Described in Holstein-Friesian calves. The affected calves have an opening in the skull because of a failure of ossification of the frontal bones. The brain tissue protrudes and is easily seen. Affected calves are stillborn or die soon after birth, probably due to a recessive.

Bulldog head (*Prognathism*). Observed in the grade Jersey herd. The skull is broad, the eye-sockets large, the nasal bones short and broad, and the forehead broader than normal. The condition is associated with impaired vision in partial or full daylight. Recessive factors are responsible.

Prolonged gestation. Gestation is prolonged to 310 to 315 days, with calves weighing from 50 to 60 kg at birth. Calves are thought to be homozygous for a lethal recessive gene.



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Example

The gene for pattern baldness in humans exhibits dominance in men, but acts recessively in women.

Table 6.3

Genotypes	Phenotypes	
	Men	Women
b'b'	bald	bald
b'b	bald	non-bald
bb	non-bald	non-bald

MUTATIONS

The phenomenon causing sudden discrete and heritable change in the genotype of an organism is called mutation.

The change if it is in germinal cells is transferable from one generation to the other. The effect is mostly unfavourable to the individual concerned but sometimes it may be favourable also.

Types of Mutation

Gene mutation. Genes arise only from genes, and heredity is due, in the last analysis, to accurate gene replication. The process of gene reproduction or replication is exact but occasionally it goes wrong; a copy of gene differs from its original and the modified gene goes on reproducing its changed structure. This is gene mutation, or point mutation. In this case usually one character is affected at one time.

Chromosomal mutation: In an organism the chromosome complement usually divides or reproduces itself accurately: but from time to time it may be altered by duplication-inversion in some chromosomes or change in the number of chromosomes. Such an individual with change in chromosome structure or number is called a mutant. The type of mutation effects large number of characters. Change in fertility is an indicator of chromosomal mutation.

Stage at which Mutations Occur

Mutation may occur at any stage in the development of an organism. It may occur during the formation of gametes when the progeny concerned will show the change. If on the other hand mutation occurs in the first mitotic division of the zygote then the individual concerned will show partly mutated and partly non-mutated tissues. Mutation may also occur at a later stage when the organism has attained maturation and if number of cells affected are large *the chimeric* tissues may arise. This mutation may be (1) Gametic, (2) Zygotic, or (3) Somatic in origin.

Probable Agencies Inducing Mutation

Mutations can be autogenous or exogenous. The most common external causes including



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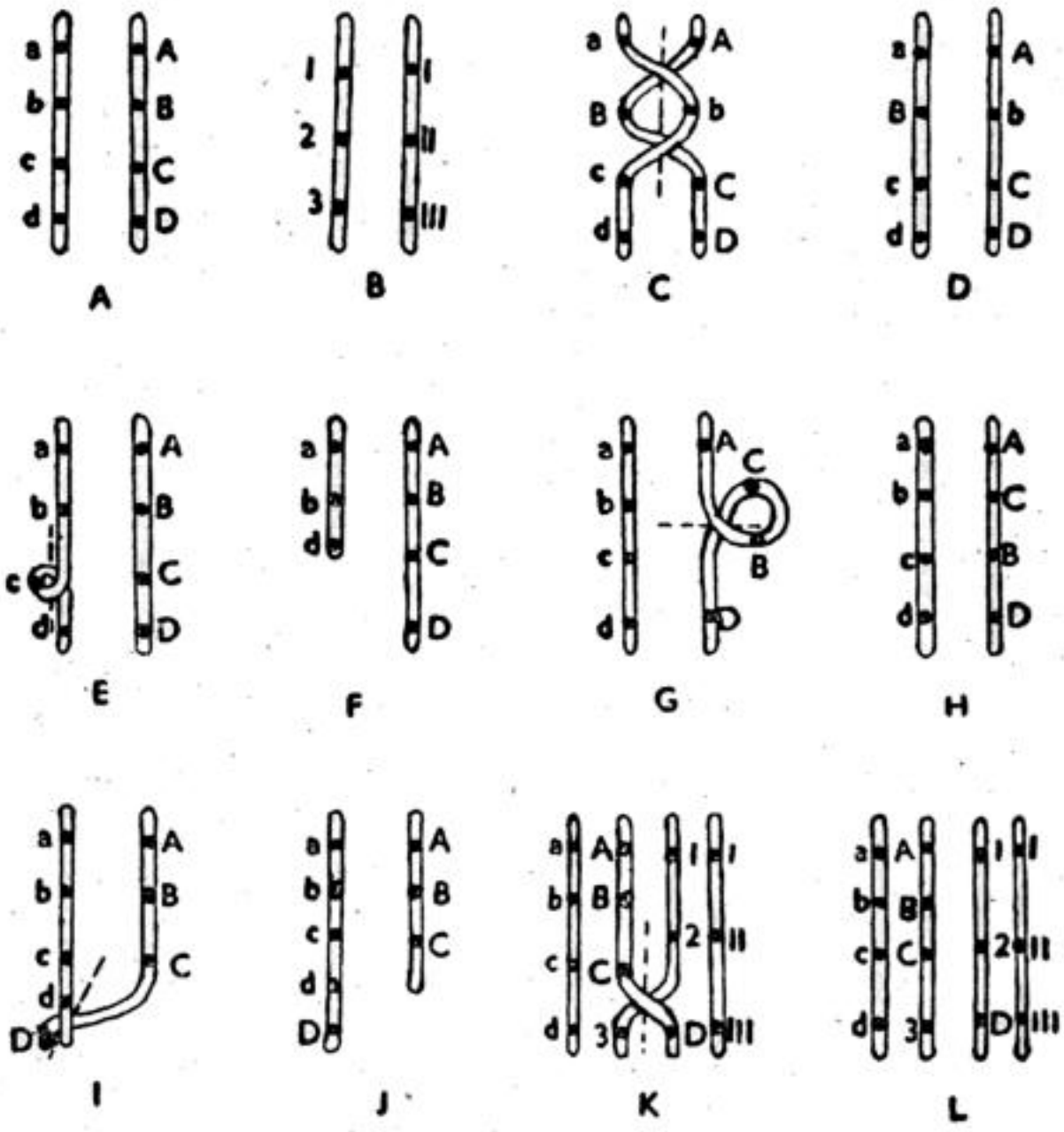


Fig.6.15 Diagram to show crossing over and various chromosomal aberrations.

gene orders but do not result in loss of genes. However, they prevent crossing over in some animals.

(iii) *Duplication.* If a part of one chromosome breaks and the broken part gets attached to the homologous pair, a condition is obtained where certain genes are present in a double dose in one chromosome while the same genes are deficient in the other chromosome of the pair. This condition is known as duplication.

If one member of the chromosome pair shown in A comes to lie across the other as shown in I and a break occurs in the plane of the dotted line, the chromosome on the left in J will have a duplication and contain both gene d and gene D, whereas the chromosome on the right will have a deficiency in the section containing gene D.

(iv) *Translocation.* When a piece of chromosome becomes broken off and attached to another chromosome, usually of another pair, the phenomenon is called translocation. This causes a change in the relation of linkage group. 'A new sex linkage is formed when translocation occurs in sex chromosome.

Translocation may be simple, when one chromosome of a pair breaks and gets attached to another chromosome of a different pair. Reciprocal translocation is the exchange of parts between non-homologous chromosomes.



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Natural Selection

Natural selection is defined to be that selection which occurs without the planning of mar. In the wild state, natural selection operates because more progeny are left by animals whose geno-types better enable them to procure food, escape predators, resist disease, attract mates, or otherwise survive and produce. Even in the "artificial" environments provided by man, there is some natural selection because certain genotypes reduce fertility or prevent conception and others produce susceptibility to disease or impair the length of life.

VARIATION

Selection is possible only when differences exist between members of the population. Variation among animals in size, colour, speed, stamina, growth rate, disease resistance, milk production and numerous other traits have often been recorded. This is indeed fortunate because genetic variation is the raw material from which the breeder creates superior stock. Without variation in the genetic make up of his herd, the breeder could not hope to produce progeny better than their parents, yet this same variation which is necessary for progress is also responsible for mediocre progeny.

Sources of Variation

Variation arises from two sources:

1. Genotypes—the particular combination of genes which directs the development of the animal.
2. Environment—the conditions of nutrition, climate, competing animals, stress, exposure to disease organisms, and other non-genetic conditions which influence the animal expression of a trait.

Genetic variation is transmitted to future generations, but that due to environmental differences is not transmitted. The relative importance of these two sources of variation determines, to a large extent, the speed and ultimate chance of achieving a desired goal through selection. The breeder tries to select the animals with the best genotypes, but often environmental effects cover up the true genotypic values.

Environmental variation. Environmental variation is often large and many of the environmental influences which cause variation are not well defined. The overall result of environmental variation is the masking of genetic differences, and the primary problem of most breeders is the elimination of (or allowance for) environmental influences so that true genetic differences may be identified. Identical twins are ideal for studying environmental variation because their genetic make-up is identical, as demonstrated by their identical sex, colour, blood antigens and other traits which directly reflect the genotype without environmental modification. When raised under different nutritional levels, these twins show dramatic differences in growth rate, milk production, and reproductive performance. Even when grown together in the same pen, indentical twins often show large differences for traits such as milk production which are greatly affected by random environmental effects.

Although different environments allow different degrees of expression for the same genotype, the environment does not directly alter the hereditary make-up of the animal. Removing the horns of cattle for many generations has not prevented the development of horns on progeny



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rarely as to constitute such a small part of the total genetic variance that it is hardly measurable. Some mutations, such as the dominant gene for hornlessness in horned breeds of cattle and certain colour mutants of mink, have been quickly recognised and used, but most viable mutations are either recessive or produce relatively small effects which are never recognised. Variations in chromosome number have been dramatically used in some varieties of plants, but are usually lethal in animals probably because of the high proportion of lethal genes and the low reproductive rates of most animal species.

Implications of Variation

Environmental Variation

Variation due to non-genetic effect are not transmitted to offspring. These variations have long been sources of frustration to breeders. Two types of environmental variation are involved:

1. Non-random
2. Random

Non-random environmental variations are those which are constant from one animal to the next in the same group. Examples of non-random environmental variations are those which result from climate, level of feeding, husbandry practices, or other influences which affect all animals in the same group. The presence of these differences is often known, but their influence usually is not. For example, in dairy cattle it is known that feeding level greatly influences milk production. The breeder often needs to know whether the cows in a certain well fed herd are genetically superior to those in another herd which are fed poorly. To rephrase the question, the purchaser wants to know from which herd he should purchase cows to get those which will perform best in his herd. He knows that the higher average yield in the well fed herd is partly due to feeding level, but he does not know how well cows from the poorly fed herd would have performed had they been in the well fed herd. The problem of known non-genetic effects is not limited to between herd comparisons, as records in the same herd but by cows calving in different seasons, years or at different ages are also difficult to evaluate because of non-random environmental effects.

Random environmental effects are those which influence individual records of animals but are not constant for all individuals being compared. Examples are lameness, minor infections, social dominance, and chance accidents. In general, random environmental influences are those which might produce differences between identical twins raised together in the same pen. These random non-genetic influences cause a large share of the total variation for many quantitative traits and often their causes are not recorded or even known. If these influences are truly random they have two important properties:

1. A good genotype is equally likely to be associated with a good or bad set of random environmental influences. This means that, on the average, the best phenotypes will have the best genotypes.
2. If several records are averaged, the favourable environment of some records cancels the unfavourable environment of others. This means that random environmental effects becomes less important as more records are included in each average. If the number of records in each average becomes large enough the difference between averages will include only genetic and non-random environmental differences.



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1. Dairy Cattle (Contd.)

Trait	Estimate
Nature of pathogens	.18
Fertility	
Abortion	.05
Calving interval	0.0 - .10
Cystic ovaries	.05
Days open	0.0 - .09
Gestation length	.50
Nonreturn rate	0.0 - .03
Retained placenta	.16
Services/conception	0.0 - .09
Stillbirths	.01 - .08
Twinning	.11
Feed efficiency	
Feed efficiency (lactation)	.56
Feed efficiency (31-60 days)	.44
Feed efficiency (121-150 days)	.44
Feed efficiency (181-210 days)	.34
Feed intake (Lactation)	.26
Feed intake (31 - 60 days)	.24
Feed intake (121 - 150 days)	.22
Feed intake (181 - 210 days)	.14
Growth/body size	
Average daily gain	.3 - .5
Birth weight	.40
Chest depth	.38
Chest girth	.36
Chest width	.31
Feed conversion	.40
Heart girth	.40 - .60
Mature size	.30 - .50
Rump length	.37
Width at hips	.38
Wither height	.50 - .70

2. Poultry

Trait	Estimate
Body weight	
2 wk (embryo)	.18
2 wk (male)	.01 - .05
2 wk (female)	.31
4 wk (male)	.43
4 wk (female)	.31
6 wk (male)	.30
6 wk (female)	.38
8 wk (male)	.38
8 wk (female)	.39
10 wk (male)	.54
10 wk (female)	.51
12 wk (female)	.58
24 wk (pullets - light)	.57
24 wk (pullets - heavy)	.53
Mature (hens-light)	.52
Mature (hens-heavy)	.49
Weight gain	
Up to 10 wk (female)	.35
4-10 wk (male)	.44
Feed consumption	
Up to 10 wk (male)	.73
Up to 10 wk (female)	.87
Feed efficiency	
Up to 10 wk (male)	.14
Up to 10 wk (female)	.29
Egg production	
Shor term, survivor production	.22
Intermediate survivor production	.19
Long term survivor production	.22
Hen-housed production	
Short term	.33
Long term	.15
Rate of production	
Short term	.11
Long term	.15
Egg mass	.25
Sexual maturity	.39
Sexual maturity	.39
Broodiness	.16
Pauses	.10
Persistency	.20
Oviposition interval	.59
Early egg weight	.45
Early egg weight	.57
Mature egg weight	.46
Yolk weight	.43
Yolk size	.39
Albumen weight	.38
Blood spots	.13
Specific gravity	.35
Egg shape	.35
Shell color	.35
Haugh units	.42
Miscellaneous traits	
Fertility	.02



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1. Selection for unimportant traits is harmful because it reduces progress in important traits.

2. Primary emphasis should be placed on one or few traits which are economically important and have the capacity to respond.

3. Selection for unimportant traits should take the form of culling only extremely undesirable individuals so that the intensity of selection for important traits will be little affected.

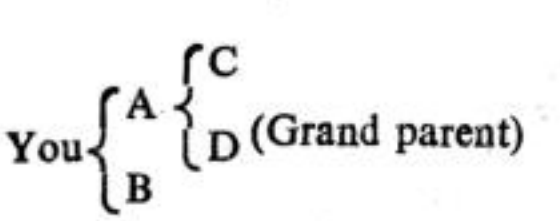
Of course, many traits are correlated (not independent), but this alters the above conclusions only by increasing the emphasis given to traits positively related to economically important trait and decreasing the emphasis on negatively related traits.

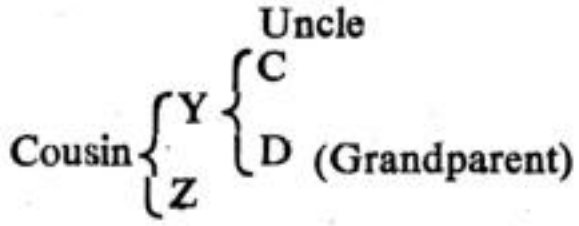
The foregoing is not intended to argue that selection should be exclusively for one trait, but that selection should not be wasted on traits which are not heritable or which have low economic value.

DEGREES OF RELATIONSHIP

The relationship between two animals can be defined as the fraction of genes obtained from common ancestors. Two animals may belong to the same breed but their relationship may be zero if they have no common near ancestors. Two animals with identical genotypes have a relationship of 100. They are alike in 100 per cent of genes, e.g., identical twins. The degree of relationship, therefore, ranges from 0 to 100.

Relationship may be of two kinds, direct and collateral. You are directly related to your father, for you are his offspring. That is you and your father have more genes in common (50%) than do unrelated members of the human population. Similarly one half of your genes are indentical with those of your mother. You and your cousins are collateral relatives, because you both have some ancestors in common. Your cousin probably has some identical genes that came to each of you from your common grand parents C and D.





The key to measurement of relationship is number of generations between the animals being studied and their common ancestors. The formula for relationship between individuals, say X and Y, is therefore.

$$Rxy = \Sigma[(\tfrac{1}{2})^{n+n'}]$$

Σ = Summation of. The contribution of all common ancestors is summed.

$\frac{1}{2}$ = the halving sampling process of inheritance in each generation.

n = number of generations between X and the common ancestor or the number of times the halving process has undergone between X and the common ancestor.

n′ = number of generations between Y and the common ancestor.



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Examples:

Full brother or sister mating:

$$X \quad \begin{cases} A \\ B \end{cases} \quad \begin{cases} C \\ D \end{cases} \quad \begin{cases} C \\ D \end{cases}$$

C.A.	n	n′	Contribution
C	1	1	$(1/2)^{1+1+1} = 12.5\%$
D	1	1	$(1/2)^{1+1+1} = 12.5\%$
			$F_x = 25.0\%$

Parent and offspring mating is the same as full brother and sister mating:

$$X \quad \begin{cases} A \\ B \end{cases} \quad \begin{cases} A \\ C \end{cases}$$

$$Fx = (1/2)^{0+1+1} = (1/2)^2 = 25\%$$

Half brother and sister mating:

$$X \quad \begin{cases} B \begin{cases} D \\ E \end{cases} \\ C \begin{cases} D \\ F \end{cases} \end{cases}$$

D is the only common ancestor to the parents of X; Hence

$$Fx = (1/2)^{0+1+1} = (\tfrac{1}{2})^2\, 12.5\%$$

What does this figure 12.5% mean ? The animal X is 12.5 per cent less heterozygous than an average animal in the herd which is unrelated. Suppose the animals D, E and F are 50 per cent homozygous (i.e., 50 per cent heterozygous). The animal X is 12.5 per cent less heterozygous or 50 per cent of 12.5 = 6.25 less heterozygous than 50 per cent. In other words, the animal X will be only 43.75 per cent heterozygous.

SYSTEMS OF BREEDING

The aim of the breeders, as stated in the beginning of the chapter, is to evolve outstanding and improved types of animals which can render better service to man. Selection and system of breeding constitute the only tools available to the breeder for improvement of animals, since



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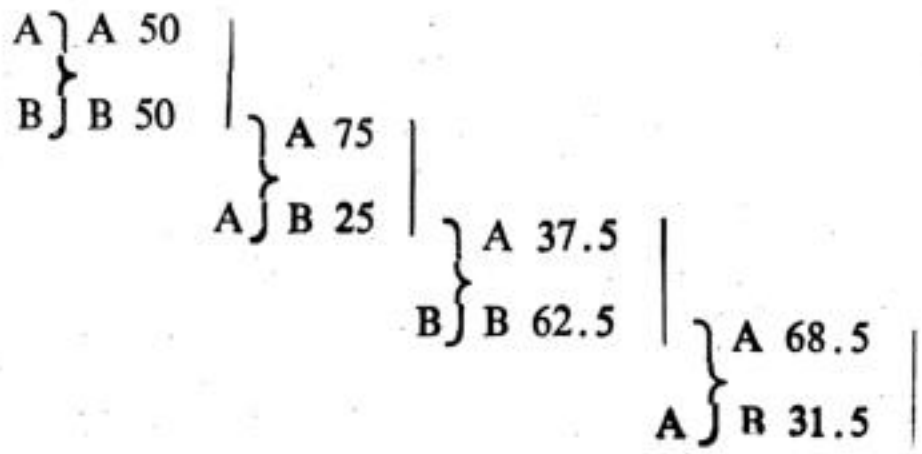
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also it is practised to a certain extent. Cross breeding for milk production has been tried with varying degrees of success. It is generally used for the production of new breeds.

Methods of Cross breeding

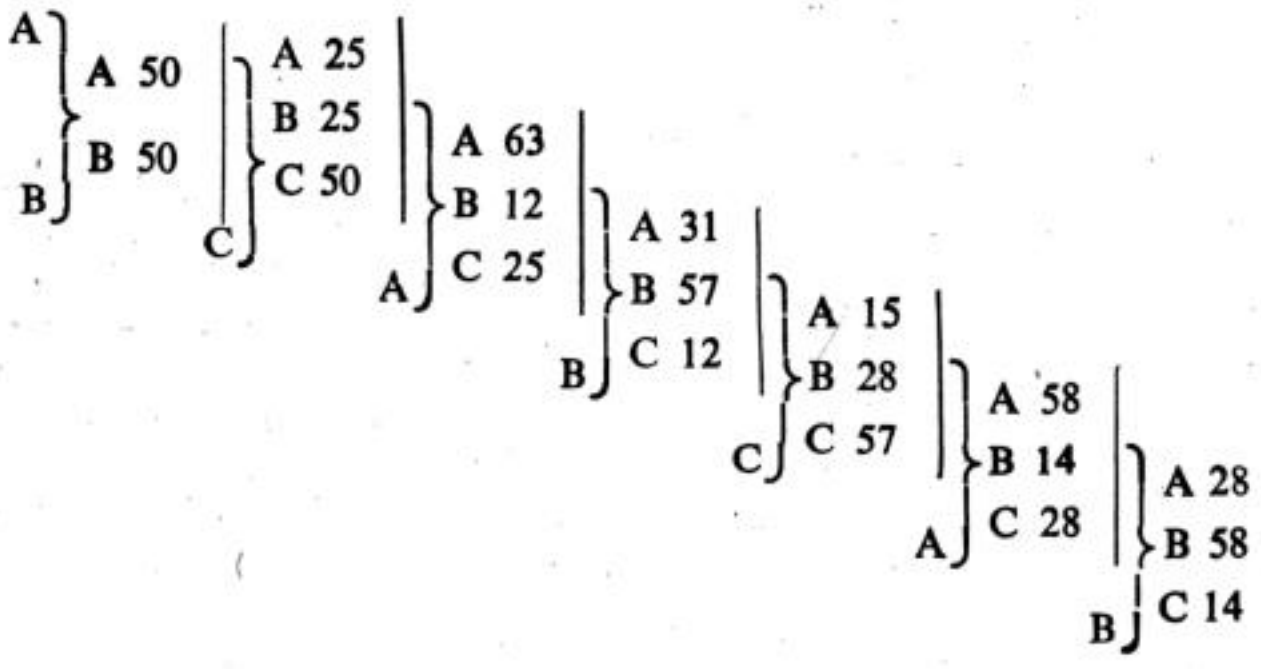
1. *Criss-crossing.* When the two breeds are crossed alternatively, the method is known as criss-crossing. This method is proposed for utilising heterosis in both dams and progeny.

Breed A females are crossed with breed B sires. The cross-bred females are mated back to sires of breed A and so on. In this system the cross breeds soon come to have about 2/3 of their inheritance from the breed of their immediate sire with 1/3 from the breed being used.



2. *Triple crossing.* In this system three breeds are crossed in a rotational manner. It is also known as rotational crossing.

Three breeds are used in this system. The females of crosses are used on a sire of pure breeds in rotation. The crossbreds will soon come to have 4/7 of inheritance of the breed of the immediate sire, 2/7 from the breed of maternal grand-size and 1/7 of the hereditary material of the other pure breed.



3. *Back crossing.* Back crossing is mating of a crossbred animal back to one of the pure parent races which were used to produce it. It is commonly used in genetic studies, but not widely used by breeders. When one of the parents possesses all or most of the received traits, the back cross permits a surer analysis of the genetic situation than F_2 does.



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The offspring, therefore, has a larger number of loci with dominant genotypes than does either parent and is likely to be more vigorous.

Another explanation for hybrid vigour is overdominance, where the heterozygous condition (Aa) is superior to either homozygous condition (aa or AA).

Heterosis is employed to produce commercial stocks with high individual merit. The successful exploitation of heterosis depends upon how superior the crosses are over the pure bred, and the cost of replacement of pure bred stock. For these reasons it is more commonly practised in poultry, swine, and sheep among whom fertility is high and the cost of replacement of pure bred stock is likely to be low. There is no advantage to cross breeding, however, if one parent line of breed is better than the crossbred progeny.

Grading Up

Grading is the practice of breeding sires of a given breed to non-descript females and their offspring for generation after generation.

Explanation of Grading

It is evident from the above definition that grading up is the successive use of purebred bulls of a certain breed of non-purebred herds. The continued use of good purebred sires for only a few generations are all that are required to bring the herd to the point at which it has all the appearance, actions, and practical value of pure breeds. The following Table shows the rapidity with which purebred sires will change the genetic composition of the non-descript one.

	Offspring	
	Per cent replaced	Per cent non-descript
1st Generation	50	50
2nd „	75	25
3rd „	87.5	12.5
4th „	93.75	6.25
5th „	96.87	3.13
6th „	98.44	1.56
7th „	99.22	0.78

From the above Table, we can see that the offsprings come closer to a 100 per cent improved breed, as we go on grading. Grading is a process by which a few purebred sires can rather quickly transform a non-descriptive population into a group of pure breeds. The grading process does not create anything new but it may transfer the good qualities of an improved breed.

For a grading up programme it is advisable to use a breed that has thrived well under local conditions. Otherwise graded animals may not adapt themselves to the local environment.

Advantages of Grading

1. Purebreds can be obtained just after a few generations (after 7th to 8th generations).
2. The start can be made with a little money in comparison to the purchase of an entire herd of purebreds.
3. It helps to prove the potentialities of the sire and adds to its market value.



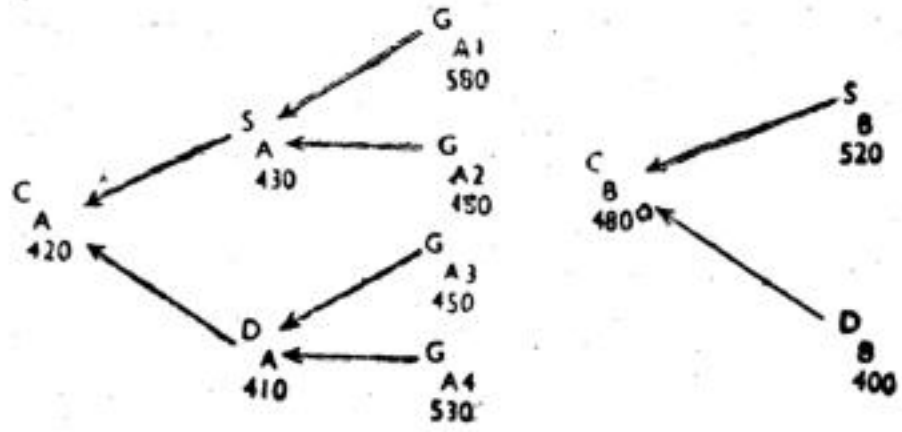
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The herd average weaning weight (H) for this herd has remained constant at 400 pounds for several years. The heritability of weaning weight is about .35, thus the index equations would be:

$$I_A = b_C (C_A - H) + b_S (S_A - H) + b_D (D_A - H) + b_1 (G_{A_2} - H)$$
$$+ b_2 (G_{A_2} - H) + b_3 (G_{A_3} - H) + b_4 (G_{A_1} - H)$$
$$= .26 (420 - 400) + .10 (30) + .10 (10) + .04 (180) + .04 (60) + .04 (50) + .04 (130)$$
$$= 26.0$$
$$I_B = b_C (C_B - H) + b_S (S_B - H)\, b_D (D_B - H)$$
$$= .27 (480 - 400) + .11 (520 - 400) + .11 (400 - 400)$$
$$= 34.8$$

Thus, candidate B would be chosen on the basis of fewer records because his own record and his sire's record are high whereas the high records behind candidate A were made by more distant relatives. If the records were made in different herds it would be necessary to substitute the appropriate contemporary herd average for H for each record.

Several principles will be clear from examination of Table 7.4.

a. The emphasis given to relatives falls off rapidly as the relationship becomes less.
b. Distant relatives are much more important when records on close relatives are not available.
c. Distant relatives add little information when close relatives have records.
d. Selection accuracy increases as heritability increases.
e. Information on relatives is more important when heritability is low.
f. Adding information on additional relatives always increases accuracy, provided they are weighted properly.

Advantages of Pedigree Selection

a. It provides information when performance tests are not available for the candidates.
b. It provides information to supplement performance test information.
c. It allows selection to be completed at a young age. Pedigree records may be used to select animals for performance or progeny testing in a multi-stage selection scheme.
d. It allows selection of both sexes for sex limited traits; i.e., bulls can be selected on the milk records of their female relatives.



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3. *Requirement for Successes in a Trogeny Test Programme*
   a. Mates of the tested candidates must be of equal merit.
   b. The average environment of all progeny groups must be the same. This is best done by:
      1. One progeny of each sire per herd.
      2. Progeny from the candidates randomly distributed among pens or herds. Definitely do not put all progeny of a parent in the same pen or herd or in adjacent stalls in the stable.
   c. High reductive rate.
   d. Several to many tested candidates for each one selected for heavy use.

Alternative Methods of Progeny Testing

The selection index method of progeny testing is presented because:

1. It is more accurate.
2. The values are directly comparable with indexes from performance and pedigree records.

Alternative forms of progeny tests have been widely used and will be discussed with a reference to the selection index procedure.

1. *The progeny (or daughter) average.* In this method the candidate whose progeny have the highest average is selected. This assumes that:

   a. All parents have an equal number of progeny.
   b. Equivalent environments were provided for all progeny groups.
   c. The mates of each candidate for selection are equal.

When these conditions are met the progeny average is equally as good as the selection index for comparison of progeny tested candidates, but does not allow a progeny tested candidate to be compared with a performance tested candidate. The selection index procedure becomes distinctly superior when some candidates have many more progeny than other candidates.

2. *The daughter-dam comparison.* In this method the sire whose progeny excel their dams by the largest amount are selected. This assumes equal merit of mates of the sires and equal environmental conditions for all records of dams and daughters. Two factors usually make this procedure very ineffective:

   a. Environmental changes—the dams usually make their records at a different time than their daughters, thus large non-random environmental effects usually remain in the daughter dam difference.
   b. The importance of the dam is overemphasised relative to including her in a selection index. Also, when one candidate has many more daughter-dam pairs than another, the procedure is very inefficient. Accurate comparisons of daughter-dam proofs with performance and pedigree records are difficult.

3. *The equal parent index.* This is an extension of the daughter-dam comparison to correct the merit of mates by adding twice the daughter-dam difference to the dam average. This usually provides slight improvement since the major drawbacks of the daughter-dam procedure remain.

4. *The contemporary comparison.* This is more a principle than a selection method. A



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$$\text{R.E.} = 12 \times \frac{\text{Number of calves born}}{\text{Age of cow (months)} - \text{age at first breeding}} \times 100 \text{ (months)} + 3$$

Factors Affecting Breeding Efficiency

Number of Ova

The first limitation on fertility is the number of functional ova released during each cycle of ovulation. In unipara as the cow, mare, etc., usually a single ovum is released, in sheep one or two and occasionally three, whereas in swine several ova even up to 25 are released in a single ovulation period.

Percentage of Fertilisation

The second limitation on fertility is fertilisation of ova. Failure to be fertilised may result from several causes. The spermatozoa may be few or low in vitality. The service may be either too early or too late, so that the sperms and the eggs do not meet at the right moment, to result in fertilisation. The spermatozoa retain their ability to fertilise for only a few hours after they are released in the female genital tract. If service occurs too early, sperms are dead by the time ova are liberated. In late service the ova must have descended considerably down in the fallopian tube and gets impenetrable by the sperms due to the mucoid coating. In dairy cattle the period of ovulation seems to be 14 hours after the end of heat. Occasionally a given mating produces no results although both the individuals later prove fertile in other matings.

Embryonic Death

From the time of fertilisation till birth, embryonic mortality may occur due to a variety of reasons. Hormone deficiency or imbalance may cause failure of implantation of fertilised ova which die subsequently. Death may occur as a result of lethal genes for which the embryos are homozygous. Other causes may be accidents in development, overcrowding in the uterus, insufficient nutrition, or infections in the uterus. The percentage of those which die between birth and maturity varies greatly with different kinds of animals. This may be due to genetic causes, or bad nutrition or management.

Age of First Pregnancy

Breeding efficiency can be lowered seriously by increasing the age of first breeding. Females bred at a lower age are apt to appear stunted during the first lactation, but their mature size is affected little by their having bred early.

Frequency of Pregnancy

The breeding efficiency can be greatly enhanced by lowering the interval between successive pregnancies. The wise general policy is to breed for the first time at an early age and to rebreed at almost the earliest opportunity after each pregnancy. In this way the lifetime efficiency is increased. Cows can be rebred in 9 to 12 weeks after parturition. Swine breeding programme can be adjusted to raise two litters per year.

Longevity

The length of life of the parent is an important part of breeding efficiency, because the



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Patna, and Montgomery (now in West Pakistan), to study these problems and to prepare for the development of artificial breeding on an all-India basis. The work carried out at these centres demonstrated the feasibility of this method of breeding in India, under both urban and rural conditions, in spite of many difficulties. The Montogomery centre was closed on August 15, 1947, on the partition of the country and the Bangalore centre closed in 1951. The State Governments of West Bengal and Bihar took over the centres at Calcutta and Patna respectively by the end of 1950 and the Government of Mysore had by then started artificial insemination work in Bangalore city.

During the First Five-Year Plan (April, 1951 to March, 1956), a master project, the Key Village Scheme, was launched, which provides for the all-round improvement of cattle and buffaloes in the country. To bring about rapid genetic improvement in the stock, artificial insemination was accepted as a major activity of the scheme. Under this Scheme 600 key villages and 150 artificial insemination centers were established during the period 1952 to 1956. One centre was attached to a group of four key villages. Each key village had 500 cows and/or she-buffaloes, so that one artificial insemination centre was responsible for 2000 animals.

Under the Second Five-Year Plan (April, 1956 to March, 1961) the scope of work has been further extended and by 1957, 400 artificial insemination centres were operating. Besides the artificial insemination centres in the Key Village Scheme almost all the states had additional artificial insemination units working in areas outside the Key Village units. Some private agencies or co-operative organisations dealing with livestock have also adopted artificial insemination for breeding work.

A semen bank has been established at the National Dairy Research Institute at Bangalore with a view to supplying semen from Jersey bulls for cross-breeding work and also from bulls of superior Indian dairy breeds for selective breeding or upgrading work. Semen from this bank is being flown to different parts of the country.

The use of AI in other species has generally lagged behind its use in cattle largely because of the problem of the satisfactory storage of semen. In the United Kingdom, France and Germany 5% or less of the total number of matings of sows and gilts are by AI, in Holland it is 20% and in some Scandinavian countries it is over 30%.

According to present status AI is currently used in dairy and beef, cattle, goats, buffalo, sheep, swine, horses, turkeys, bees, dogs, red fox, fish, mink, humans and many other species in many countries of the world.

The first buffalo calf through AI was born in 1943 at the Allahabad Agricultural Institute in U.P. India.

Advantages of AI over Natural Breeding

1. The main advantage of A.I. is that it increases the usefulness of superior sire to an extraordinary degree. It makes available sires of inheritance for milk and butter fat production to all dairymen within a limited area. Previously only a few could get the advantage of good bulls.
2. The services of superior sires are greatly extended. By natural services, a bull can be bred to 50 to 60 cows per year; on the contrary New York Artificial Breeders Co-operative have sired 10,000 in one year by one bull. It would have taken about 200 years to accomplish this by natural service of that bull.
3. The breeder does not need to maintain a herd sire and thus can avoid the botherations accompanied with the management of a bull. It helps to regulate the breeding programme



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whole human semen. In men the prostatic secretion also provides the main source of calcium.

Among the chemical peculiarities, the prostatic secretion is rather high in content of zinc.

Table 8.1

Semen volume and sperm density and number in ten animal species

Species	*Semen volume (ml)*	*Range*	*Sperm concentration (×10⁶/ml) = million/ml*	*Range*	*Total sperm ejaculate (×10⁶)*
Man	3.5	2.0–6.0	100	50–150	3,500
Bull	8	0.5–12.0	1,200	300–2,000	9,600
Buffalc	2.5	0.5–4.5	600	200–800	1,500
Ram	1.0	0.7–2.0	3,000	2,000–5,000	3,000
Goat	1.0	0.2–2.5	3,000	1,000–5,000	3,000
Boar	215	125–500	250	25–1,000	53,750
Stallion	125	30–320	120	30–800	15,000
Jack	50	10–115	400	95–600	20,000
Dog	10	1–25	125	10–540	1,250
Rabit	0.5	0.2– 2.0	300	100–700	150

SOURCE: *The Artificial Insemination of Farm Animals*, edited by Enos J. Perry, 4th edition, Oxford & IBH Publishing Co., 1969.

Seminal Vesicle Secretion

In several species including the rat, guinea-pig and bull, boar, stallion, etc., the seminal vesicles alone contribute more fluid than the rest of the accessory glands together.

Compared with the prostatic fluid the seminal vesicle secretion is usually less acidic and is sometimes distinctly alkaline. It has a higher dry weight, and contains more potassium bicarbonate, acid soluble phosphate and protein.

In certain animals, e.g., the dog and the cat, the seminal vesicles are altogether absent.

The normal seminal vesicle secretion is usually slightly yellowish but occasionally, specially in man and bull, it can be deeply pigmented. The yellow pigmentation is probably of composite origin but much of it is due to flavins.

The reducing power of the vesicular secretion is one of its most characteristic chemical properties.

It is also important to note that the seminal vesicles are the main sources of fructose in higher mammals. The identification of the seminal sugar as fructose by Mann (1945) opened the way for detailed studies of the fructose generating capacity of the accessory tissues.



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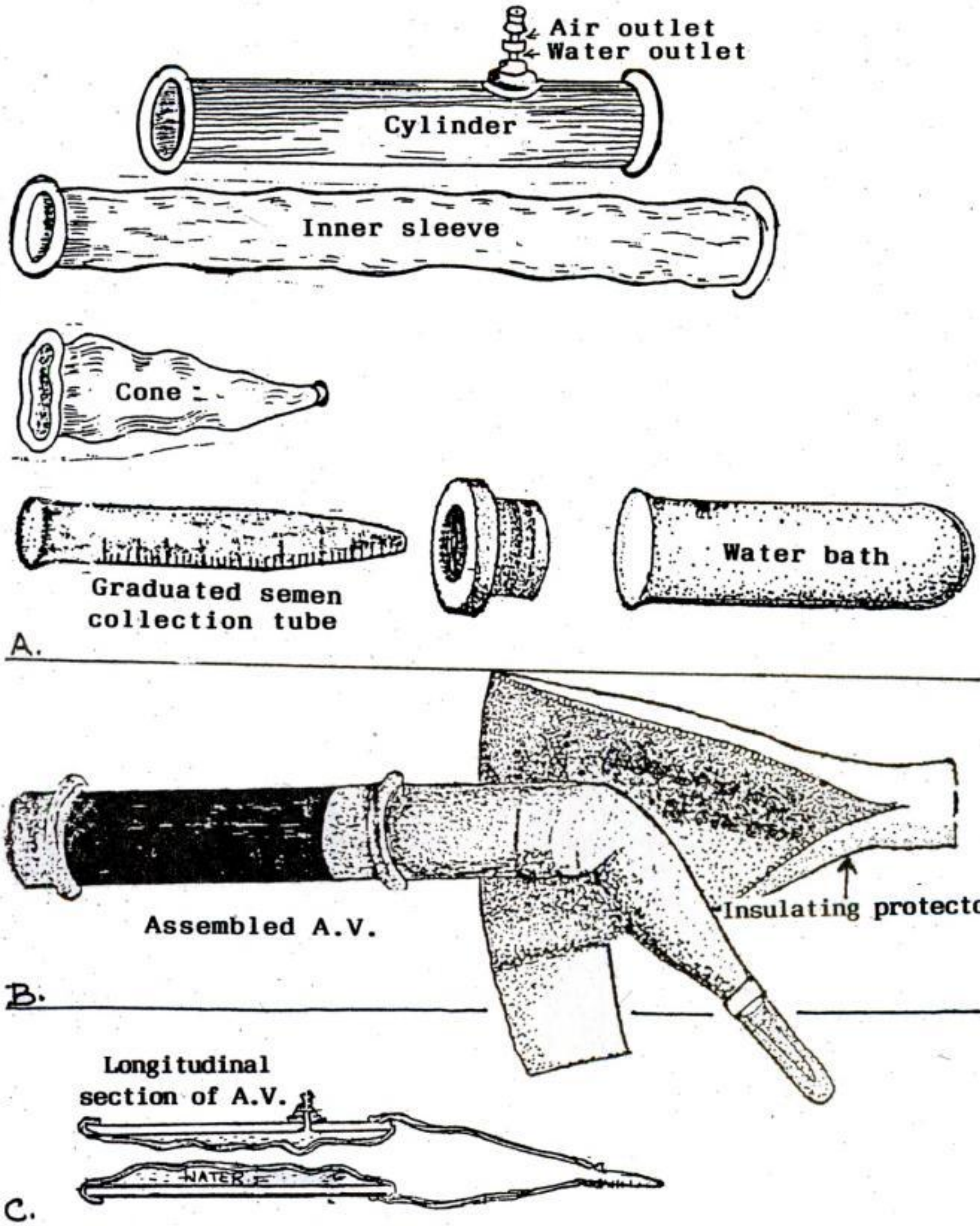


Fig. 8.2 (A) Various parts of bovine artificial vagina (A.V.) (B) Assembled A.V. (C) Longitudinal section of an A.V.

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by straightening the sigmoid flexture so that the glans penis can be grasped with a clean hand and the penis withdrawn from the prepuce. A piece of gauze is then secured behind the glans penis and the glans and the urethral process are inserted into a clean, sterile test tube. It is best to hold the penis and test tube with one hand so that other hand is free to massage the penis in a forward direction between electrical stimuli.

The rectal probe is pressed towards the floor of the pelvis by an assistant and a short stimuli (3–8 seconds) are applied at 15–20 second intervals. After several stimuli accessory gland secretions will flow, followed by semen. When a large amount of clear fluid is obtained initially this should be discarded to avoid diluting the semen. There is considerable variation between males in the amount of stimulation required to produce a satisfactory ejaculate. However, apart from the discomfort and muscular contractions occurring during treatment there are no permanent ill effects.

Collection of Semen from Boar

Pressure is especially important for collecting semen from the boar. The boar ejaculates when the curled tip of the penis is firmly engaged in the sow's cervix or in AV specially made to suit male boar or the operators gloved hand and pressure is exerted on the coiled distal end of the penis throughout ejaculation.

The ejaculate from the boar consists of the following four fractions:

1. *Pre-sperm fraction*—Very thin like water, having no colour. The quantity is about 10 ml and is sperm free. The deflection of this secretion is over at the height of excitement. Its importance is in rinsing the urethral tract which usually has a high bacterial count. This fraction is always preferred to discard.

2. *Sperm-rich fraction*—The volume of second fraction is about 40–80 ml, is dense and milky and contains about 80% of spermatozoa.

3. *Low-sperm fraction*—The third fraction consists of 150 to 200 ml of thin fluid with low-sperm concentration. This fluid originates from the secretions of seminal vesicles and prostate gland which is known as seminal plasma.

4. *Post-sperm fraction*—The fourth fraction is gelatinous and secreted by bulbourethral glands. It tends to seal cervix of the sow during mating, preventing loss of semen.

Semen Collection by AV in Boar

Mating is a prolonged process in boar, varying from 3-25 minutes, and waves of high and low sperm concentrations exist in the flow. The tip of the penis locks into the entrance of the uterus, cervix and ejaculation occurs directly into the uterus. For boar, the Norwegian type of artificial vagina is more common, the length of which is about 18 cm while the diameter is like that of bull. (Fig. 8.5).

It contains two inner tubes, one for air and the other for water. When the boar mounts the dummy, the collector guides the penis into the AV through the Y-shaped hole in foam rubber piece. The collector then tries to catch and hold the penis through the vagina with his right hand (Fig. 8.3). Ejaculation is produced by digital pressure on the spiral portion of the glans penis.

Latest design of a very simple AV for boar consists of only one simple smooth rubber liner (Fig. 8.4) where by applying continuous pressure by hand near distal end of penis, semen is collected.

Some 200 cc of semen is produced, but of this about 50 cc consists of a gelatinous material sperm, and this is strained off before insemination or storage.



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Bull	...	0.54–0.73
Ram	...	0.55–0.70
Stallion	...	0.58–0.62

Whereas the specific gravity of the sperm cell is due to the highly condensed nuclear and protoplasmic protein constituents, the specific gravity of the seminal plasma is the direct outcome of the actual osmotic pressure exerted by electrolytes and is thus related to the depression of the freezing point. It would seem that generally more reliance should be placed on the results obtained with seminal plasma than with whole semen.

5. *Specific gravity.* The average specific gravity of whole semen is 1.028 in man, 1.011 in dog and 1.035 in bull, with fluctuations due in first place to the variable ratio between sperm and seminal plasma. The latter is so much lighter than the spermatozoa (1.240–1.334) in bull that in practice the specific gravity of semen is often found to be directly proportional to sperm concentration. In bull semen, low specific gravity is usually associated with low sperm concentration and poor quality whereas high values accompany good density and good quality.

6. *Electro conductivity.* It has been claimed that the spermatozoa possesses at the head and tail small but directly opposite electrical charges. However, all that can be claimed with certainty is that an electric charge is associated with the sperm cell but that its magnitude depends largely on the concentration of the various positively and negatively charged ions in the surrounding medium. The following values for electro-conductivity in semen at 25°C expressed in reciprocal ohms $\times 10^{-4}$ were given by Bernstein and Shergin (1936) Bull 89.5—116.3, Ram 48.5 to 80.5, Stallion—111.3 to 129.5.

B. Microscopic Tests

1. *Counting of sperms* (by Heamacytometer). The counting chamber contains in the centre 16 big squares divided into 256 small squares. The size of the small square is 1/400 sq mm and the height of the cover glass above it is 1/10 mm. Therefore, the space in each small square is 1/4000 cu mm.

Semen dilution to be made with 0.9% NaCl containing 0.01% mercuric chloride to suppress the motility of the sperm,

0.1 cc. of semen to 9.9 cc of Normal Solution—1: 100...A
1.0 cc from A to 9.0 cc of Normal Solution—1000
0.2 cc from A to 9.8 cc of Normal Solution—1: 5000
0.1 cc from A to 9.9 cc of Normal Solution—1: 10,000

It is better to add a colouring fluid, e.g., Rose Bengal Eosin etc., to give colour to the sperms for better visibility under a microscope.

$$\text{No. of sperms in 1 cc of semen} = \frac{\text{No. of sperms counted} \times 4000 \times \text{dilution factor} \times 100}{\text{No. of squares counted}}$$

Counting of sperms can also be made by the help of (a) Visual estimation of concentration—by Blom's comparator, (b) Estimation by comparison with Opacity tubes, (c) Estimation by Absorptiometer.

2. *Motility of spermatozoa.* A drop of sample is taken just after collection and after properly mixing on a clean dry hollow ground slide kept at body temperature. It is then examined under the low power and rated on the basis of the swirling currents.



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from a single dose of his ejaculate. In natural mating, one ejaculate is used to inseminate one female, whereas by extension of the same volume of semen, several hundred (500–1,000) females can effectively be made pregnant. (2) Moreover, ejaculated sperm do not survive for long period and thus to preserve fertilizing capacity of the spermatozoa for a long period various agents are added. The agents that comprise good extending media have the following functions:

1. Provide nutrients as a source of energy
2. Provide lipoproteins and/or lecithin to protect sperm cells against low-temperature shock
3. Provide a buffer to prevent harmful shifts in pH as lactic acid is formed
4. Maintain the proper osmotic pressure and electrolyte balance
5. Inhibit bacterial growth
6. Provide a source of reducing substances to protect the sulfhydryl containing cellular enzymes
7. Provide a buffer for a proper balance of mineral elements essential to the life of sperm cells
8. Increase the volume of the pure semen so that it can be used for multiple inseminations.

Functions of Common Extender Ingredients

Glucose: Provides energy

Egg yolk and milk: Protect against cold shock of the sperm cells as they are cooled from body temperature to 5°C and by providing lecethin, proteins, lipoproteins and similar compounds found in egg yolk or milk. These substances also contain nutrients utilised by sperm.

Buffers: A variety of buffers are used for maintaining a neutral pH and an osmotic pressure of approximately 300 milliosmoles, which is equivalent to that of semen, blood plasma and milk. A satisfactory extender for one animal or one set of condition may not be acceptable for others. This has resulted in a number of diluents for various species.

Antibiotics: Penicillin, streptomycin, polymycin B or other combinations of antibiotics that cover a broad bacterial spectrum are used to enhance the keeping quality of semen. Procain penicillin is toxic to spermatozoa. Antibiotics will not completely eliminate *Corynebacterium pyogenes*, *Brucella*, *Trichomonas fetus*, *Mycobacterium*, *Rickettsiae* and *Fungi*. Addition of glycerol further reduces the efficacy of antibiotics. Hence addition of antibiotics is not an extra precaution and cannot be taken as an effective tool to permit use of semen from infected bulls or unhygienic semen processings.

Glycerol: Most widely used cryoprotective agent for bull spermatozoa particularly for frozen semen. The exact mechanism and the loci of activity is not clearly understood. The possible modes of action proposed are:

1. Modifies size and shape of ice crystals formed.
2. Binds water and decreases freezing point of solution and less ice is formed.
3. Prevents denaturation of proteins and rupture of plasma membrane.
4. Reduces the soluble concentrations.

Fructose: Provides glycolysable substrate for the sperm, prevent sperm agglutination, maintain required osmotic tension and electrolyte balance and gives added cryoprotection during deep freezing.

Composition of Extenders

For many years the emphasis in AI programmes was on the use of liquid extended semen generally preserved at 5°C for 2 to 4 days for the purpose of increasing usefulness of superior



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	Citric acid	...	1.73 g
	Fructose	...	1.27 g
	Distilled water	...	99.13 ml
	(pH adjusted to 6.8 with citric acid or NaOH)		
(b)	Tris buffer, as in (a)	...	74 ml
	Egg-yolk	...	20 ml
	Glycerol	...	6 ml

(c) To a diluent add penicillin at a dose of 1000 I.U. and streptomycin at 1000 microgram per ml.

C. Coconut Milk Based Dilutors

The use of coconut milk (water) extender (CME) for the preservation of active sperms for 7 to 10 days at room temperature was first worked out by Norman *et al.* (1960, 1962). It is made up of sterilized coconut water and a 4.3% sodium citrate solution plus 100 mg per cent calcium carbonate, 80 mg per cent penicillin and 90 mg per cent streptomycin. The pH is adjusted to 7.4 with 10% solution of NaOH. The same workers in 1962 observed that CME to which 5 per cent egg-yolk was added maintained motility better than EYC and skim-milk extenders.

Exposure to light produces photo-oxidation which results into poor motility and depression of metabolic rate. Tomar and Sharma (1974) modified the CME by selecting the following components:

2% sodium citrate dihydrate solution	...	50 ml
Coconut water	...	25 ml
Egg-yolk	...	12.5 ml
Egg-albumin	...	12.5 ml

Limited availability of superior quality coconut water all round the year and all over the regions in India restricts its popularity.

D. Other Commercial Diluents:

Fruit and vegetable juices have been used in some countries for extending bovine semen, with apparently acceptable results. Such juices as tomato broth and carrot juice, which are abundant and economical, have been used.

In New Zealand an ambient temperature dilutor, known as *Caprogen* has been found very effective in maintaining maximum fertility for a 24 hour period. The dilutor includes caproix acid in an IVT-CUE type of extender followed by gassing with nitrogen.

Recently at N.D.R.I. Karnal in Haryana, a diluent named as 'Citrate Acid Whey' (CAW) at pH 6.8 found to be the best diluent for preservation of buffalo semen. When CAW was compared with EYC, the former could preserve the sperms for 5 days at refrigerated temperature (5°C) with 60% motility as against 2 days in the case of the later diluent.

The CAW is now available in a packet containing cow skim milk powder and citric acid together. The entire contents of the packet is dispersed in 100 ml distilled water. The curdled material is filtered after 10 minutes through cotton plug and the pH is adjusted to 6.8 using 10% NaOH. The preparation is now ready for diluting semen. CAW packet can be preserv-



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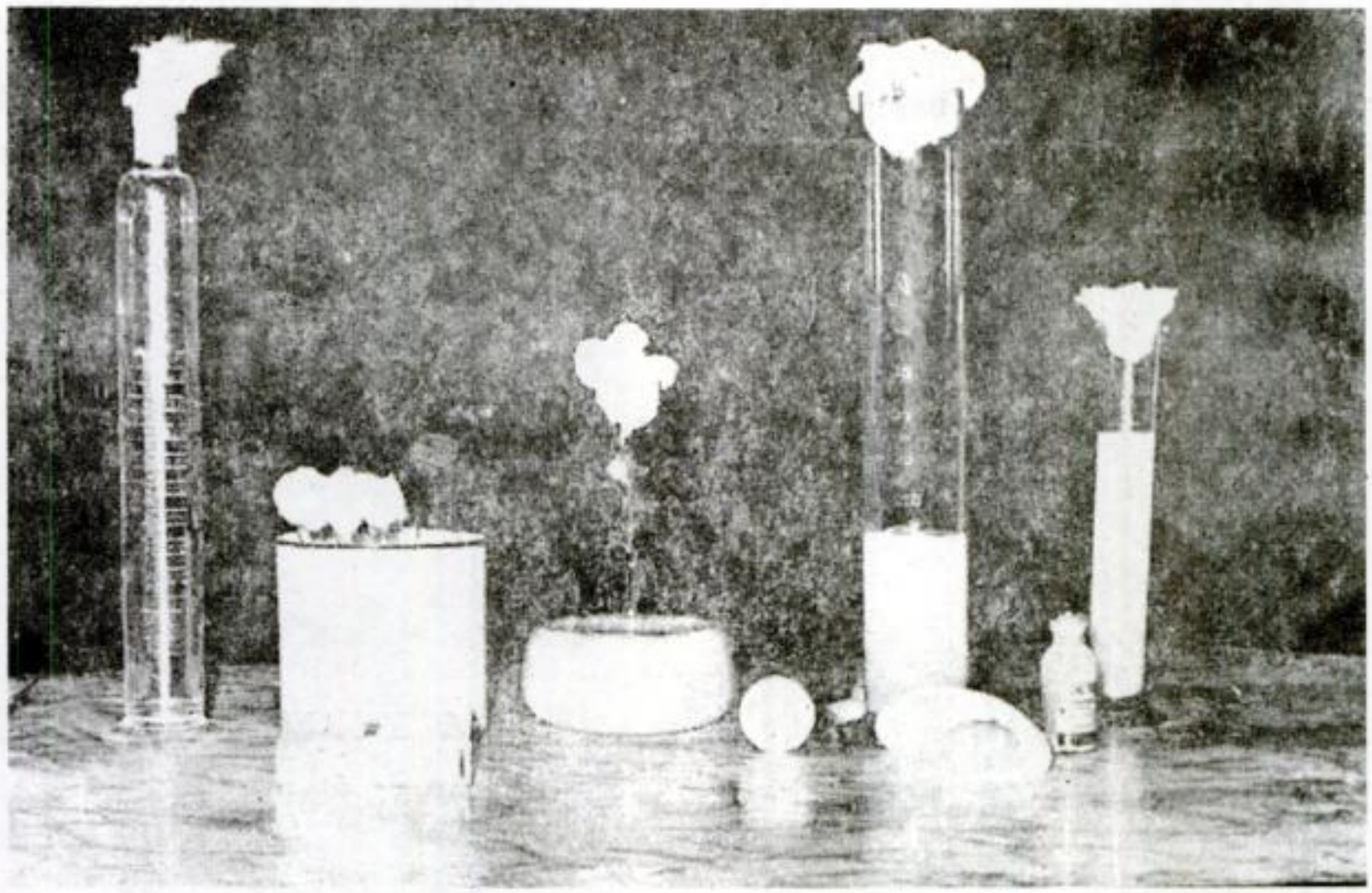


Plate 8. Preparation of Egg yolk buffer Extenter, (Chapter 8).



Plate 9. Artificially insemination of a cow (Chapter 8).

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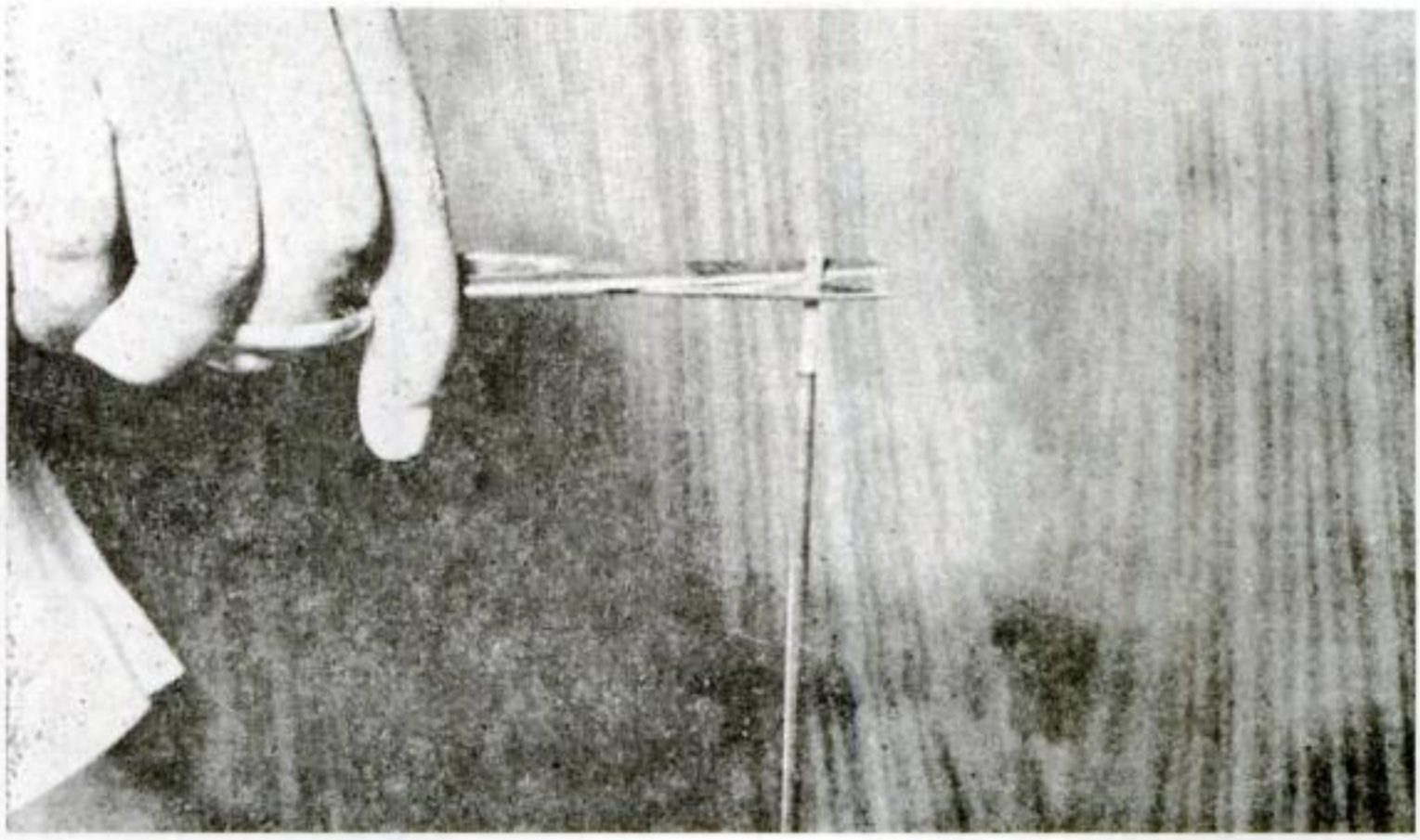


Plate 13. Cutting of straws at 90° Angle (Chapter 8).

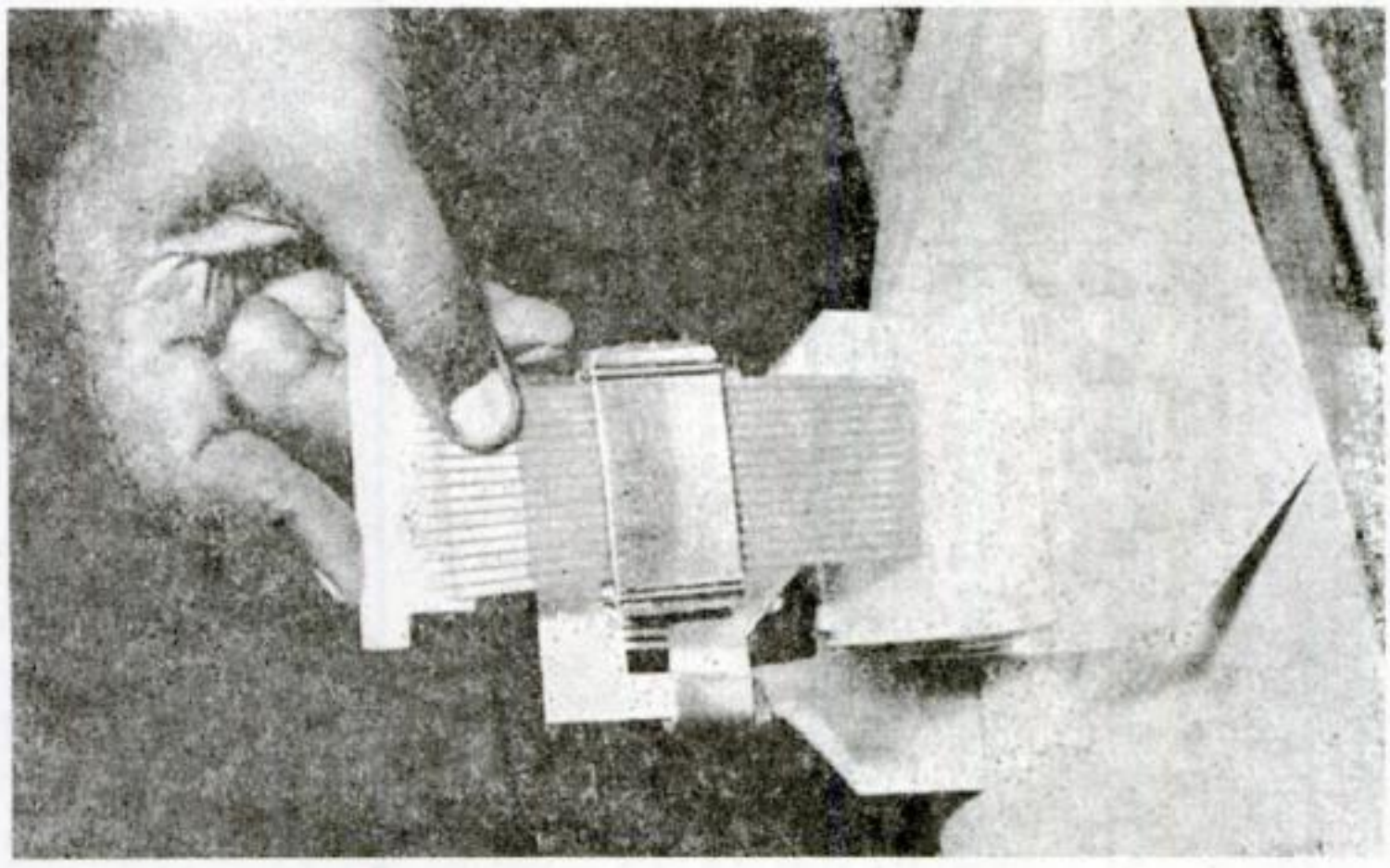


Plate 14. Filling of Semen (Chapter 8).

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C.

Glucose-D	40.0 gm
Sodium bicarbonate	1.0 gm
Sodium citrate	3.8 gm
Cheloplex Helaton	2.6 gm
Egg yolk	100.0 ml
Combiotic	2.5 ml
Glass distilled H_2O	1000 ml

D.

Glucose-D	120.0 gm
EDT-A	7.4 gm
Sodium bicarbonate	2.4 gm
Sodium citrate	7.5 gm
Penicillin	100,000 I.U.
Streptomycin	1.0 gm
Glass distilled H_2O	2000 ml

The above dilutors can preserve boar semen for 3 to 6 days at a temperature of +10°C to +15°C

Dilutor for Stallion

It is very much in practice to use undiluted stallion semen for insemination of mares when the number of mares to a stallion is very limited. When large number of mares are assigned to one stallion, the semen has to be diluted and extended for use either for a single or repeated inseminations.

On account of the sensitivity of the stallion sperm it is recommended that dilutor at body temperature should be added to semen by slow rotating movements as soon as collection is obtained. Before this operation the viscous fraction is separated from the sperm bearing fraction.

Diluted semen is held in waterbath at 20 to 27°C and is used for inseminations within a few hours of the extension. When egg yolk dilutor is used the cooling process can be very rapid. The entire diluted semen is then placed in a refrigerator or into a thermoflask containing ice water at a temperature of 5 to 10°C.

The composition of a most effective dilutor is as follows:

Glucose	. . .	30 gm
Lactose	. . .	20 gm
Sodium potassium tartarate	. . .	10 gm
Glass distilled H_2O	. . .	1000 ml
Fresh egg yolk	. . .	200 gm
Para-amino benzoic acid	. . .	6 gm

The egg-yolk is freed of albumin membrane and chalazae. The dilution rate varied from 1 : 3 to 1 : 5. Fairly good results are obtained even after 48 hours storage and long transport.

Method of Dilution

Dilution of semen should be done soon after collection and routine examination. Both the semen and the diluent are placed in a waterbath at 30°C and must be at the same temperature at the time of dilution. The diluent should therefore be placed in the waterbath before collection of semen. Addition of cold diluent to semen may result in cold shock to the spermatozoa with consequent reduction of fertility. For dilution, a calibrated glass pipetter, or an inseminating pipette attached to a 1.0 ml syringe can be used .The pipette used should be thoroughly washed and sterilised



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Table 8.5
Comparative Oestrous and Oestrous Cycle in Sheep and Goat

Oestrous cycle lengths (days)			Length of Oestrous (hrs)	Time of Ovulation
Species	*Mean*	*Range*		
Sheep	16.7	(14–19)	24 – 36	Near end of oestrous
Goat	20.6	(18–22)	26 – 42	Shortly after end of oestrous

In contrast to goat, in sheep relatively quiet heat (oestrous) is the rule. Oestrous in the ewe is extremely difficult to detect if there is no ram in the flock. But, with a ram in the immediate environment, it is usual for the ewe in oestrous to associate closely with it for most of a 24 hour period. Ewes frequently initiate the first sexual contact by seeking out the ram and thereafter following the ram while heat persists. Sometimes the ewe will rub herself against the ram. Further behavioural evidence of oestrous sometimes appears as tail shaking but this only occurs at mating. Different grades of intensity occur in the sex drive of ewes, although the general mating pattern is similar in all. Many ewes in oestrous actively seek out the male and, when a choice of ram is possible, it is the most active ram which is generally chosen. Although the normal period is recognised as being just over 24 hour, oestrous can last for upto 3 days in some ewes. Mutual riding among ewes, one of which is in oestrous, has not been reported.

When the ewe is presented for insemination, the lips of the vulva should be cleaned by wiping them towards the anus with cotton wool soaked in normal saline. A sterilized speculum lubricated with white vaseline is slipped into the vagina with a rotary motion and the cervix is located and imprisoned in the opening of the speculum. The semen is drawn into the insemination pipette along and inserted greatly into the opening of the cervix for depositing about 0.1 ml semen. Because of the peculiar structure of the cervix in ewe it is not possible to deposit semen in uterus. It may be placed (i) in the opening of the cervix, (ii) on the cervix as it projects into the anterior end of the vagina.

It is recommended that at least 50 million motile sperms should be inseminated for liquid semen while for frozen semen the number should increase up to 200 million motile sperms. With progestogen treatment of ewes to induce oestrous at a synchronised time, sperm number requirements may be as great as 1500 million cells. Double inseminations 12 hours apart increase fertility.

It is to be noted that optimum time of insemination is mid oestrus i.e., 12 to 18 hours after the onset of heat.

The volume of insemination is very important, for example, insemination of more than 0.2 ml of semen into the cervix of the ewe or doe is of no advantage as much of the semen would flow back into the vagina. Recommended inseminate volumes for sheep and goat are the following:

For vaginal insemination	0.30–0.50 ml
For cervical insemination	0.05–0.20 ml
For intrauterine insemination	0.05–0.10 ml

These volumes should contain at least the recommended minimum number of motile spermatozoa. For sheep and goat many more spermatozoa are needed than for insemination of cows. This is due to the differences in anatomical structure of the cervices of ewes, does and cows. Whereas the cervix of the cow in oestrous is open and allows deep cervical or intrauterine insemi-



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However, using semen fresh, or stored upto two hours on normal mares, it has been found that an inseminating dose of 100 million sperms is satisfactory.

The minimal number of frozen sperm required for high conception rates has not been established.

DEEP FREEZING OF SEMEN

In India Artificial Insemination (AI) utilizing liquid (chilled) semen from exotic dairy breeds has been playing vital role for nearly four decades. The advent of "Frozen semen technology" has by this time become remarkable by any measure in turning this century to the gateway of white revolution.

As early as 1938 a German scientist, Jahnel found that by deep freezing testicular tissue of rabbits, sperms could survive freezing to –192°C. During 1949 Polge, Smith and Parkes accidentally added 15–20% glycerol to a fowl sperm solution and observed very good motility after freezing to –79°C. Thus the remarkable property of glycerol in maintaining life of deep frozen sperms were established. Later on it was observed that the resistance against deep freezing is quite different in different species. It is known that bull semen cannot withstand a sudden drop in temperature so called temperature shock. For that reason Smith and Polge (1950) cooled the glycerol treated bull semen slowly to –79°C and got a much better survival of the semen than that by rapid cooling. The first insemination with deep frozen semen were performed by Steward (1951) in cooperation with Polge and Rowson. Out of 5 inseminated cows one became pregnant.

Subsequent developments have been the introduction of new freezing techniques, improved semen dilutors and additives.

Principle of Deep Freezing

The general principle of deep freezing of semen is to dilute the semen with an extender containing glycerol. After equilibration the suspension is frozen according to special rules and thereafer stored in liquid nitrogen (–196°C) as the cooling medium.

As intra and extra cellular water of media crystalised as ice, the salts get concentrated in the residual fluid which becomes progressively more hypertonic. Thus the sperm cells become subject to severe osmotic stress and in particular to increase concentration of electrolytes when the water is freezing out. Glycerol has the ability to attach itself a considerable quantity of water, which is then not available to form ice but can still act as a solvent. The use of glycerol therefore enables freezing to be carried out slowly enough to avoid thermal shock without exposing the sperm cells to lethal concentrations of electrolytes.

Merits and Limitations of Frozen Semen

Merits

1. Frozen semen permits maximum utilization of semen from a given sire. No semen need to be discarded because of age, as with liquid semen.
2. Long term preservation removes barrier on time and distance in AI International semen transport has come into existence today.
3. Can be undertaken for:
   a) Selective breeding
   b) Grading
   c) Cross breeding
   d) Progeny testing of bulls



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tail with a rope on one side so that swinging of the tail does not cause any obstruction in proper mounting. The dummy should not be taller than the bull to be collected.

The artificial vagina prewarmed with hot water and refilled to bring the inner temperature of 40°C to 46°C when ready for use. Half to two third capacity of the A.V. should be filled with warm water. The inflation of air should be done in such a way that the opening of the A.V. should close, resulting in building out of the inner lining to form a cushion. Insulation bag may be fixed on the graduated glass tube to avoid temperature shock.

During collection, A.V. should be held at 45° angle to the ground, so that the long axis parallels the line of the penis. Excessive bending of the penis before or during the thrust can distract and injure the bull. The A.V. should be handled in such a way that the penis just touches the lining. The condition inside AV should equal to that of inside the natural vagina and this condition stimulates the ejaculation. The vagina must never be pressed on the penis. Generally 15 minutes of teasing and 1 or 2 false mounts will suffice.

3. *Evaluation of Semen*

Immediately after collection semen is evaluated for volume, colour, consistency and presence of foreign matter. One drop of semen is placed on glass slide and is evaluated under phase contrast microscope for initial forward motility. Samples showing more than +3 are taken for further processing. From this, 0.1 ml of semen is taken for estimating concentration of spermatozoa either by photoelectric colorimeter method or by haemocytometer counts. Till the final dilution rate is decided, semen is pre-diluted to a known low volume of extender and stored in water bath. The individual motility of the sperm is assessed with the diluted semen using phase contrast microscope. Sample showing more than 60 per cent of motility is taken for further processing.

4. *Dilution of Semen*

The basic idea of dilution of semen is (1) to preserve fertilising capacity of the spermatozoa for a long period and (2) to increase services to a number of females.

The dilution rate is decided based on the motility rate, sperm concentration and capacity of straw used. In general a minimum of 30 million motile sperms in each dose is recommended. As soon as the final volume of diluted semen has been determined the remainder of the diluent is added and the flask containing diluted semen is gradually cooled to +5°C in a refrigerator over a period of 45 to 60 minutes.

5. *Equilibration of Semen*

Before storing the diluted semen at frozen state (–196°C), the practice is to preserve it at much higher temperature (+5°C) for about 6 hours. This pre-freeze storage of diluted semen is known as '*Equilibration*' of diluted semen. This is so done for the glycerol to bring about its beneficial action on the spermatozoa. Glycerol permeates sperms and gives better resistance to withstand freezing stress.

During this equilibration period, filling of straws with diluted semen is carried out inside a cold handling cabinet maintained at +5°C. Equilibration period of 6 hours is generally practised. At the end of equilibration period, the pre-freeze motility is again recorded. Samples showing more than 60 per cent motility are taken for "Test freezing". This is done by filling processed diluted semen in 2 to 3 straws for each sample which are initially kept either in big semen containers or in mini-freezer firstly in liquid nitrogen vapour having a temperature between –120 to –130°C and then plunged in liquid nitrogen. The entire treatment will take about 10–15 minutes. After this the



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goblets 100 straws and even smaller holds out 25 straws. These goblets are then immersed in liquid nitrogen and kept in already identified canisters, stainless steel container (with long handle) to hold goblets deep inside liquid nitrogen of highly insulated double wall stainless steel wide mouthed semen containers (LR 320, LR 250).

12. ***Thawing of Frozen Semen (Melting)***

Thawing means to melt or become liquid. Thawing of frozen semen should be done immediately before use and as quick as possible to prevent recrystallisation of the water into bigger crystals. After thawing, frozen spermatozoa do not survive long as unfrozen semen and also do not withstand re-freezing. Therefore, one must be certain that the semen is going to be used soon once it has been thawed.

The time and temperature to be allowed for thawing depends upon size of the packaging used. A universally adopted system does not exist. The most widely practised temperature of 37–40°C for 30 seconds is suitable to get optimum survival of spermatozoa. Following steps should be taken while thawing the semen.

1. The straw should be removed with the forceps from the liquid nitrogen.
2. The straw should be shaken vigorously once or twice to remove liquid nitrogen from the cotton plug.
3. Immediately after this procedure straw should be placed in warm water (37–40°C) for only 30 seconds.
4. Dry the straw with a tissue paper; also wipe the scissor.
5. Warm the chamber of the insemination gun by rubbing vigorously.
6. Hold the straw vertically with the cotton plug or ball downwards.
7. Cut the straw at right angles to remove the powder plug or sealed plug through the air space.
8. Withdraw the piston of the syringe.
9. Place the straw in the warmed up chamber of syringe.
10. Take the sheath from the container and fix the sheath over the straw to ensure the firm union between the straw and sheath.

13. ***Procedure for Loading the A.I. Gun***

1. Identify the canister from which the desired semen is to be taken. Ascertain the colour of the straw by reading of identification tag.
2. Remove the lid from the container, lift the proper canister upto the level of the frost line. Never lift the canister above the neck level.
3. With a pair of tweezers grasp an individual straw and remove it, at the same time lower the canister immediately back into the container.
4. With the wrist movement give one or two jerks to the straw to expel liquid nitrogen trapped at end of factory seal.
5. Dip the straw into a clean waterbath at 37–40°C for 30 seconds. During this period the entire straw must be *completely* submerged in water bath.
6. Remove the straw from bath, dry the straw with a clean tissue paper or cotton. Inspect the straw carefully and discard straw with cracks or defective seals. Semen must never come in contact with water.
7. Place the straw in the chamber of insemination gun. To obtain a perfect fit with medium straw, it is essential that the laboratory seal is removed by cutting *at right angle* through middle of the air space. The air space could be brought to the top by gentle tapping of straw.



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1. Temperature

The temperature of semen in most of the domestic animals except for on ejaculation is about that of the body (37.5°C). Exposure of semen to temperatures above this increases the metabolic rate, exhausts the energy reserves and decreases the life-span of spermatozoa. Temperatures above 45°C will kill spermatozoa.

Reduction of temperature will reduce the metabolism of spermatozoa, but a sudden drop in temperature, particularly to below 10°C, will cause irreversible loss of their viability. Motility is not regained on rewarming and fertilising ability of the spermatozoa is lost. This is called *cold shock* and can occur through careless over-exposure to cold air or by use of a cold collecting glass or microscope slide. Care must also be taken when semen is diluted to ensure that the diluent is at the same temperature as the semen.

Slow cooling of spermatozoa to 2–5°C is not fatal. The reduction in metabolism at this temperature helps to prolong the viability of the spermatozoa. On rewarming, motility is restored and the spermatozoa may still be fertile.

2. Sunlight

Direct sunlight is detrimental to semen. Short exposure to sunlight may reduce the viability of spermatozoa and 30–40 minutes exposure will kill them. Consequently, it is best to avoid exposure of semen to direct sunlight at all times, and all collection and handling procedures should be carried out indoors and away from sunny windows. It is also wise to avoid prolonged exposure to strong fluorescent lights or ultra-violet radiation.

3. Contact with Metal

Contact with metal of any kind is harmful to spermatozoa. For this reason only glass utensils or equipment made of inert synthetic materials should be used for collection, dilution and storage of semen, and for insemination.

4. Contact with Water

Water reduces the osmotic pressure of the seminal plasma and may thereby kill the spermatozoa. Thus, water is a powerful spermicidal agent and semen should never be allowed to come into contact with it. All equipment should be thoroughly dried before use, including the artificial vagina and collecting glasses. Caution must be exercised when maintaining semen in a waterbath so that water is not accidentally splashed into the semen.

5. Impurities and Bacteria

Bacteria, dust, hairs, urine and other such contaminants that may get into semen will reduce the viability or kill the spermatozoa. Contamination of semen occurs most frequently during collection and can best be avoided by thoroughly cleaning the prepuce of the male beforehand. After collection, the semen should be protected from airborne contaminants by keeping it covered with aluminium foil or a watch glass. Special attention should be paid to protection of semen from flies and other insects. Aerosol fly-sprays or antiseptic sprays should not be used as these too are very



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9. Hygiene

Careless handling or contamination of equipment may result in a reduction in viability of spermatozoa or spread diseases of the reproductive tract.

It is important to note that, when disappointing results are obtained, the AI technology itself is unlikely to be at fault. The fault will almost certainly be found in (i) improper application of that technology, (ii) improper management, or (iii) environment factors.



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Each quarter is composed of secretory tissue and some supporting connective tissue. The secretory tissue consists of numerous *alveoli* or tiny chambers (Fig. 9.6) lined with many secretory cells. Each alveolus is supplied with tiny capillaries which lie outside the secretory cells (Fig. 9.4). Small muscle fibres, called myoepithelial cells also surround each alveolus which cause contraction of the alveoli and produce "let-down" of milk.

Each alveolus is drained by a small duct called "terminal duct". A cluster of alveoli and their ducts resembling a bunch of grapes, constitute a lobule (Fig. 9.6). A group of lobules are surrounded by a septum of connective tissue and form a lobe. The terminal ducts unite to form *intralobular* ducts. These ducts unite successively to form larger ducts called *interlobular*, *intralobar* and *interlobar* ducts. The interlobar ducts join to form galactophores that empty into the *gland cistern* or *milk cistern*, a sinus at the tip of the udder. The gland cistern is continuous immediately below with the *teat cistern*. The teat cistern is joined with the *streak canal*,

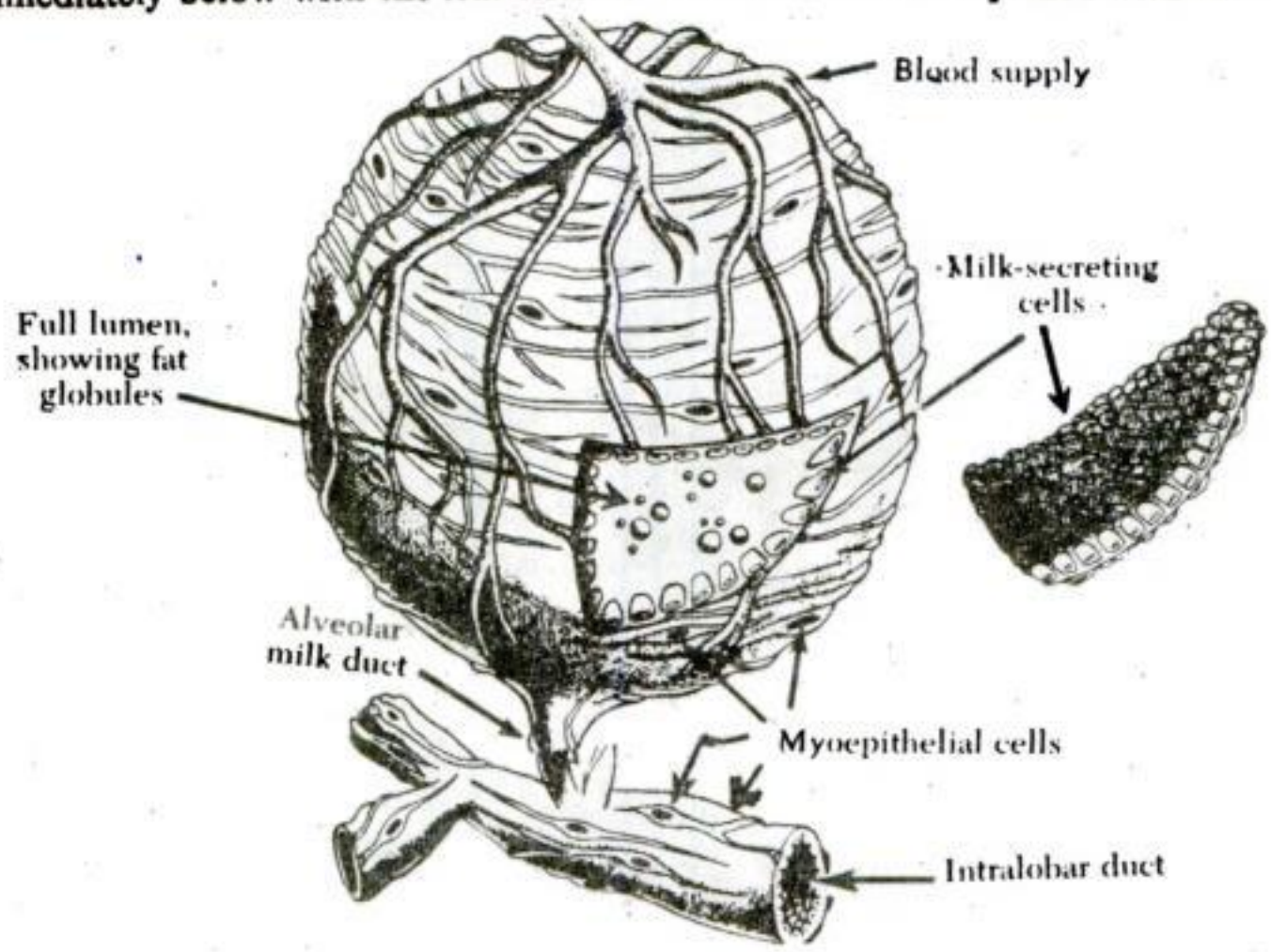


Fig. 9.4 The blood vessels and myoepithelial cells surrounding an alveolus.

a narrow tube ½ to ¾ inch long, that opens at the lower end of the teat. The streak canal is surrounded by a true muscular *sphincter* which remains constricted and prevents leakage of milk until milking commences. The streak canal and its sphincter are also responsible for preventing entrance of bacterial and other contaminants into the teat.

Milk collecting system. Milk from the lumen of the alveoli is passed via many thousands of small ducts into eight to twelve main milk ducts. These lead into the gland cistern, and the milk leaves the teat via the streak canal or papillary duct. Each cell of the udder including of epithelial cells of alveoli are in intimate contact with blood, lymph and nerve supply.

Blood which supplies milk constituents to the udder, comes from the heart via two large arteries each about 10 mm in cross section. Then, after passing round the alveoli in the udder, the blood enters the venous system and returns to the heart via two routes. One route is inter-

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mary sprout is the antecedent of the streak canal, teat cistern and gland cistern. Secondary sprouts grow out at angles from the primary sprout, canalise and later divide into tertiary sprouts. These secondary and tertiary sprouts are the forerunners of the duct system of the udder. At birth, only primary and secondary sprouts are present: tertiary sprouts appear later

From Birth to Puberty. In the Holstein cow, between birth and two months of age there is little growth of the udder. But between two months and the time of puberty (7-8 months),

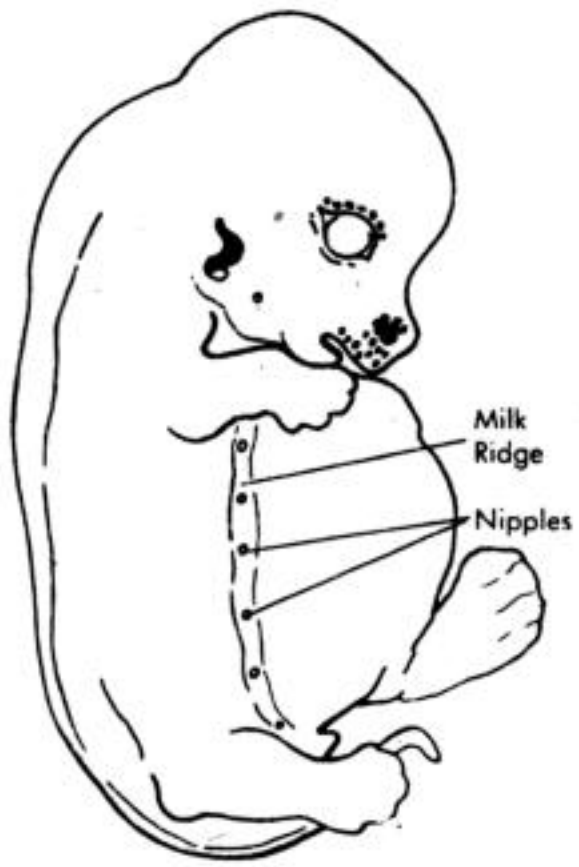


Fig. 9.7. Drawing (x515) of 20 m.m. pig embryo showing milk ridge (milk line).

the mammary gland grows 3½ times faster than the body weight and reaches the peak pubertal development at 10 to 12 months of age. The mammary gland does not grow much after this period until the animal becomes pregnant. These time ranges may differ slightly for Indian breeds of cows but the fact that a very rapid phase of mammary growth starts quite early in life—well in advance of the age of puberty—and plateaus only after a few estrous cycles should be true.

During the Estrous Cycle. After the attainment of puberty, the animal undergoes recurrent estrous cycle. The mammary gland undergoes cyclic changes during the course of the estrous cycle, the duct system growing during the estrogenic phase and regressing during the progestational phase. Cumulative growth of the mammary gland occurs for the first 4 to 5 cycles; thereafter, there is not much net gain with each recurrent estrous cycle.

During Pregnancy. The largest portion of the mammary growth occurs during pregnancy. During the first three months of pregnancy only the duct system proliferates From the third month on there is rapid growth of the secretory tissue (lobule-alveolar system) which continues even after the calf is born. Secretion of colostrum begins a short time before the birth of the calf and results in a great enlargement of the udder at this time.



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Placental lactogen has got the properties of both growth hormone and prolactin but is identical with neither. In cattle, the bovine placental lactogen (bPL) has been identified. Since the source of bPL is lost when the placenta is expelled, its effect must occur prior to peak milk secretion in the subsequent lactation.

Insulin promotes mammary cell growth and cell division during gestation and lactation but alone is incapable of inducing synthesis of milk proteins by the daughter cells.

MILK SECRETION RATE

It has already been stated that milk is secreted by the alveolar cells of the udder. The daily milk yield of mammals is thus dependent upon the number of secretory tissue in the mammary gland and the rate of secretion per unit of tissue. The secretion rate is controlled

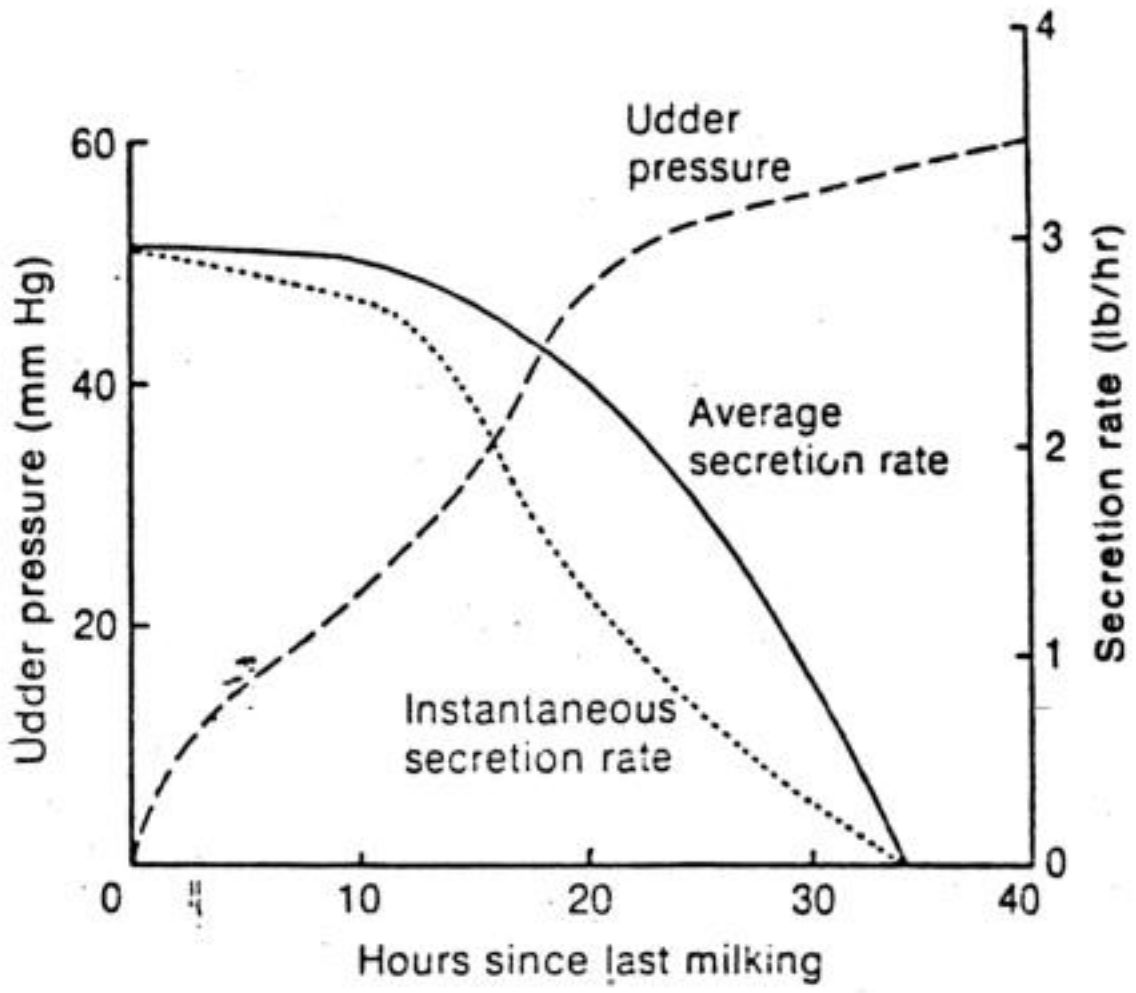


Fig.9.10 Relationship of udder pressure to secretion rates of dairy cows.

in part by the pressure in the alveolar lumina due to the accumulation of milk. Measurement of pressure in the teat cisterns at various intervals after milking indicates that three distinct phases occur in milk pressure curve. Within one hour after milking, a marked increase in pressure to approximately 8 mm Hg occurs in the teat cistern (Fig 9.10.). This hydrostatic pressure is caused by the residual milk moving from the alveoli and smaller ducts into the cisterns. This is followed by a slower increase in pressure due to the accumulation of milk in the secretory tissue and its further oozing into the teat and gland cisterns. This is followed by an acceierated rate of pressure increase and constitutes the third phase of the pressure curve.



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of ruminants contains a trypsin inhibitor which protects the immunoglobulins from digestion. The globulin fraction in colostrum declines quite rapidly with successive milkings. Within three or four days after parturition milk loses its colostral properties and becomes normal.

Table 9.3

Composition of colostrum (first 24 hours after calving) and of milk

Component	*Colostrum*	*Milk*
Total Solids (%)	22.5	12.5
Fat (%)	3.5	4.0
Protein (%)	14.3	3.3
Casein (%)	5.2	2.6
Albumin (%)	1.5	0.5
B-Lactoglobulin (%)	0.8	0.3
a-Lactalbumin (%)	0.27	0.13
Serum albumin (%)	0.13	0.04
Immunoglobulin (%)	5.5-6.8	0.09
Lactose	3.0	4.6
Ash	1.8	0.8
Calcium (%)	0.26	0.13
Phosphorus (%)	0.24	0.10
Magnesium (%)	0.04	0.01
Sodium (%)	0.07	0.06
Potassium (%)	0.14	0.16
Chloride (%)	0.12	0.10
Iron (mg per 100 g)	0.20	0.05
Copper (mg per 100 g)	0.06	0.02
Vitamin		
Carotenoids (ug/g fat)	35	7
Vitamin A (µg/g fat)	45	8
Vitamin D (ng/g fat)	30	15
Vitamin E (µg/g fat)	125	20
Thiamine (µg per 100 g)	60	40
Riboflavin (µg per 100 g)	500	150
Niacin (µg per 100 g)	100	80

Source : Roy, J H. B. (1980) The Calf. 4th edition, London: Butterworths & Walker, D.M. - (1979). Digestive Physiology and nutrition of ruminants vol.2, 2nd edition (D.C. Church, editor) page 258 - 280



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FROM ELEMENTS TO MILK

ELEMENTS

Carbon, Hydrogen, Oxygen, Nitrogen, Sulphur, Phosphorus, Potassium, Calcium, Magnesium Iron, Sodium, Silicon, Chlorine, Manganese

COMPOUNDS

are a combination of two or more elements

PLANTS

are made of compounds

Dry Matter

Organic Matter

Water	Proteins	Carbohydrates	Fats	Minerals
Compound of:	Compounds of:	Compounds of:	Compounds of:	Compounds of:
Hydrogen, Oxygen	Nitrogen, Carbon, Hydrogen, Oxygen, etc.	Carbon, Hydrogen, Oxygen	Carbon, Hydrogen, Oxygen	Calcium, Phosphorus, Potassium, Sulphur, Magnesium, Iron, Sodium, Silicon, Chlorine, Manganese, etc.

FEEDS

Composed of:

Water
Proteins
Carbohydrates
Fats
Minerals

Which Go To Make

ANIMAL BODY			MILK	
Composed of:	Per Cent		Composed of:	Per Cent
Water	56	Water	Water	87.1
Muscle Tissues, Internal Organs, Hair, Horns, and Skin	18	Proteins	Casein and Albumen	3.5
Fat	21	Carbohydrates and Fats	Butterfat and Milk Sugar	8.7
Bone	5	Minerals	Minerals	0.7

Fig 9.13

Chart showing interrelation of common component elements of plant and animal life that go to make up feed and finally milk.



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Factors affecting Milk Composition

The variation in composition and daily yield of milk is a regular phenomenon in any milking animals. Broadly, the factors which are responsible for such variations can be divided into (1) Physiological, which will be governed by the genetical make up and (2) Environmental, such as age, number of previous lactations, pregnancy, nutrition status, etc. The dairyman has hardly got any control over the physiological factors but he has some control over the environmental factors. A thorough understanding of the factors those change the environment of the dairy cattle can be used to take advantage of some of the changes in milk composition and yield that occur during a normal lactation.

Variations in the composition of milk may result from one or more of a number of causes described below:

1. *Breed*

The composition of milk varies with a number of non-nutritional factors, one of the most marked being the effect of breed. The within-breed variation in milk composition is also very common. The fat and crude protein content of the milk are related inversely to the lactation yield. Lactose values tend to be slightly higher in the milk from breeds with high fat content and thus the SNF contents (protein + lactose + ash) are also higher. Because of this fairly close relationship between fat and SNF contents, the selection of cows producing a higher fat content should also ensure a high SNF content.

There are some exceptions noted among strains and individual animals, where some individuals have high fat and low SNF and vice versa. Recorded differences are only partly genetic in origin as they reflect also environmental differences including diet, climate and other management practices.

Animals belonging to all Indian milch breeds produce more milk with compositional variations.

2. *Changes occurring during a Normal Lactation*

Lactation period of an animal is the period from the time animal gives birth to a young one till she goes dry. Throughout this period which generally considered for about 305 days, there is a variation of both in composition and total yield.

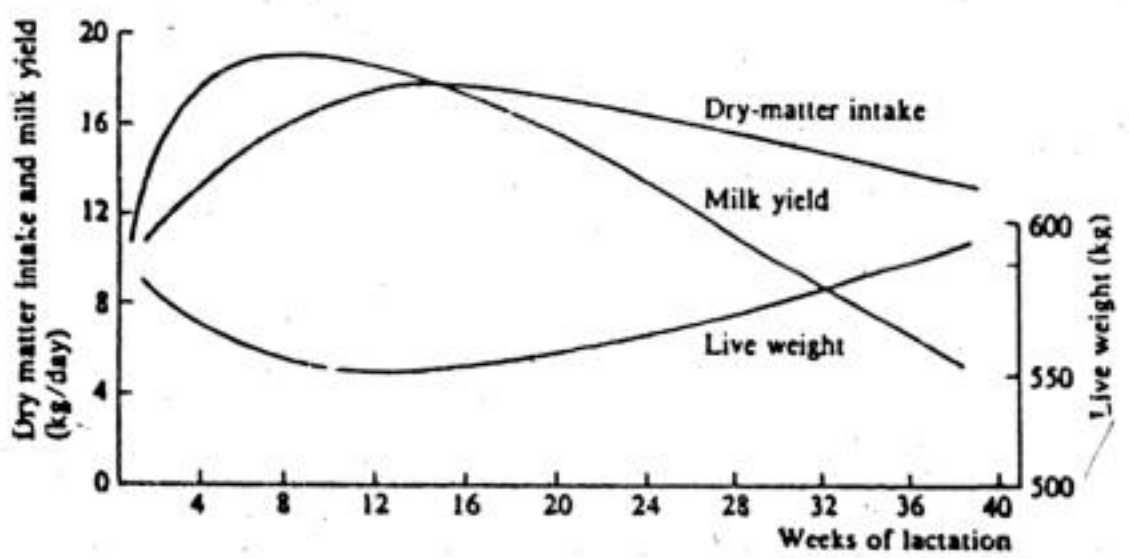


Fig. 9.14 A schematic representation of the lactational curves of milk yield, live weight and voluntary feed intake of cows.



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10. *Disease*

Very little is known about the influence of certain diseases on protein and SNF. An increase in body temperature frequently will be accompanied by an increase in fat % and a decrease in milk yield and SNF content. Udder infections, such as mastitis, cause a decrease in milk fat, SNF, protein, lactose and a notable increase in the mineral and chloride contents of milk. Mastitic milk frequently has a salty taste, which is attributed to a high concentration of chlorides. Scientists at Texas in U.S.A. and others have noted that mastitic milk contains more chloride, sodium, copper, iron, zinc and magnesium, but less calcium, phosphorus molybdenum, and potassium than normal milk.

Ketosis reduces milk yield and also markedly increases the fat content of the milk. The effect of other diseases on milk composition is not so clear.

11. *Feeds and Feeding*

(a) *Changes in milk fat content.* One of the most marked changes in milk composition due to diet is the effect on fat content.

Milk fat is highest when the fermentation in the rumen favours the production of acetic acid, and thus diets which depress this acid will depress the content of milk fat. These are as follows:

1. High concentrate rations
2. Low roughage rations
3. Grass from lush (tender and full of juice) pasture
4. Finely ground hay
5. Heat treated feeds
6. Feeds in pelleted form
7. Fish oils will depress the fat content of milk from 1 to 0.5% for as long as they are fed.

It has been noted that the above rations decrease milk fat by decreasing the acetic acid production on one hand and on the other hand by increasing propionic acid content.

Research findings suggest that the fat depression in milk can partially be rectified by feeding the following materials:

1. Sodium or Potassium bicarbonate
2. Calcium hydroxide
3. Magnesium carbonate
4. Magnesium oxide
5. Sodium bentonite
6. Partially delactosed whey

Some of the above compounds increase the rumen pH and others decrease propionate production and increase rumen acetic acid production. The drawback in using these substances is that most of them are unpalatable and decrease appetite.

The following types of rations will help to increase milk fat percentage:

1. Feeding of rations having at least 17% fibre.
2. Use of a screen that is more than 1/8 inch in diameter if ground forage is used.
3. Feeding of unground forage at a minimum rate of 1.5 kg hay per 100 kg of body weight per day.
4. Vegetable oils have been shown to cause a temporary increase in milk fat.



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14. ***Stress***

Recently, more attention has been focused on the role of stress in the secretion of milk. As animals are selected to secrete higher levels of milk, any sort of stress will play an increasingly important role in lactation.

15. ***Effect of Milker***

The amount of milk drawn from a cow is definitely influenced by the change of milker. Due to change of milker, the slight variation in milking process, upsets the cow and thereby affects milk yield.

16. ***Disease***

Any one of many diseases may significantly reduce the amount of milk secreted. Disease may affect heart rate, and therefore, the rate of blood circulation through the mammary gland, which influences milk secretion is also affected.

Milking of cow and its care

Milking is an act of removing milk from the udder. The method involves experience and skill. It is important that the cow be milked at a very fast rate at regular times to make each milking a pleasant experience. Cows like to be milked—if it is done properly. Milking programme is made up of the following coordinated steps.

1. *Time of milking.* Milking should be done twice or thrice a day, but at regular intervals. The intervals should be as equal as possible in case of twice a day milking. Abrupt changes in the time of milking affects the total yield.

2. *Milking order.* Cows that have mastitis or a history of chronic mastitis are a source of infection to non infected cows. Hence, it is well to milk "clean" cows first. A desirable milking order in a herd is:

(a) First, calf heifers that have been free of mastitis.
(b) Older cows that have been free of mastitis.
(c) Cows that have been a previous history of mastitis, but which no longer show symptoms.
(d) Cows with quarters producing abnormal milk.

3. *Preparing the cow and milker.* The milker and the animal have a mutual liking for each other. The animal should not be excited or beaten before milking; otherwise she may hold up the milk. The "let down of milk" in case of buffaloes is rather time consuming and the milker should not lose his patience.

At the onset of milking the udder and teats should be washed with any antiseptic lotion or boiled *neem* leaves and then dry it with clean cloth. The milker should wear clean dress, cover their hairs with caps or towels and must trim their nails regularly. Milkers having filthy habits like spitting, blowing nose and even talking while milking should be cautioned.

4. *Use clean utensils.* Sanitary milking pails with dome-shaped top should be used instead of open buckets. After each milking the milking pails should first be washed with warm water, scrubbed and rinsed well with clean cold water. Afterwards they are stacked in racks upside down until next milking.

5. *Keep cows free from flies etc.* While milking, all efforts to be made if necessary by taking the help of an assistant, to keep the milking cows undisturbed by flies, unnecessary noise or



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4. *Control flies.* Fly control measures are important to dairymen since they can carry typhoid, dysentery and other contagious diseases.

5. *The milkers cleanliness.* They themselves should be free from communicable diseases and must be of clean habits as will be noted from their clean clothes, trimmed nails, do not spit around or talk while milking.

6. *Clean utensils.* All types of milking utensils should be as clean and free from pathogens as possible. Best way to achieve this is to rinse the utensils immediately after use. Following washing with ordinary water, the utensils should be washed with warm water containing a suitable detergent. Soap should not be used as it leaves a greasy film.

7. *The type of milk pan.* Sanitary milking pails with dome-shaped top should be used instead of open buckets or vessels during milking.

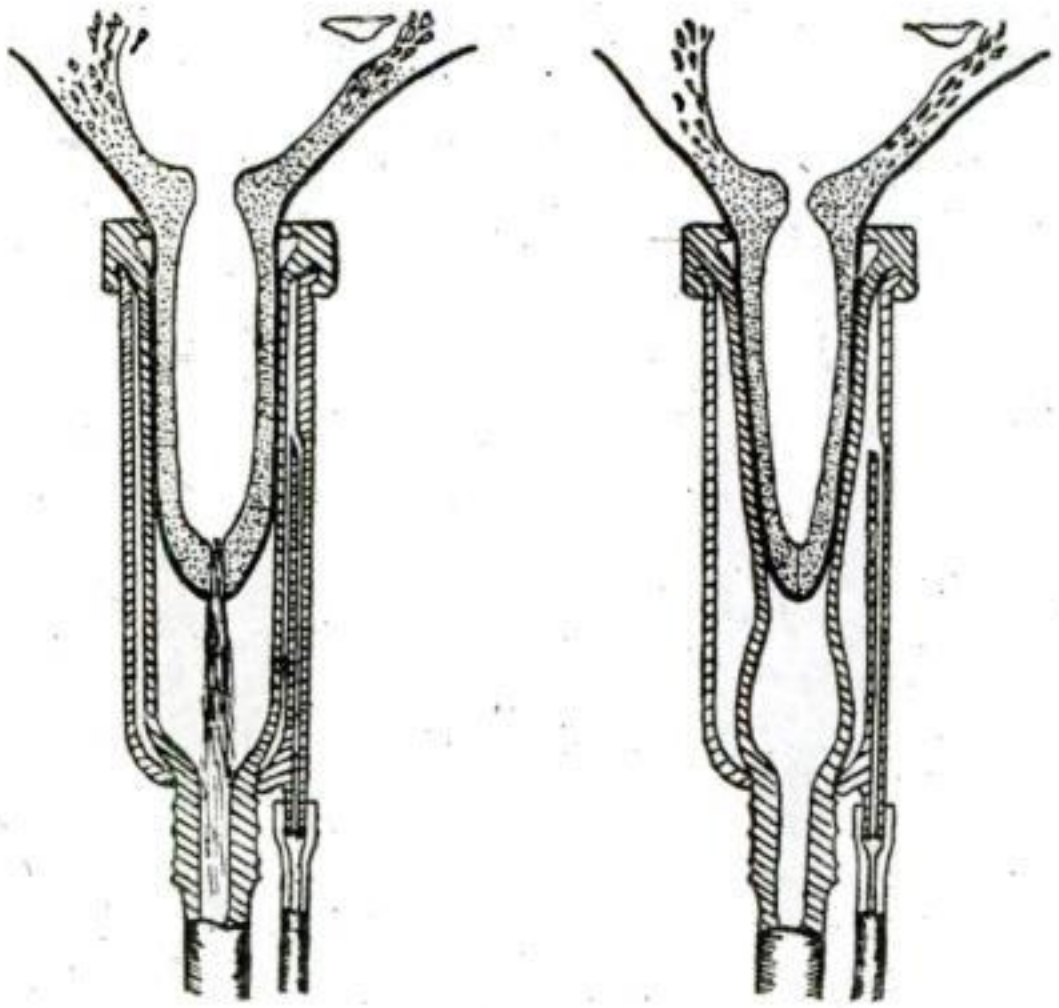


Fig. 9.20 *Machine Milking.*

8. *Straining.* Straining is done to remove sediment and other foreign materials. It should not be used as a cover for unclean milk. If cloth is used, it should be washed and dried daily otherwise dirty cloth will spoil the quality of milk further rather than to improve it.

9. *Feeding.* Feeding of the animals should be made an hour before milking. At the time of milking for the purpose of keeping milking cows busy, provide only concentrates which will be less dusty.

10. *Cool and store milk properly.* After milking, milk should preferably be cooled by keeping milking pails in cold water in winter. In summer ice cubes may be added to water if cost permits.

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Lactation Number

A cow in her life time may calve as high as fifteen to sixteen times depending on breed character (genetical) and on health condition. Usually the number averages between 8 to 10 times resulting equal number of lactations.

Lacteal

Pertaining to milk. Also used for the special lymphatic capillaries of the small intestine that take up chyle.

Lactogenesis

A process by which mammary alveolar cells acquire the ability to secrete milk. The first stage includes increases in mammary enzymatic activity and differentiation of cellular organelles that coincides with limited secretion of milk before parturition. The second stage is associated with copious secretion of all milk components shortly before parturition in most species, continuing for several days after parturition.

Lactogenic

Stimulating the secretion of milk

Mamogenesis

Growth and development of mammary gland

Milk

The whole lacteal secretion obtained by the complete milking of one or more healthy lactating females.

Milking

The extraction of milk from cows udder by hand or by milking machine.

Milk Ejection

It is the thrown out of the synthesized milk from the alveoli and ducts portion of the gland by the squeezing action of the hormone oxytocin.

Milk let-down

During milking, milk secretion inside the alveolus again commences thus the alveoli ducts, gland and teat cisterns get filled up with milk. This does not flow easily unless extra pressure is given to each and every alveoli including the cistern and larger ducts. Stimulation of the teats or udder results in a neuroendocrine reflex secretion of oxytocin from the posterior pituitary gland which on reaching the myoepithelial cells (covering each and every alveoli) causes them to contract and thereby removal of milk from the mammary gland is made possible.

The phenomenon associated with contraction of the myoepithelial cells is generally referred to as milk let-down. This effect ends in 10 to 15 minutes because of dissipation of oxytocin. Until milk let-down, the pressure within the mammary gland is relatively low (0–8 mm Hg.), but it increases to 30–50 mm Hg. at the beginning of myoepithelial cell contraction.



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3. TREE LEAVES. The utilization of tree leaves for feeding to livestock is not common. They are, however, used for feeding sheep and goats, and are sometimes fed to cattle during periods of fodder crisis. In the early stages of their growth, leaves contain fairly high amounts of crude protein and a comparatively low percentage of crude fibre. As maturity progresses, there is a gradual decrease in protein content with a concomitant increase in crude fibre. The tree leaves and shrubs are generally rich in calcium but poor in phosphorus.

Investigations conducted at I.V.R.I. have shown that leafy fodder from the following species of trees and shrubs are suitable for use as maintenance ration for livestock: Jharberi (*Zizyphus numlaria*); Katchnar (*Bauhinia variegata*); Pipal (*Ficus religiosa*); Babul (*Acacin arabica*) Bel (*Aegle marmelos*).

4. ROOT CROPS. Root crops like turnips, swedes, mangolds, fodder beet, carrot are used extensively in U.K. and other European countries for feeding during winter, when other succulent fodders are not available. The main characteristics of root crops are their high moisture content (75–92 per cent) and relatively low crude fibre content (5–11 per cent of the dry matter). An important root crop in southern India is tapioca (*Manihot utilissma*) which is grown extensively in Kerala. The yield per acre varies from 5–6 tons. The tuber is used industrially as a source of starch.

5. SILAGE. The most economical method of raising livestock is to feed them on grasses and legumes directly from the fields. Seasonal influences, however, limit the supply of these feeds at a uniform rate throughout the year. They are, therefore, conserved as hay or silage for use at the time of crisis.

Dry Roughages

1. HAY. A method of conserving green crops is that of hay making. The aim in hay making is to reduce the moisture content of the green crop upto 15–20 per cent to inhibit the action of plant and microbial enzymes. Thus a green crop in a mature state is preserved for a long time. According to the type of forages which are dried, hays are categorised as leguminous, or non-leguminous. Among the leguminous plants, the most suitable is lucerne (known as alfalfa in U.S.A.). Properly prepared lucerne hay contains 14–15 per cent of D.C.P. and 50 per cent T.D.N. Berseem and cowpea are more difficult to be converted into hay. The former has got a hollow stem, while the latter has very thick stem both of which make drying a difficult process. Non-legume hays made from grasses are not as good feeds as legume hays. These are less palatable and contain less protein, mineral matters and vitamins than legume hays.

2. STRAWS. Of all feeding-stuffs, straws are perhaps the poorest in protein and have the largest percentage of crude fibre. They are comparatively poor in phosphorus, in available calcium and also in trace elements, but are rich in silica. Their D.C.P. content is practically nil while that of T.D.N. is about 40%. In western countries straws are never fed to livestock but are usually used as bedding. In India usually 1–2 kg of a concentrate mixture is added to a basal regime of straw to form a maintenance ration. In addition, a mineral mixture rich in calcium and phosphorus at the rate of 20–25 gm daily/head is recommended. If legumes are available, 10–20 kg such feeding stuffs can be used in place of concentrate mixture for maintaining cattle kept on a basal regime of straw. In general straws of leguminous fodder like cowpea, pea, groundnut, mung, gram, etc., have higher mutritive value varying from 2 to 3 per cent D.C.P. and 30–40 per cent T.D.N.



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7. *Hulls*

Outer covering of grain. Generally not utilised as livestock feed.

8. *Malt sprouts*

The radicle of the embryo of the grain removed from sprouted and steamed whole grain e.g., barley, wheat, rye malt sprouts.

These are obtained as by-products of liquor processing. Barley sprouts used as livestock feed must contain 24% crude protein.

9. *Meal*

Feed ingredient of which the particle size is larger than flour, e.g., corn and oat meal contains protein between 9-18% and of C.F. between 3-10%. Oat meal must contain less than 4% fiber.

10. *Middlings*

A by-product of flour milling industry comprising several grades of granular particles consisting of varying proportions of bran, endosperm and germ, each of which contains different percentages of crude fiber.

The product is having protein percentage of 15-20% and that of CF is between 4-8 percent. Deficient in calcium, carotene and vitamin D.

11. *Polishings*

By-product of rice, consisting of a fine residue that accumulates during polishing of rice kernals after initial removal of hulls and bran. It contains about 10-15% protein, 12% fat, and CF between 3-4%. It is an excellent source of energy and vitamin B complex. Due to high fat content rancidity can pose problems.

It is an excellent feed ingredient for cattle, buffaloes, sheep, swine and poultry.

12. *Red dog*

By-product of milling spring wheat consists primarily of the aleurone with small amounts of flour and fine bran particles. Protein is about 17-20% with CF 2-4 percent.

13. *Shorts*

A by-product of flour milling consisting of a mixture of small particles of bran and germ, the aleurone layer and coarse fiber. It has protein percentage between 17-20% while that of CF is between 6-7 percent.

C. Molasses

There are various types but all are concentrated water solutions of sugars, hemicelluloses, and minerals obtained usually as by-products of various manufacturing operations of the juices or extracts of selected plant materials.

(a) Cane or blackstrap molasses

This is the by-product of sugar industry from which a maximum of sugar has been extracted. About 25-50 kg of molasses results from production of 100 kg refined sugar. Cane molasses contains 3% protein, 10% ash comprising excellent source of minerals except phosphorous. It is also rich in niacin and pantothenic acid.



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Table 10.3

Average composition and nutritive value of common Indian feeding stuffs
(on dry matter basis)

A. Green Fodders :

Name	Botanical name	CP	CF	NFE	EE	DCP	TDN	Total ash	CA	P
Anjan	*Cenchrus ciliaris* Linn.	10.00	35.30	42.60	1.12	5.49	56.0	10.98	—	—
Bajra	*Pennisetum typhoides* (Burm. f.) Stapf & C.E. Hubb.	6.90	31.80	48.90	1.52	4.31	59.24	10.88	—	—
Bermuda grass	*Cynodon dactylon* Pers.	6.76	24.15	55.99	0·62	3.68	43.04	12.48	0.35	0.26
Berseem	*Trifolium alexandrinum* Linn.	15.45	26.06	35.88	2.36	12.51	59.18	20.25	1.66	0.33
Cowpea	*Vigna unguiculata* (L.) Walp	28.12	26.66	33.05	3.00	20.26	62.19	9.17	1.43	0.30
Dal grass	*Hymenachne amplexicaulis* C. Muell (syn. *H. amplexicaulis* Ness.)	9.38	22.10	54.32	2.30	5.81	57.24	12.20	0.13	0.21
Dhus	*Erianthus longisetosus* Anderss. ex-Benth.	7.50	32.20	48.80	3.40	3.03	56.25	9.19	0.21	0.01
Ghiabati	*Ipomoea pes-tigridis*	11.41	23.75	50.39	2.20	7.45	60.90	12.25	1.17	0.39
Clusterbean (*guar*)	*Cyamopsis tetragonoloba* (L.) Taub.	18.13	31.91	37.65	1.87	6.13	48.83	10.44	2.49	0.39
Guinea grass	*Panicum maximum* Jacq.	7.88	38.38	37.01	1.19	5.83	65.09	15.54	0.51	0.39
Sorghum (prime)	*Sorghum bicolor* (L.) Moench	7.75	32.30	49.61	1.73	3.44	54.03	8.55	—	—
Joya-jha	*Ischaemum rugosum* Salisb.	6.63	33.72	47.84	2.18	4.42	56.61	9.63	0.49	0.27
Karrah	*Carthamus tinctorius* L.	15.6	23.6	48.3	1.9	9.19	58.14	11.2	1.30	0.34
Kharika	*Microstegium ciliatum* A. Camus	6.04	37.50	44.95	1.80	2·66	49.85	9.71	0.32	0.12
Lucerne	*Medicago sativa* L.	19.90	29.61	34.68	1.81	15.92	57.79	14.10	2.00	0.32
Maize	*Zea mays* L.	6.74	35.95	47.07	2.09	4.14	67.77	8.15	0.52	0.28
Morara	*Melilotus indica* All.	16.02	35.15	37.99	1.94	13.30	64.01	8.90	0.75	0.22
Napier	*Pennisetum purpureum* Schum.	6.16	28.07	47.47	2.26	3.85	55.39	16.04	0.33	0.35
Natal grass	*Rhynchelytrum repens* (Willd.) C. E. Hubb. [syn. *Tricholaena rosea* Nees.]	5.61	41.61	43.39	1.40	2·42	53.12	7.99	0.34	0.11
Oat	*Avena sativa* L.	9.90	26.60	50.50	2.22	7·10	69.70	10.88	—	—
Para grass	*Brachiaria mutica* Stapf	11.98	28.22	45.70	1.01	7.91	59.54	15.16	0.32	0.35
Rhodes grass	*Chloris gayana* Kunth	9.36	36.16	42.14	1.16	5.13	58.43	11.08	0.30	0.10
Senji	*Melilotus indica* All.	15.46	31.62	41.95	3.32	12.61	64.04	9.50	1.35	0.18
Spear grass	*Heteropogon contortus* (L.) Beauv. ex Roem. & Schult.	6.97	34.52	47.94	1.35	0.84	44.77	9.22	—	—
Star grass	*Cynodon plectostachyum* Pilger	5.44	37.60	45.24	0.90	2.39	46.42	10.82	0.37	0.11
Sudan grass	*Sorghum sudanense* (Piper) Stapf	8.80	29.90	42.90	1.60	4.30	48.5	8.00	0.25	0.17
Sugarcane	*Saccharum officinarum* L.	5.47	37.18	49.78	1.48	0.00	46.30	6.09	0.41	0.20
Sunflower	*Helianthus annuus* L.	11.04	23.98	45.26	3.44	8.55	52.50	15.38	—	—
Ulu	*Imperata cylindrica* Beauv.	5.52	32.40	51.00	3.21	2.59	43.66	8.18	0.29	0.19
Urochloa	*Urochloa pullulans* Stapf	5.81	33.29	46.27	1·42	2.81	50.87	13.21	0.51	0.31
Velvet bean	*Mucuna cochinchinensis* Cheval	15.14	19.27	48.53	2.13	10.66	63.38	14.93	—	—
Venezuela	*Melinis minutiflora* Beauv.	4.38	37.78	47.99	1.02	1.61	55.79	8.83	0.54	0.31

(Contd.)



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Groundnut or Peanut Oil meal

1. It is the most widely used high protein feed
2. The meal is usually made from the kernels (a grain or seed) ground to a meal with occasional use of whole pod when it is known as undecorticated groundnut meal
3. Its composition and feeding value vary considerably, depending on the quality of the nuts, the method of fat extraction used and the amount of hull included
4. It has about 45% protein and 10% oil in expeller variety
5. It is deficient in lysine, methionine and cystine
6. The cake is satisfactory as a source of protein for all kinds of livestock and poultry
7. Liable to contain a toxic factor—*Aflatoxin* a metabolite of the fungus *Aspergillus flavus* particularly in warm rainy season
8. The cake tends to become rancid specially in warm moist climate. It should not be stored longer than 6 weeks in the summer or 3-4 months in winter

Linseed meal

1. The meal is produced from flax seeds and the oil being a drying one used in paints, linoleum and soft soap
2. The cake is satisfactory for all classes of livestock except for poultry where if fed in more than 5%, it has a depressing effect on the growth. The toxicity can largely be eliminated by soaking the meal in water for 24 hours or by adding pyridoxin, one of the B vitamins
3. The meal has a very good reputation as a feed for ruminant animals due to high content (3-10%) of mucilage. The compound is capable of absorbing large amounts of water which results higher retention time in the rumen and give a better opportunity for microbial digestion. The lubricating character of the mucilage also protects the gut wall against mechanical damage and together with the bulkiness, regulates excretion, preventing constipation without causing looseness.
4. It is a satisfactory source of protein (about 35%) for almost all livestock. D.C.P. is about 30% with low T.D.N. (about 65%).
5. Immature linseed contains a small amount of a cyanogenetic glycoside, *linamarin*, and an associated enzyme, *linase*, which is capable of hydrolyzing it with the evaluation of hydrogen cyanide (HCN). Normal processing conditions however, destroy linase and most of the linamarin and the resultant meals are quite safe.

Mustard Cake (*Sarson*)

1. Widely used in many parts of India for cattle feeding.
2. Nutritive value is much less than that of groundnut cake. D.C.P. and T.D.N values are 27% and 74% respectively. It should preferably be mixed with other, more well-liked feeds. The deoiled type can be used for poultry upto 10 percent of the ration and for pigs the amount may go as high as 20 percent.
3. The calcium and phosphorus content are much higher, being about 0.6 percent and 1.0 percent.

Cottonseed Cake

1. It is an excellent high protein feed (about 40%) for ruminants but low in cystine, methionine and lysine.



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mixture and the temperature of the mash increased to about 65°C. After the mashing process is complete the sugary liquid or "wort" is drained off, leaving *brewer's grains* as residue and are sold wet or dried as food for farm animals. Dried grains contain 18 per cent crude protein and 15 per cent crude fiber.

The wort is then fermented in an open vassel with yeast for a number of days, during which time most of the sugars are converted to alcohol and CO_2. The yeast is filtered off, dried and sold as *brewer's yeast.* Dried yeast is rich protein concentrate containing about 42 per-cent crude protein. It is highly digestible and may be used for all classes of farm animals. It is a valuable source of B group of vitamins, is relatively rich in phosphorus but has a low calcium content.

B. ANIMAL PROTEINS

Protein supplements derived from animal tissues are obtained primarily from inedible tissues, such as meat packing, from surplus milk by-products or from marine sources.

Many such compounds are difficult to process and store without some spoilage and nutrient loss. If not properly dried or heated to destroy disease producing bacteria they may be a source of infection. On the other hand, protein availability will be reduced and some nutrients are lost if the feed is heated excessively.

These materials are given to animals in much smaller amounts than the oilseed derivatives so far discussed, since they are not used primarily as sources of protein but to make good deficiencies of certain indispensable amino acids from which non-ruminant animals may suffer when they are fed on all vegetable protein diets. Due to high cost, large scale use of animal proteins become uneconomic.

Meat meal or Meal scrap.

1. It is obtained from mammal tissue exclusive of hair, hoof, horn, stomach contents and hide trimmings by proper drying and grinding to which no otner matter has been added, but which may have been preliminarily treated for the removal of fat and dried blood.
2. The product is normally used for swine and poultry.
3. Rich in crude protein (50-55%) and ash (21%) with high calcium about 8% and 4% phosphorus—but low in methionine and tryptophan.
4. Good sources of vitamins of B complex, specially riboflavin, choline, nicotinamide and B_{12}.

Meat and Bone meal or scrap

1. The product is similar to meat scrap except it contains more bone, and consequently is higher in calcium and phosphorus and lower in protein, about 40%.
2. Used primarily in rations of swine and poultry.

Blood meal

1. The meal is prepared by passing live steam through the blood until the temperature reaches 100°C. The treatment causes sterilization and the blood gets clotted. It is then drained, pressed to express occluded serum, dried by steam heating and ground.
2. It has got high protein value, 80%, but the protein is lower in digestibility and quality



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Young calves below 6 months also not be fed urea in any form.

Urea should never be mixed with raw soybean as it contains *urease* and thus it will liberate ammonia and carbon dioxide which will be lost before consumption.

While mixing urea to concentrates, utmost care should be taken for uniform distribution otherwise chances of toxicity may be observed in those cases where excessive amounts of urea are consumed.

2. Liquid Supplements

This is a homogenous mixture of urea in the liquid molasses along with minerals and vitamins. Normally, it is prepared by completely dissolving 2.5 parts of urea in equal amount of water. The mixture is fortified with vitablend AD$_3$ at the rate of 25 grams per 100 kg of liquid feed. Common salt @ 1 part and mineral mixure @ 2 parts are sprinkled over 92 parts of sugarcane molasses. (2.5 parts urea + 2.5 parts water + 1 part salt + 2 parts mineral mixture + 92 parts molasses = 100). Special attention is required for the uniform mixing of urea solution in the liquid molasses. Undiluted urea-molasses liquid feed containing 65% or more dry matter can be safely stored for a long period. Animals started on a feed containing liquid molasses supplement should be given an initial period of 15 days as adaptation.

For initial 3 days feed your animals by substituting ¼th of the grain mixture with that of 500 ml of liquid feed after feeding concentrate part of the ration.

In the next 3 days substitute half of grain mixture with that of 1 kg. liquid feed.

From 7th day entire concentrate mixture may be substituted by offering liquid feed *ad libitum*. Animals should first be fed about 1 kg dry matter in the form of forage.

It is important to provide fresh drinking water at all times.

3. Urea Mixed with Silage

Another way of feeding urea to cattle—especially dairy cattle—is through the addition of urea to crops which are being ensiled. If chopped, whole maize plant is being ensiled at 35% to 40% dry matter, urea is then added at a level of 0.5% of wet material. This level should increase the crude protein level of the silage on a dry matter basis about 5 points.

4. Urea Added to Dry Roughages

To-day the availability of wheat and paddy straw in India is around 50 and 100 million tonnes per year respectively. Knowing fully well about the extremely poor nutritive value (DCP% = 0, TDN% = 38 to 40), the farmers have no other alternative but to use these straws as sole dry roughage.

A newer method of adding urea has not only enhanced the palatibility and the nutritive value of straw but also partially solved the crisis of quality dry roughages in the country. The following formula has been suggested by the National Dairy Research Institute at Karnal in India for enrichment of straw quality by adding urea.

Ingredient	Quality
Straw	100 kg of 90% DM
Urea	4 kg
Clean water	50 litres

According to this ratio, it is better to prepare 10, 25 or 50 quintals stack at a time.



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Eventually, the pH of the ruminal fluid increases, thus facilitating the passage of ammonia across the rumen wall. If the levels of ammonia abosrbed are greater than the capacity of the liver to convert ammonia to urea, ammonia accumulates in the blood which when exceeds 1 mg/100 ml in cattle, the animal is under toxic condition. Such a condition may arise due to followings :

a. Poor mixing of urea in feed
b. Error in ration formulation
c. Inadequate period of adaptation
d. Low intake of water
e. Feeding of urea in conjunction with poor quality roughages
f. Rations that promote a high pH in ruminal fluid.

Symptoms of ammonia toxicity may include tetany, respiratory difficulty, bloat, excessive salivation, ataxia, convulsions and bellowing. If not promptly treated, death will follow in 30 minutes to 2.5 hours. The common treatment consists of drenching 20-40 litres of cold water which inihibits ureolytic activity of the rumen. Another way of curing is by drenching 4 litres of dilute acetic acids like vinegar along with cold water.

Biuret

The compound is produced by heating urea. The formula of the colourless crystalline compound is $NH_2CO.NH.CO.NH_2$. It contains 30 percent nitrogen, equivalent to 188 per cent of crude protein. A considerable period of adaptation is necessary for ruminants before the compound is effectively utilised. The compound is expensive and at present not produced in this country and moreover it is utilised by the ruminant less efficiently than urea. The advantage is that biuret is not toxic even at higher level.

Poultry litters

The composition varies, but on an average it contains about 5 percent nitrogen equivalent to about 31 per cent crude protein. The nitrogen is in the form of ureates. In concentrate diets, levels of inclusion may be as high as 35 per cent. The inclusion of poultry manure necessitates an allowance for extra energy and proper calcium and phosphorus inclusion.

SINGLE-CELL PROTEIN (SCP)

Single-cell protein (SCP) is obtained from single-cell organisms, such as yeast, bacteria and algae, that have been grown on specially prepared growth media. Production of this type of protein can be attained through the fermentation of petrolium derivatives or organic waste or through the culturing of photosynthetic organisms (algae) in special illuminated ponds. Microbes grow very fast. While 1,000 kg of livestock can produce a maximum of 1 kg protein in 24 hours, 1000 kg of yeast in the same period of time may increase to 5,000 kg of which half is edible protein

		Time required to double the biomass
Yeast and bacteria	...	20 min —2 hours
Algae	...	1 hour—2 days
Grass	...	1 to 2 weeks
Broilers	...	2 to 4 weeks



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popularity as a dairy feed. Nutritive value depends on the stage of the growth of the crop when cut and on the percentage or dry matter in it.

C. Wet by-product feeds

Wet by-product feeds might be confused with fresh forages on the one hand, and root crops, on the other, based on their content of DM. However, the fresh forages can usually be differentiated from the wet by-products on the basis of carotene content. Root crops likewise be differentiated from wet by-products in that the latter will contain over 3% crude fibre on a wet basis while the root crops will have lower values.

D. Root crops

Occassionally root crops might be confused with fresh milk on the basis of DM content, but when crude fibre content is taken into consideration (root crops always have some amount of CF) the confusion can be cleared out.

III Identifying Individual Feeds

With more experience it is possible to distinguish between two feed ingredients of the same feed group on the basis of their composition. For example fresh whole milk can be distinguished from fresh skimmed milk on the basis of fat content.

Ghani, expeller and deoiled type of oilcakes can be differentiated again on the basis of oil and protein content.

Meat scrap might be distinguished from meat and bone meal on the basis of higher bone content and so on the basis of higher calcium and phosphorus contents for the latter product.

USE OF UNCONVENTIONAL LIVESTOCK FEEDS IN INDIA

The importance of utilising the unconventional feeds to augment the existing resources of conventional livestock feed was recognised more than 30 years ago. India is facing a shortage of animal feeds and fodder which in terms of nutrients works out to 77 per cent D.C.P. and 62 per cent S.E. for feeding the livestock population. Moreover, this condition aggravates due to natural calamities like drought and flood. Recent studies indicated that quite a large number of agricultural by-products and industrial waste materials could be used for feeding livestock. Some of the unconventional livestock feeds used in India are described below:

A. Vegetable protein sources
B. Animal protein sources
C. Energy sources
D. Other miscellaneous unconventional feeds

A. VEGETABLE PROTEIN SOURCES

1. Sunflower Meal

Indian work on Sunflower seed oil meal is limited but studies abroad indicate that decorticated sunflower seed oil meal in combination with other protein supplement is good for poultry. Recent move by the Government to locate areas for cultivation of sunflower seed is, therefore, welcomed by the animal nutritionists.



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18.6 per cent and T.D.N. 54 per cent, and for pigs 16.7 per cent D.C.P. and 78.8 per cent T.D.N. The material can successfully be used in the feed of cattle and pigs. It is suggested that rubber seed cake may be used at 10 per cent and 20 per cent level in concentrate mixture of pigs and calves without any deleterious effect on growth. It can be used in lactating cows at 20 per cent level in concentrate mixture. Rubber seed cake can also be used at a maximum level of 10 per cent in poultry ration without any adverse effect.

7. Sunnhemp Seed *(Crotolaria Juncea)*

The seed is grown throughout India but in most cases this is used as manure. In some parts, however, this is fed as fodder. After crushing this can be fed to cattle but feeding as such is not palatable. This can, however, be mixed with other palatable feed stuffs in a concentrate mixture and fed to cattle.

The nutritive value in terms of D.C.P. and T.D.N. is 30 per cent and 71 per cent respectively. Sunnhemp contains about 4.7 per cent lysine and 1.7 per cent methionine (on protein basis) and inclusion of this in chick ration at 80 per cent level resulted in improved growth rate.

8. Dhaincha Seed

This is a leguminous seed and is excellent in protein quality. It contains 30-33 per cent protein, and 8.32 per cent and 1.019 g/16 g N lysine and methionine respectively.

The seed cannot be used as such, as it contains deleterious factors like gum, trypsin inhibitor and tannin. Enzymic treatment as in the case of guar meal can improve the feeding value of this material. Recent studies indicated that deleterious factors can be removed by microbial fermentation. The growth rate of chicks fed on fermented dhaincha seed was almost similar to that of control. With the majority of seeds, the gum content and trypsin inhibitory activity increased while the tannin content decreased.

Fermentation by fungi decreases the gum content and trypsin inhibitory activity appreciably and increases the crude protein content of the seed.

Studies with dhaincha seed in cattle is limited. However, autoclaved dhaincha seed may be used in cattle in limited quantities.

9. Cassia Tora Seed

Available in plenty in Gujarat. Feeding this as part of the ration for milch cows has given encouraging results. Boiled cassia tora seeds up to the level of 15 per cent in the concentrate ration can safely be fed to milch cows. Cassia tora seeds (unboiled), however, can be incorporated up to the level of 10 per cent in concentrate mixture for cows without affecting milk yield and composition.

10. Kapok Seed Cake

It can be used as one of the components of cattle feed concentrate. D.C.P. and T.D.N. being 26 per cent and 69 per cent approximately.

11. Kidney Bean Chuni

Kidney bean chuni, a by-product from pulse, is a good source of cattle feed. It consists chiefly of broken kidney grains and kidney bean hulls. It contains 20.5 per cent crude protein, 7.8 per cent ether extract, 10.9 per cent crude fibre, 5.8 per cent NFE, 7 per cent ash, 0.52 per



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8.58 per cent for sal seed and seed meal respectively. Sarkar and Banerjee, however, found 2.64 and 2.34 Kcal/gm when the oil content was 13.64 per cent and 1.31 per cent respectively for sal seed and sal seed cake.

D.C.P. was 1.52 per cent and T.D.N. 65.34 per cent with pigs at 10 months of age and D.C.P. 1.55 per cent and T.D.N. 58.96 per cent at 14 months of age.

Growth studies on pigs by replacing 50, 75 and 10 per cent ragi in the concentrate mixture by deoiled sal seed meal for 8 months indicated progressive decrease in growth rate with the increase in the percentage of deoiled sal seed meal in the concentrate mixture.

Research works are in progress to remove tannins from sal seed meal. Panda et al (1968) showed that washing sal seed cake overnight in cold water could remove 60 per cent tannic acid. Boiling for half an hour also had the same result. Patel et al. (1972) found that 65 per cent of tannins could be removed by decinormal caustic soda. Treatments with calcium hydroxide at 0, 1, 1.5 and 2.0 per cent level have been tried without any significant improvement. Passing of steam at 15 lbs pressure for 1 hour, however, eliminated tannic acid to the extent of about 70 per cent as found by Sarkar and Banerjee (1973) at Bidhan Chandra Krishi Viswavidyalaya. Studies with such processed sal seed meal have shown very encouraging results and much greater percentage could be used.

2. Cassava (Tapioca) Root

It is a very good source of energy and rich in carbohydrates. Tapioca roots contain a glucoside, linamarin, which when acted upon by an enzyme liberates HCN (0.03 per cent in the flesh). Varieties considered poisonous contain much higher HCN. It is low in protein (2 per cent) and rich in NFE (85 per cent). Reports from Philippines suggest the possibility of making cassava silage from chopped, freshly dug tubers.

In India, dried tapioca roots are sold in the name of tapioca chips, and the meal in the name of tapisoca flour. This can be used safely upto 10 per cent level in chick and broiler feeds. In laying, ration upto a maximum of 20 per cent can be included with supplementation of methionine (0.15 per cent) or when proper care is taken of protein quality due to replacement of cereals from the diet. In ruminants this may be used in higher percentage with economic advantage provided it is mixed with other palatable feed stuffs.

3. Tapioca Starch Waste

This is a by-product obtained during the manufacture of starch from tapioca roots. Like chips it is also low in protein and fat. It is, however, rich in fibre, about 10-12 per cent. This is mostly used in the ration for cattle and buffaloes. It has 2.00 per cent D.C.P. and 64 per cent T.D.N. on DM basis for ruminants. Tapioca waste can be used safely upto 30 per cent level of the concentrate mixture with a considerable economy for maintaining body weight, milk yield and butterfat production. Tapioca waste can replace at least 50 per cent of maize as a source of energy for growing pigs without affecting the carcass characteristics.

4. Tapioca Thippi

During manufacture of sago, first the tapioca roots/tubers are deskinned and soaked in water. The tubers are then fed into the crusher adding equal amount of water for extraction of milk. The milk thus obtained is allowed to pass through a sieve to remove the fibrous material. This fibrous material in pulp form when dried is known as Tapioca thippi.

Studies in chicks at Bidhan Chandra Krishi Viswa Vidyalaya by Sarkar and Banerjee



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NUTRIENTS OF FEEDING STUFF AND ANIMAL BODY

A nutrient is a substance that promotes the growth, maintenance, function, and reproduction of a cell or an organism. The principal nutrients of all feeding stuffs are water, organic and mineral matters. The organic in turn is composed of crude protein, ether extract, crude fibre and nitrogen free extract. The occurrence of these nutrients in feeds and their role as constituents of feed in the nutrition of animal body may briefly be stated as follows.

WATER

Water is one of the most vital of all nutrients. In fact animals may live for more than 100 days without organic food but they die in 5–10 days when deprived of water. In general it makes up about two thirds of the fat free animal body weight (the water content of the fat free adult body is relatively constant) for many species averaging 73 per cent of total body weight. As a result of this constant relationship, the composition of the animal body can be estimated with reasonable accuracy if either the fat or water content is known. Body water can be estimated with various dyes, deuterium oxide, or tritium by administering through intravenously and determining the amount of dilution of the test compound; fat content of the tissues may be calculated by the formula:

$$\text{Per cent fat} = 100 - \frac{\text{per cent water}}{0.732}$$

The greatest amount of water in the body tissues will be found as *intracellular fluids*, which may account for 40% or more of total body weight. Most of the intracellular water is found in muscle and skin with lesser amounts in other tissues. Extracellular water is found in interstitial fluids, which occupy spaces between cells, blood plasma, and other miscellaneous fluids such as lymph, synovial, and cerebrospinal fluids. *Extracellular water* accounts for the second largest water "compartment," or roughly one-third of the total body water of which about 6% is blood plasma water.

Most of the remaining body water will be found in the contents of the GI tract and urinary tract. The amount present in the GI tract is quite variable, even within species, and is greatly affected by the type and amount of feed consumed. As indicated, body water tends to decrease with age and has an inverse relationship with body fat. Body water is apt to be higher in lactating cows than in dry cows (usually less body fat also), and extracellular water is greater in young male calves than in female calves of the same age. An embryonic calf is composed of 90 per cent or more water, a new born calf is slightly more than 70 per cent and a steer (bullock) in adult comprises only 45–60 per cent water.

Table 10.8

Average water content of bovine and human body at various ages

Bovine	% H_2O	Human	% H_2O
Embryo	90	Embryo	93
New born calf	80	New born infant	72
6–12 mo calf	65	2 mo infant	70
Adult steer	55	Adult	60



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ture, 589 cal. are required. By this means the body is able to rid itself of 589 cal. of heat for every gm of water it evaporates.

8. RESPIRATORY FUNCTION. Although CO_2 and O_2 are only slightly soluble in water, yet this solubility is of immense importance for the gaseous exchange in the tissues and lungs. The fishes derive oxygen almost exclusively from dissolved oxygen in water.

9. REFRACTIVE MEDIUM. The aqueous humour helps to keep up the shape and tension of the eye ball and acts as a refractive medium for light.

It is, therefore, apparent that the animal should be given liberal quantities of water. Deficiency of water on the other hand, delays digestion, assimilation and excretion of waste products through urine. If the deficiency of water in an animal be continued long then its blood tends to thicken with a rise in temperature. Animals, like men, can stand lack of food much longer than lack of water.

Water Requirements

In a given environmental situation water requirements are highly related to dry matter intake with the result that an increased consumption of dry matter will increase water consumption and vice versa. Water intake of adult cattle is 3–5 kg for every kg of dry matter intake; for suckling calves it is much higher, being 6–7 kg per kg dry matter. Milking cows require additional amounts of water to the tune of 4–5 kg of water for each kg of milk produced. Egg laying, likewise, increases water requirement.

At an environmental temperature which causes no heat stress, water intake tends to be about 3–5 units/unit of dry feed intake in adult cattle.

Consumption is increased during late pregnancy. The presence of mineral salt, particularly sodium chloride in the diet, ingestion of high protein diets, pentosans, fibre and silage in diet increase water requirement.

Table 10.11

Estimated daily Water Intake of Various Groups of Cattle

Body weight (kg)	*Litres per day by temperature**	
	20°C	*30°C*
	Dairy heifers	
50	3.6	5.3
100	11.0	16.3
200	20.0	26.5
300	27.3	37.0
400	35.2	46.2
	*Lactating dairy cows***	
400	26.5	27.0
500	31.0	32.0

* Estimates include both the free water consumed and water contained in the feed.

** Not including allowance for production.

Source: NDRI Handbook (Production), 1980, p. 13.



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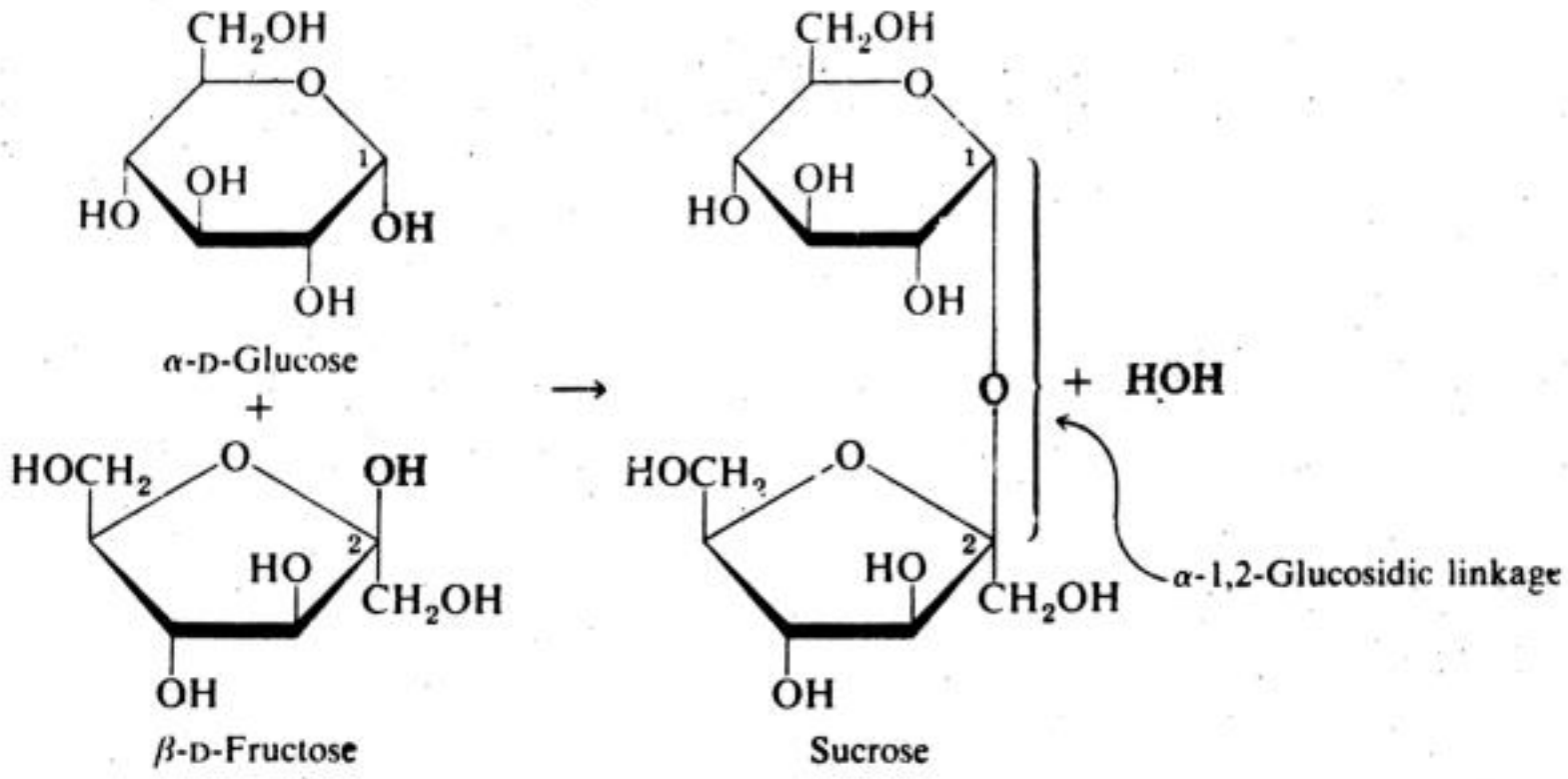
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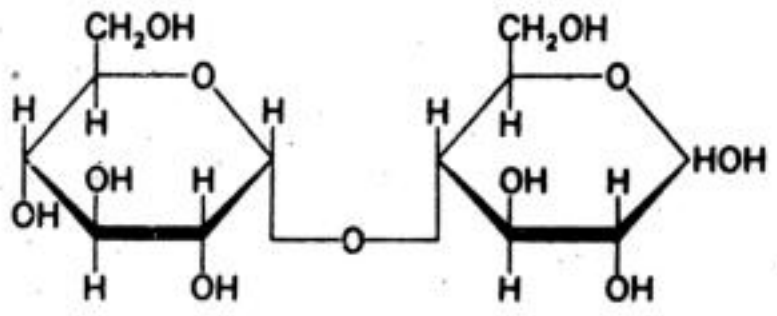


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The presence of the 1, 2-glucosidic linkage makes it impossible for sucrose to exist in the alpha or beta configuration or in the open chain form. This is a direct result of the fact that the potential aldehyde group of the glucose moity and the ketone group of the fructose moity have been tied up in the formation of the 1, 2 (head-to-head) linkage. As long as the sucrose molecule remains in tact, it can not uncyclise to form the open chain structure. Sucrose, therefore, does not undergo reactions that are typical of aldehydes and ketones, and it is said to be a *non-reducing* sugar.

2. *Maltose* : It does not occur in free state but occurs in animals as the principal sugar formed by the enzymatic (ptyalin) hydrolysis of starch. It is fairly abundant in germinating



grain where it is formed by the enzyme (diastase) breakdown of starch. In the manufacture of beer, maltose is liberated by the action of malt (germinating barley) on starch, and for this reason it is often referred to as *malt sugar*.

3. *Cellobiose* : Cellobiose is obtained by the partial hydrolysis of cellulose. It may be



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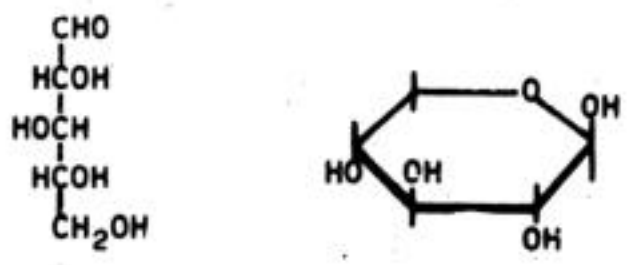
While cellulose may have chemical uniformity as β-glucan, nutritionally it is quite variable, principally because as forage ages, the lignin-to-cellulose ratio rises and digestibility declines. Native celluloses also vary widely in fermentation rate, which may be limited by crystallinity or some kind of cross-linking. Most forage or vegetable celluloses are apparently uncrystalline, as they exist in the plant cell wall but may become crystallized when the branched hemicelluloses and three-dimensional lignin components are removed by chemical treatments. This allows cellulose chains to come together. Drying may be an important part of the process to elicit such crystallization. Thus it is possible through de-lignification to obtain a cellulose that is both more potentially digestible, but which ferments at a slower rate than the available part of native carbohydrate.

Cellulose yields, D-glucose upon complete acid hydrolysis, yet human and the carnivorous animals cannot utilise cellulose as a source of glucose. Our digestive juices lack the enzymes that hydrolyse beta glucosidic linkages. Ruminants can do so as they contain microorganisms in the digestive tracts whose enzyme *(Cellulose)* catalyse cellulose hydrolysis.

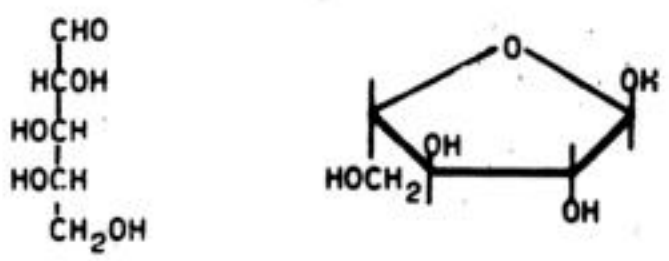
Hemicellulose: These are the most complex plant carbohydrates which are present not only in the ceil walls of all plants and trees but also found in certain seeds. Hemicellulose and lignin together form the incrusting material of the secondary wall thickening of plant cells, thus the cell walls gets strengthened.

Hemicellulose is much less resistant to chemical degradation than cellulose, soluble in mild alkali as well as in mild acid.

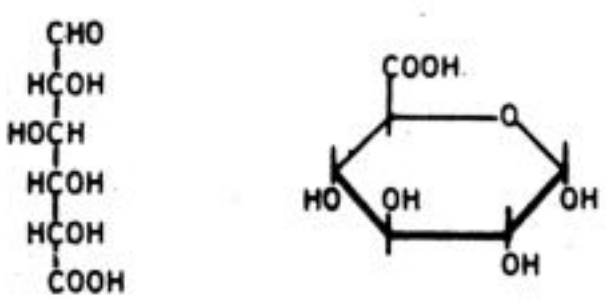
Basically it is a polymer of D-xylose made up of β 1, 4 linked xylose units (a pentose sugar) with side chains of other sugars or compounds derived from sugars. Hemicelluloses obtained from leaves and stems of most plants have main chain of xylose units linked with side chains of arabinose and uronic acids like glucuronic and galacturonic acids. (These acids are formed form glucose and galactose respectively upon oxidation. The sugar acids contains their aldehyde group). In many plant seeds the xylose chain is linked up directly with glucose or mannose. The composition of hemicelluloses thus are found variable among plant parts and with species. Hemicellulose *A* is less bonded, often higher in xylan and relatively richer in stems than leaves. Hemicellulose *B* contains more branched fractions often high in arabinose or in various urononic acids.



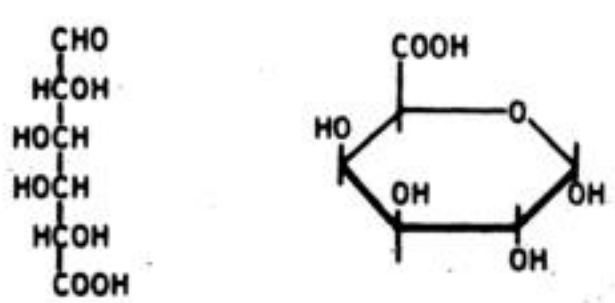
D-XYLOSE



L-ARABINOSE



D-GLUCURONIC ACID



D-GALACTURONIC ACID



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Nitrogen-free Extract (NFE)

The relatively soluble carbohydrates are classified as the nitrogen-free extract (NFE) and include the mono-and disaccharides plus the starches and perhaps a part of the hemicelluloses, based on their relative solubility and digestibility and some cellulose and pentosans along with a limited amount of lignin.

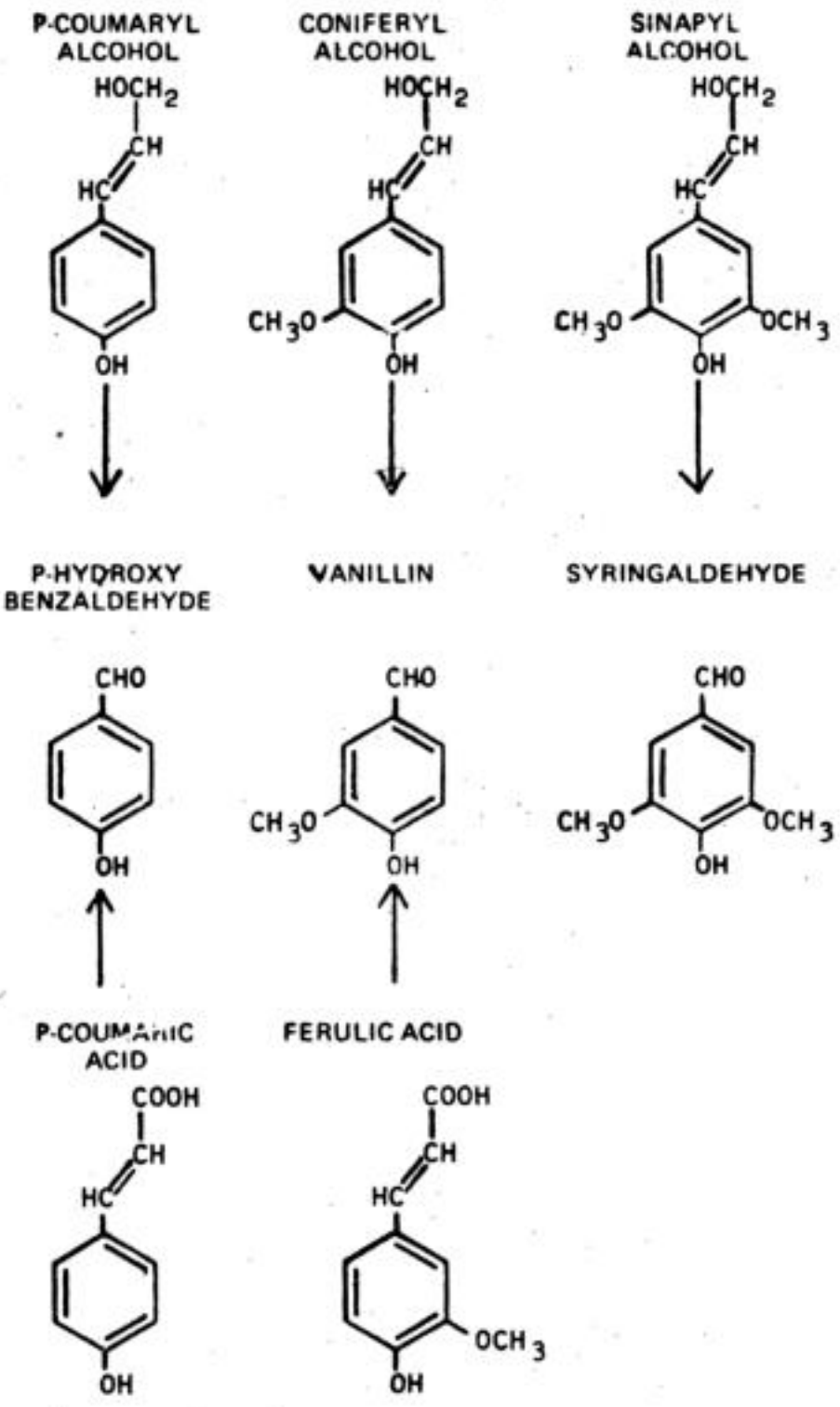
There is no practical method for exact determination of the NFE portion of feedstuffs. Rather, it is determined mathematically by subtracting all other from 100 :

$$\text{NFE } \% = 100 - \left(\begin{array}{c} \text{Moisture } \% + \text{Crude protein } \% + \text{Ether extract } \% \\ + \text{Crude fiber } \% + \text{Ash } \% \end{array} \right)$$

For feeding purposes this calculation has proved satisfactory, although it is not too accurate.

Lignin

The term lignin is not a single substance but a class of substances which are indigestible and



The relation between cinnamyl alcohols, acids and their nitrobenzene oxidation products. Ferulic and P-Coumaric acids occur mainly in grass lignins and perhaps other monocots.



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that are liquid at body temperature. 98% of animal lipid is fat. *Waxes are esters of fatty acids with alcohols other than glycerol.*

Ration for adult ruminants should contain no more than 3–5 per cent fat and 15–20% fat for non-ruminants.

Lipids include all substances extractable from biological materials with the usual fat solvents (ether, chloroform, benzene, carbon tetrachloride, acetone, etc.) and are important constituents of plant and animal tissue. These are important energy storage compounds of animal kingdom and structural compounds. The modern discoveries established the concept of the dynamic state of lipid metabolism. Fatty acids from the depots are being constantly mobilised and transported. A portion of absorbed fatty acids also degraded in the same way while others are combined with glycerol and transported back to the depots. All of these reactions are so balanced that mixtures of fatty acids in the depots, blood and organs tend to remain at equilibrium condition. In the proximate analysis of foods lipids are included in the ether extract portion which actually contains glycerides of fatty acids, free fatty acids, cholesterol, lecithin, alkalies, volatile oils, etc. The ether extract will differ in composition among different foods particularly in sterol content and also wax. Since this has no energy value it will affect the energy value of the entire ether extract. The useful energy of dietary ether extract is its gross energy minus that found in subsequent faecal excretion. However, when faeces are extracted with ether, soaps that may have been formed in the intestinal tract from free fatty acids and calcium will not be removed. This incomplete recovery of the faecel fat gives erroneously high value, for the digestibility of the ration fat, particularly in practical diets containing relatively high calcium content. Lipids include fatty acids, soaps, neutral fats, waxes, cholesterol and other types of steroids, phosphatides, prostaglandins, fat soluble vitamins like A, D, E, K, and the very abundant chlorophylls in green forages.

Chemically lipids are made up of carbon, hydrogen and oxygen.

The percentage of each by molecular weight is: carbon 77%, hydrogen 12% and oxygen 11%. Because there is more carbon and hydrogen and less oxygen in the molecule, fats and oils supply approximately 2.25 times as much energy as an equal weight of carbohydrates or protein. One gram of typical carbohydrate yields 4.2 kcal of gross energy when completely oxidized while a gram of typical fat yields 9.45 kcal,.

Body fat when in excess are stored mainly in adipose tissue, approximately 50% of which are found under the skin, i.e., subcutaneous fat.

Apart from adipose tissue, fats are also present in the cytoplasm as well as the cell wall throughout the body. Nervous tissues are particularly rich in lipids.

Excess fat accumulation, however, can be deterimental. It puts constant strain on the heart, forcing it to pump blood further. It contributes to circulatory diseaseas and shortens our lives. Exercise discourages fat accumulation by consuming energy. On the otherhand deficiency of fats and particularly essential fatty acids will hamper absorption of fat soluble vitamins, will affect productivity of the animals and in extreme cases it may prove to be fatal.



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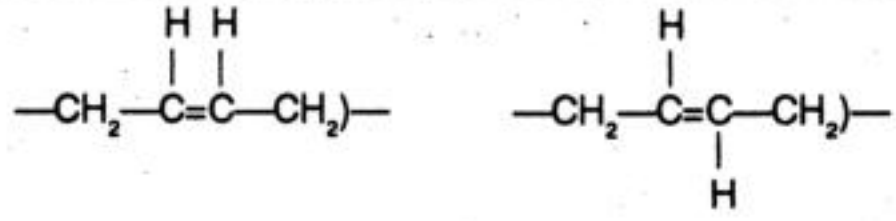


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(Contd.)



Cis *Trans*

- **Source**
  1. **Nonessential fatty acids**. All nonessential fatty acids can be synthesized from acetyl coenzyme A (acetyl CoA) derived from glucose oxidation. They are nonessential in the sense that they do not have to be obligatorily included in the diet. However, the bulk of nonessential fatty acids in humans may in fact be obtained from the diet, particularly in the case of the high-fat diets of affluent societies.
  2. **Essential fatty acids**. Fatty acids of the linoleic (18:2:$\Delta^{9,12}$) and linoenic (18:3:$\Delta^{9,12,15}$) families, which are the precursors of the prostaglandins, must be obtained from the diet. There are no mammalian enzyme systems that can introduce a double bond beyond the ninth carbon atom (9-10 position) of a fatty acid chain, and all double bonds that are introduced are separated by three-carbon intervals. ;This rule, combined with the fact that fatty acid elongation only occurs by two-carbon additions, makes it impossible to synthesize do novo certain polyunsaturated fatty acids.

ESSENTIAL FATTY ACIDS

It is fact that excess of the absorbed carbohydrates are readily changed into fat and that essential lipid constituents such as phospholipids and cholesterol can be made in the body naturally led to to the view that lipids as such are not required in the diet.

Some fifty years ago it has been first observed that the following fatty acids are dietary essentials : linoleic, linolenic and arachidonic acid. Deficiency symptoms of these fatty acids have been observed in mice, poultry, dogs, guinea pigs, swine and human infants. Suggestive evidence that calves, lambs and kids need these acids in their rations has also been reported. Depending on the type of animals, numerous manifestations of these deficiencies are seen ; among them, dermatitis, reduced growth, increased water consumption and retention, necrosis of tail, impaired reproduction and increases in metabolic rate.

Two functions of the essential fatty acids (EFA) have been postulated : (1) precursors of the prostaglandins—a group of hormone like compounds widely distributed in reproductive organs and other tissues of humans and animals. The prostaglandins are biosynthesized from arachidonic acid and have a wide variety of metabolic effects including the following : lower blood pressure, stimulate smooth muscle contraction etc. (2) The other function of EFA is that they are widely distributed in phospholipids and cholesterol esters which inturn constitute a significant part of all cell membranes and lipid transport moieties.

Among the three EFA, linoleic acid (C 18 : 2) and linólenic acid (C 18 : 3) apparently can not be synthesized by animal tissues, or at least not in sufficient amounts to prevent pathological changes, and so must be supplied in the diets. Arachidonic acid (C 20 : 4) can be synthesized from linoleic acid, and therefore, is required in the diet only if linoleic acid is not available or insufficient.



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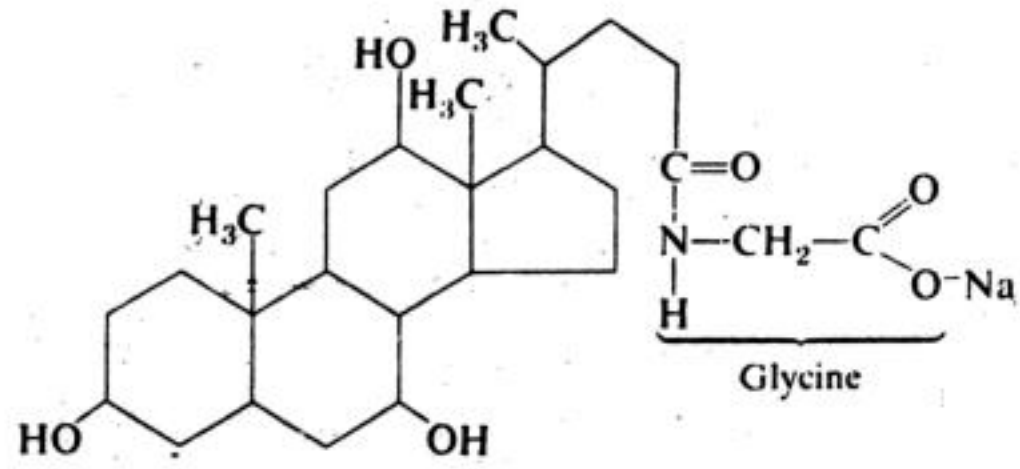
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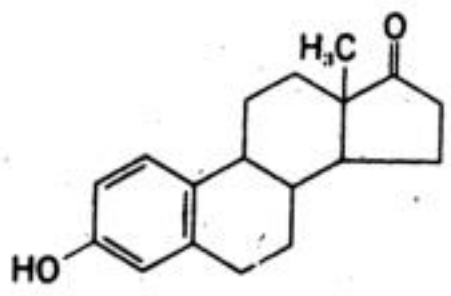


Sodium glycocholate
(a bile salt)

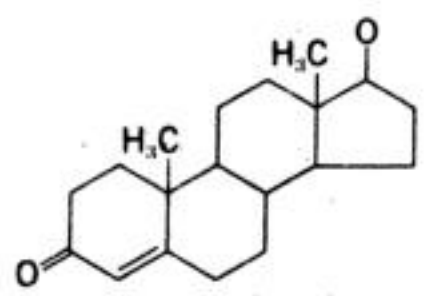
The amides, taurocholic and glycocholic acids, are excellent emulsifying agents, as they possess a nonpolar structure and a changed side chain. Their main role in the organism is to emulsify fats during digestion and facilitate their absorption and enzymatic breakdown.

Sex Hormones

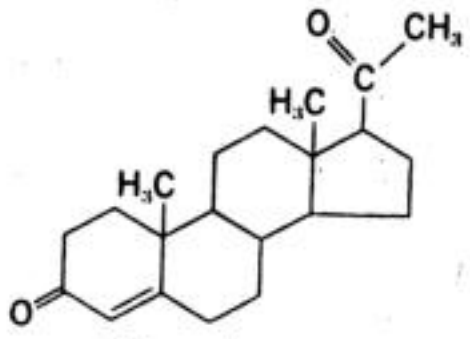
The estrogen and progesterone are commonly known as female sex hormones and the androgens as male sex hormones. Of the estrogens, estradiol is produced in the ovaries and estrone and estriol formed as a result of enzymatic transformations of estradiol. Progesterone, which is also produced in the ovaries, is related more closely to the androgens in structure.



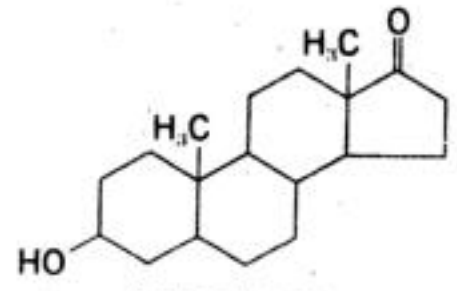
Estrone



Testosterone



Progesterone



Androsterone

Testosterone is produced in the testes and biochemically transformed to androsterone, which is the product found in urine.



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glycerides of seeds are mostly unsaturated and contain high amounts of linoleic and linolenic acids. In forages the amount of galactolipids decreases with the age of the plant.

Effect of Storage & Handling

It is well known that the ether extract and carotenoid content of forage decline with storage. The decline is a result of slow oxidation and polymerisation of the unsaturated oils to form resins. The polymerised products are indigestible, generally insoluble in fat solvents, and in the analytical scheme become associated with the cutin fraction of crude lignin.

Miscellaneous Lipid Components

Roughly half of the ether-soluble matter of forages is composed of galactolipids, the remaining portion being made up of a variety of substances. These are grouped into (i) pigments, such as chlorophyll, carotenoids, the related xanthophylls, saponins, etc., (ii) waxes, (iii) essential oils include anything that is steam volatile, including terpenes, aldehydes, ketones, etc.

PROTEINS

The term protein is taken from the Greek work *proteus* which roughly translated means first. The terminology was suggested in 1840 by Mulder, who clearly recognised that protein was necessary for life in a more fundmental way than could be attributed to either carbohydrate or lipid: "Without it no life is possible."

Nearly half of the dry weight of a typical animal cell is protein. Structural components of the cell, antibodies, and many of the hormones are proteins, but as much as 90 per cent of cellular proteins are the enzymes upon which fundamental cellular function depends. There may be up to 1000 different enzymes in a single cell.

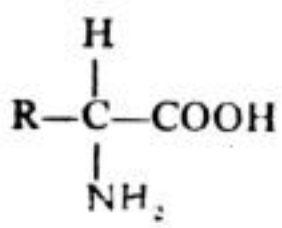
Table 10.21

Elements	*Per cent*	*Elements*	*Per cent*
1. Carbon	50	4. Nitrogen	16
2. Hydrogen	7	5. Sulphur	0 to 3
3. Oxygen	23	6. Phosphorus	0 to 3

All proteins contain C, H, O, N, and generally sulphur with occasional occurrence of phosphorus. Approximately average composition of protein is as given in the Table 10.21.

Amino acids—Building Blocks of Protein

As each flower constitutes a garland, as each brick constitutes an unit of any big wall, similarly each amino acid constitutes an unit of any protein. The amino acids are chemical compounds which contain both an acidic carboxyl (—COOH) and a basic amino ($—NH_2$) group. The common amino acid has a general structure,





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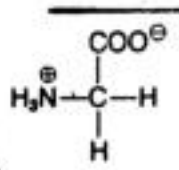


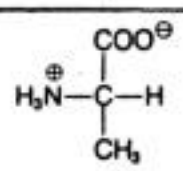
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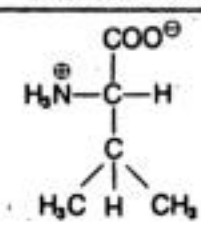
urine for each 100 gms of protein metabolised; this means, 60 per cent of protein is potentially glucogenic. Thus it has been proved that amino acids differ in yielding products from the degradation of their carbon skeleton and accordingly amino acids are classified into three groups.

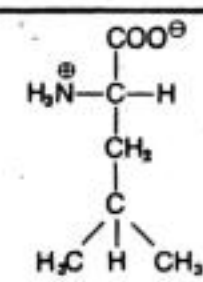
Monoamino, monocarboxylic

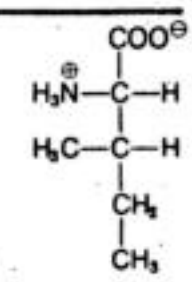
Unsubstituted


Glycine

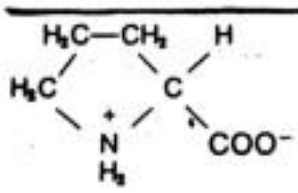

L-Alanine


L-Valine

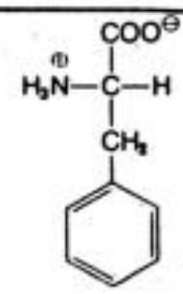

L-Leucine

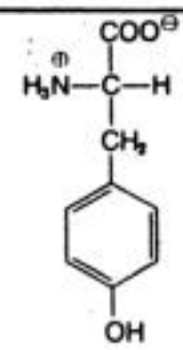

L-Isoleucine

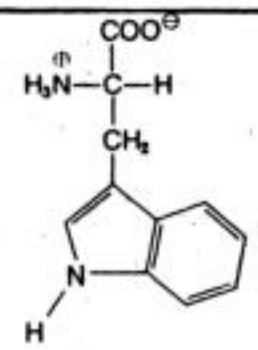
Heterocyclic


L-Proline

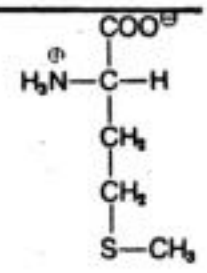
Aromatic


L-Phenylalanine

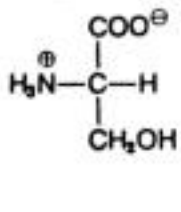

L-Tyrosine

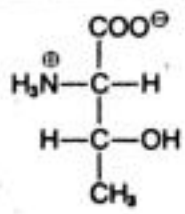

L-Tryptophan

Thioether

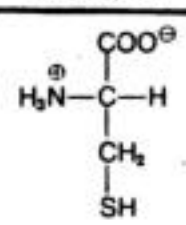

L-Methionine

Hydroxy

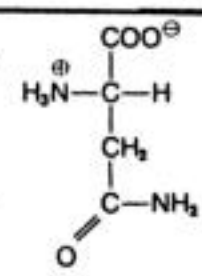

L-Serine

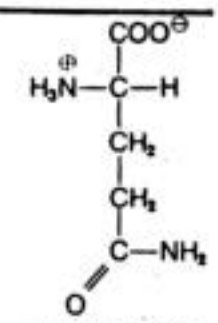

L-Threonine

Mercapto

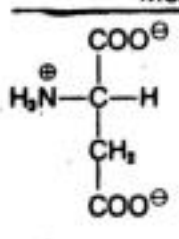

L-Cysteine

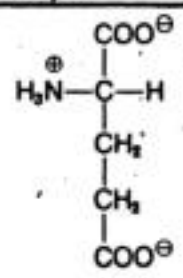
Carboxamide

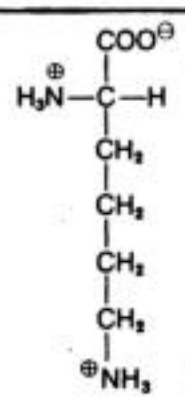

L-Asparagine


L-Glutamine

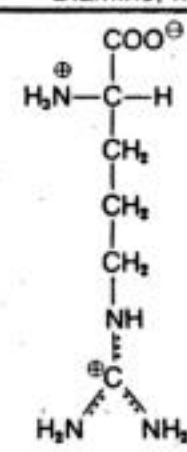
Monoamino, dicarboxylic

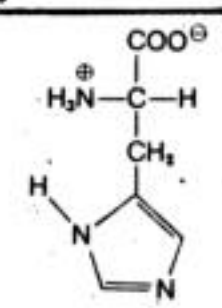

L-Aspartate


L-Glutamate


L-Lysine

Diamino, monocarboxylic


L-Arginine


L-Histidine

Structures of the common amino acids.

Fig. 10.6



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Feed intake is depressed via the same mechanism described for an amino acid deficiency.

Note that in this case a deficient protein source has been made more deficient by the addition of other amino acids (except first limiting amino acid) thus resulted growth retardation much greater than that caused by original deficient diet.

In such cases, the addition of small quantities of the limiting amino acid alone can prevent growth retardation.

The significance of amino acid imbalance in practical human nutrition is not yet clear. It seems possible, however, that at low protein intakes in which certain of the essential amino acids may be limiting, supplementation with amino acids without the first order limiting acid could have detrimental effects.

2. Amino Acid Antagonism

In special cases it has been shown that one amino acid affects the requirement of another by interfering with its metabolism. An example is the lysine-arginine antagonism, wherein dietary lysine increases the requirement of arginine. Lysine acts by competing with arginine for reabsorption in the renal tubules increasing arginine excretion and by increasing renal arginase activity and thus splitting arginine into urea and ornithine. However, excessive intake of lysine does not affect absorption of arginine for the gut. High lysine normally suppresses feed intake and growth depression in chicks, which can be reversed by additional arginine.

Antagonism differs from imbalance in that the supplemented amino acids need not be limiting amino acid. Secondly it refers to an excessive amount of amino acid in the diet which affects only those amino acids belonging to members of the structurally similar group.

3. Amino Acid Toxicity

The term, *amino acid toxicity*, is used when the adverse effect of an amino acid in excess cannot be overcome by supplementation with another amino acids.

Ingestion of methionine, tyrosine or tryptophan in large amounts, up to about 2–3 times the requirement is followed by serious irregularities apart from growth depression. A dietary excess of tyrosine causes severe eye lesions. The toxic action of excess methioine has been attributed to inhibition of ATP synthesis.

The effect of the inclusion of the gross amounts of an individual amino acid within a diet varies among amino acids. Threonine, even in very large amounts (50 g/kg of the DM of the diet), is tolerated well and causes only a moderate depression of feed intake and growth. Tyrosine, however, when ingested in large amounts by young growing rats given a low protein diet, not only depress severely feed intake and growth but causes severe eye and paw lesions, and in great excess is lethal. Methionine is the most toxic and in amounts exceeding 20 kg/kg of the dry matter of the diet may produce severe histopathological changes.

NON-PROTEIN NITROGENOUS COMPOUNDS

A considerable variety of nitrogenous compounds which are not classed as proteins occur in plants and animals. In plant analysis these compounds have been frequently classed together as non-protein nitrogenous compounds to distinguish them from "true proteins" determined in routine chemical analysis. In general above 50 per cent of the total non-protein is the free



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nitrogen contents and therefore different factors should be used in the conversion of nitrogen to protein for individual foods.

The second assumption that the whole of the food nitrogen is present as protein is also false, since many simple nitrogenous compounds such as amides, amino acids, glycosides, alkaloids, ammonium salts may be present in the food.

From practical point of view, as all ruminants can utilise nitrogen from protein and non-protein equally and hence the two assumptions that are made to calculate CP will not affect the ruminants. In the diet of pigs and poultry, cereals and oilseed meals predominate, and in these there is little non-protein nitrogen. Hence in practice there is little to be gained from attempting to distinguish between the two types of nitrogen.

True Proteins

True proteins are sometimes determined to know the actual nitrogen substances present as only protein. This is done by boiling the feeding stuff with suspension of copper hydroxide in glycerol (Stutzer's reagent) followed by filtration. All the true protein remains on the filter paper and can be determined in the usual manner, while the non-protein nitrogen compounds pass through into the filtrate.

Table 10.28

Biological Functions of Proteins

Protein function	Characterization of protein function	Example(s) of proteins exercising the function
Enzymic, or catalytic	A most essential protein function is in exercising the acceleration of chemical conversions (synthesis and degradation of materials; transfer of electrons, atoms and molecules from one compound to another)	*Fumarate hydratase* : catalyzes the reversible conversion fumarate + $H_2O \Rightarrow$ malate *Cytochrome oxidase* : participates in the transfer of electrons onto oxygen
Hormonal, or regulatory	Regulation of intracellular metabolism and integration of cellular metabolism throughout the whole organism	*Insulin* : participates in the regulation of metabolic processes involving carbohydrates, proteins, fats, and other materials *Luteotropin* : participates in the regulation of progesterone synthesis in the ovarian corpus luteum
Receptory	Selective binding of various regulators (hormones, mediators, and cyclic nucleotides) on the surface of cell membranes or inside the cells (cytosolic receptors)	*Cytosolic receptor of estradiol* : binds estradiol inside the cells, for example, those of endometrium *Glucagon receptor* : binds the hormone glucagon on the surface of a cell membrane, for example, that of liver *Regulatory subunit of protein kinase* : binds cAMP inside the cells
Transport	Binding and transport of materials between tissues and through the cell membranes	*Lipoproteins* : responsible for the transport and distribution of lipids in the organism tissues *Transcortin* : responsible for the transport of



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Amino Acid Availability in Ruminants

Since the great bulk of dietary protein fed to ruminants is subject to microbial attack in the rumen, methods of protecting a portion of protein from ruminal degradation, are matter of current investigations. It has been estimated that 20 percent of the nitrogen found in the crude protein fraction of the ruminal microorganisms is actually nitrogen from nucleic acids. This fraction of crude protein is essentially wasted as the nucleic acids are, for the most part degraded to form urea in the postruminal section of the gastrointestinal tract. Moreover, the true protein fraction from ruminal microorganisms is not as digestible as the dietary protein in many cases.

It has been observed that when amino acids and high quality proteins such as casein have been infused in the abomasum by-passing ruminal degradation, it always lead in improved N_2 retention, more rapid wool growth, greater milk production, and so forth. Qualitatively, ruminants have the same essential amino acid requirments as non-ruminants on a tissue level. Therefore, if certain essential amino acids are deficient in microbial protein, maximum performance cannot be achieved.

Many factors influence the rate of protein degradation such as (1) secretion of urea into the rumen via saliva and of ammonia through the rumen epithelia, (2) absorption of ammonia and other nitrogenous compounds by rumen epithelia, (3) recycling of bacterial and protozoal proteins in the rumen, (4) protein solubility and (5) flow rate through the rumen. The last two factors are most important.

Dietary proteins are degraded in proportion to their solubility in the ruminal fluid, For this reason, it may not be advantagious to feed ruminants high protein feeds which are highly soluble. Zein, a protein present in maize, is extremely insoluble, thus 40-60% is escaping ruminal breakdown. On the other hand, casein is highly soluble and is almost totally degradable in the rumen.

Various methods of protecting protein from ruminal degradation are described below :

1. *Heat treatment*

When protein feeds are heated, free amino groups within and between forms cross linkages which not only reduces the solubility but also reduce the surface of the protein for enzymatic attack.

2. *Treatment of proteins with tannins*

Tannins form hydrogen bonds with proteins, thereby protects protein from enzymatic degradation. As the treated protein travels down the digestive tract, the acidity of the fluids is altered and the tannin-protein complex dissociates.

3. *Treatment with formaldehyde*

The aldehyde reacts with free amino groups and N-terminal groups to form Schiff bases and cross-linkages between protein chains thus reduces the solubility of the protein and protects it from enzymatic degradation. Once the treated protein enters into a highly acid medium in the abomasum, the reaction is reversed and the protein is degraded.

4. *Encapsulation of amino acids*

The theory of encapsulating specific amino acids appears to be an easy, efficient means of ruminal bypass but yet the technique has not proven to be entirely successful.



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B. Minerals Act as Body Regulators or Aid in the Formation of Body Regulators

1. For the maintenance of proper osmotic pressure in the body fluids.
2. For the maintenance of neutrality of the blood and lymph, which is essential for the normal action of the blood cells.
3. To maintain a proper physiological balance between the various mineral ingredients in the blood and also for digestion.
4. As co-enzyme, minerals are also important for metabolism.

C. In Milk Production

1. To make good, losses of minerals secreted in the milk in milking animals. Cow's milk contains 5.8 per cent ash or mineral matter on a dry basis.

Milk normally contains significant amounts of all of the essential minerals—except iron.

ORGANIC CHELATES

The word "chelate' is derived from the Greek word "Chele" meaning "claw" which is a good descriptive term for the manner in which polyvalent cations are held by the metal binding agents. Prior to union with the metal these organic substances are termed as "ligands". Ligand + mineral = chelate element.

Recently, animal nutritionists have come to realize that organic chelates of mineral elements which are cyclic compounds may be the most important factors controlling absorption of a number of mineral elements. A particular element in chelated form may be released in ionic form at the intestinal wall or might be readily absorbed as the intact chelate. Chelates may be of naturally occurring substances such as chlorophyll, cytochromes, haemoglobin, vitamin B_{12}, some amino acids, etc., or may be of synthetic substances like ethylenediaminetetracetic acid (EDTA).

Chelates show exceptionally high stability. The bonds between the ligand and the metal ions are of "coordinate" type and occur because of peculiarities in the electron shell of the transition metals. Sometimes the chelates are so stable that the metal ion is released with great difficulty resulting in difficulties in availability by the animal or plant tissues.

In biological systems there are three types of chelates:

Type I. Chelates that Aid in Transport and to Store Metal Ions

Chelates of this group behave as a carrier for proper absorption, transportation in the circulatory system and passing across cell membranes to deposit the metal ion at the site where needed.

(a) Among amino acids, cysteine and histidine are particularly effective metal binding agents and may be of primary importance in the transport and storage of mineral elements throughout the animal body.

(b) Ethylenediaminetetracetic acid (EDTA) and other similar synthetic ligands also may improve the availability of zinc and other minerals.

Type II. Chelates Essential in Metabolism

Many chelates of animal body are holding metal ions in such a cyclic fashion which are absolutely necessary to be in that form to perform metabolic function. Vitamin B_{12}, cytochrome



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to know the ionized amount, as it is the free ionized calcium in the body fluids that is necessary for blood coagulation, heart and skeletal muscle components, nerve transmission, etc. Ultracentrifugal method is used to determine the ionized amount.

The hormone of parathyroid gland causes the mobilization of bone calcium to the blood serum and the hormone of thyroid gland—calcitonin causes the deposition of calcium ions, in the bone; thus the two hormones maintain of calcium concentration of blood at uniform concentration.

Sources

Legumes like alfalfa, sterilised bone meal and milk products are major sources of calcium. Shell grit, oyster shell, dicalcium phosphate are the chief sources of calcium for poultry.

PHOSPHORUS (P at. wt. 31)

Phosphorus is found in every cell of the body, but most of it (about 80 per cent of the total) is combined with calcium in the bones and teeth. About 10 per cent is in combination with proteins, lipids and carbohydrates, and in other compounds in blood and muscle. The remaining 10 per cent is widely distributed in various chemical compounds. The amount of phosphorus present in blood serum is usually within the range of 4-12 mg per 100 ml.

Functions

1. Constituents of bone and teeth.
2. A constituent of the high energy compound ATP and thus is necessary for energy transductions essential for all cellular activity.
3. The oxidation of carbohydrate leading to the formation of ATP also requires phosphorus since phosphorylation is an obligatory step in the metabolism of any type of monosaccharides.
4. Phospholipids are constituents of all cellular membranes and are active determinants of cellular premeability.
5. DNA and RNA, the genetically significant compounds responsible for cell reproduction and therefore for growth and for all type of protein synthesis these phosphorylated compounds are absolutely necessary.

Symptoms of Phosphorus Deficiency

1. Since phosphorus is required for bone formation, a deficiency can cause rickets or osteomalacia.
2. 'Pica' or depraved appetite has been noted in cattle when there is a deficiency of phosphorus in their diet; the affected animals have abnormal appetite and chew wood, bones, rags and other foreign materials. Although Pica can be developed by other causes—a blood serum analysis of phosphorus may be run to know the exact cause of Pica, i.e., whether Pica is due to phosphorus deficiency or due to other reasons.
3. In chronic phosphorus deficiency animals may have stiff joints and muscular weakness.
4. Low dietary intakes of phosphorus have also been associated with low fertility and low-milk yield in cows and with stunted growth in young animals.



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involving ATP. Among the later groups are glucokinase, phosphoglucokinase, creatine transphosphorylase, arginine transphosphorylase, etc.

3. Controls the irritability of neuromuscular system.

Symptoms of Deficiency

Symptoms due to a simple deficiency of magnesium in the diet have been reported for a number of animals. In rats fed on purified diets the symptoms include tetany which is exhibited by (a) redness of exposed skin surface, (b) hyperirritability, (c) cardiac arhythmia, (d) marked vasodilation.

In adult ruminants a condition known as *hypomagneseamic tetany* associated with low blood levels of magnesium has been recognised since the early thirties. The condition is known as *Grass tetany* or *Grass staggers* characterized by (a) convulsions, (b) hyperirritability, (c) twitching of the facial muscles, (d) staggering gait and ultimately tetany. Tetany is usually preceded by a fall in blood serum magnesium to amount 0.5 mg per 100 ml.

Symptoms can be reversed by injecting magnesium sulphate at an early time, but in practice this is sometimes difficult.

The exact cause of grass tetany is yet unknown, although a dietary deficiency may be a factor. Some research workers consider that the condition may be caused by a cation-anion imbalance in the diet. Others suggest that soils which are heavily fertilized with $(NH_4)_2SO_4$ and when cattles are pastured on such soils develop the disease as ammonium interferes with absorption of magnesium. Still others suggest that excessive ruminal ammonia production may be the cause.

Experimental magnesium deficiency has been produced in dogs, rabbits, guinea pigs and chicks. In most cases the deficiency diseases are similar to those of rats and cattle. Magnesium deficient chicks grow slowly for about one week, then growth stops and they become lethargic.

Source

Green fodders, pericarp of cereal grains, bran, cotton seed cake and linseed cake are good sources of magnesium. When hypomagneseamic tetany is likely to occur it is generally considered that about 50 gm of magnesium oxide should be given to cows per day as a prophylactic measure.

TRACE ELEMENTS

IRON (Fe at. wt. 56)

About 65 per cent of the total body iron is present in the form of haemoglobin (which contains about 0.34 per cent of the element). Myoglobin accounts for another 4 per cent, 1 per cent in the form of various heme enzymes that control intracellular oxidation, 0.1 per cent in the form of transferrin in the blood plasma, 15 per cent stored in the form of ferritin or hemosiderin and 10–15 per cent probably in other forms. Broadly, iron is utilized in the body for (a) transport of oxygen to the tissues, (b) for maintenance of oxidative enzyme system within the tissue cells and (c) it is also concerned in melanin formation. Without all these important functions life would cease within a few seconds.



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in the form of *erythrocuprein*. About 96 per cent of the plasma copper is firmly bound to an α-2 globulin as *ceruloplasmin*, the form in which copper is transported in the body. *Cerebrocuprein* is another form of copper protein isolated from human brain by Porter and Folch (1957). It differs from erythrocuprein in that the copper of cerebrocuprein reacts directly with diethyl dithiocarbamate.

Interest in copper nutrition was markedly increased when in the 1930's certain diseases of sheep and cattle in various parts of the world were shown to be due to copper deficiency. The first that copper deficiency is responsible for a disease known as "*salt sick*" in cattle came from Florida (U.S.A.). In 1933 a report from Holland showed that copper deficiency was responsible for the disease of sheep and cattle characterised by diarrhoea, loss of appetite and anemia, called "*Lechsucht*". Bennetts and Chapman (1937) in Australia showed that a disease of lambs called "*enzootic ataxia*" was due to a copper deficiency and could be prevented by feeding copper to the ewes during pregnancy. These studies led to an extensive mapping of the copper deficient areas in most parts of the world. In all copper deficient areas the situation was markedly similar, as follows: (*a*) Sheep and cattle failed to thrive unless supplied with extra copper, either directly or indirectly; (*b*) blood and liver of the copper deficient animals contained copper levels which were greatly below normal, and (*c*) the forages and the soils contained low levels of copper.

Copper Content of the Body

A normal adult human contains approximately 100-150 mg of copper, or 1.5-2.0 ppm. Similar concentrations of copper occur in the bodies of the adult animal species. The body of the new born calf apparently is much richer in copper than that of any of the other species. By far the largest concentration of copper is in the liver. The liver copper level reflects the dietary intake; with high copper levels it may be increased manifold.

Deficiency Diseases

1. *Spontaneous fracture of bone.* Bone defects in grazing cattle and sheep on copper deficient pastures are characterized by spontaneous fracture and a condition very similar to rickets in young calves and osteoporosis in older animals.

2. *Demyelination of the central nervous system.* Severe ataxias have occurred in lambs and calves in various parts of the world and is known as *Sway back* or *Swing back* or *Gingin rickets* or *Enzootic neonatal ataxia.* The last name has been widely accepted throughout the world. Two types of neonatal ataxia are now recognised in lambs: (1) a common acute form occurs in new born lambs and (2) a delayed type often occurs in which clinical symptoms are not observed for several weeks or sometimes months after birth. In both diseases the symptoms are characterised by spastic paralysis, incoordination of the hind legs, a stiff and staggering gait and an exaggerated swaying of the hind quarters. Some lambs are completely paralyzed or ataxic at birth and die immediately.

3. *Pigmentation and structure of hair and wool.* A syndrome consisting of achromotrichia, alopecia and dermatitis is the most sensitive index of copper deficiency in the rabbit occurring even before a pronounced anemia. In sheep, copper deficiency produces a lack of black wooled sheep, and characteristic loss of "*crimp*" from the fibers of all wool. This has been found in Merino sheep, which normally have a crimpy wool, grow relatively straight when allowed to graze on copper-deficient fields. Copper content of the wool is decreased but



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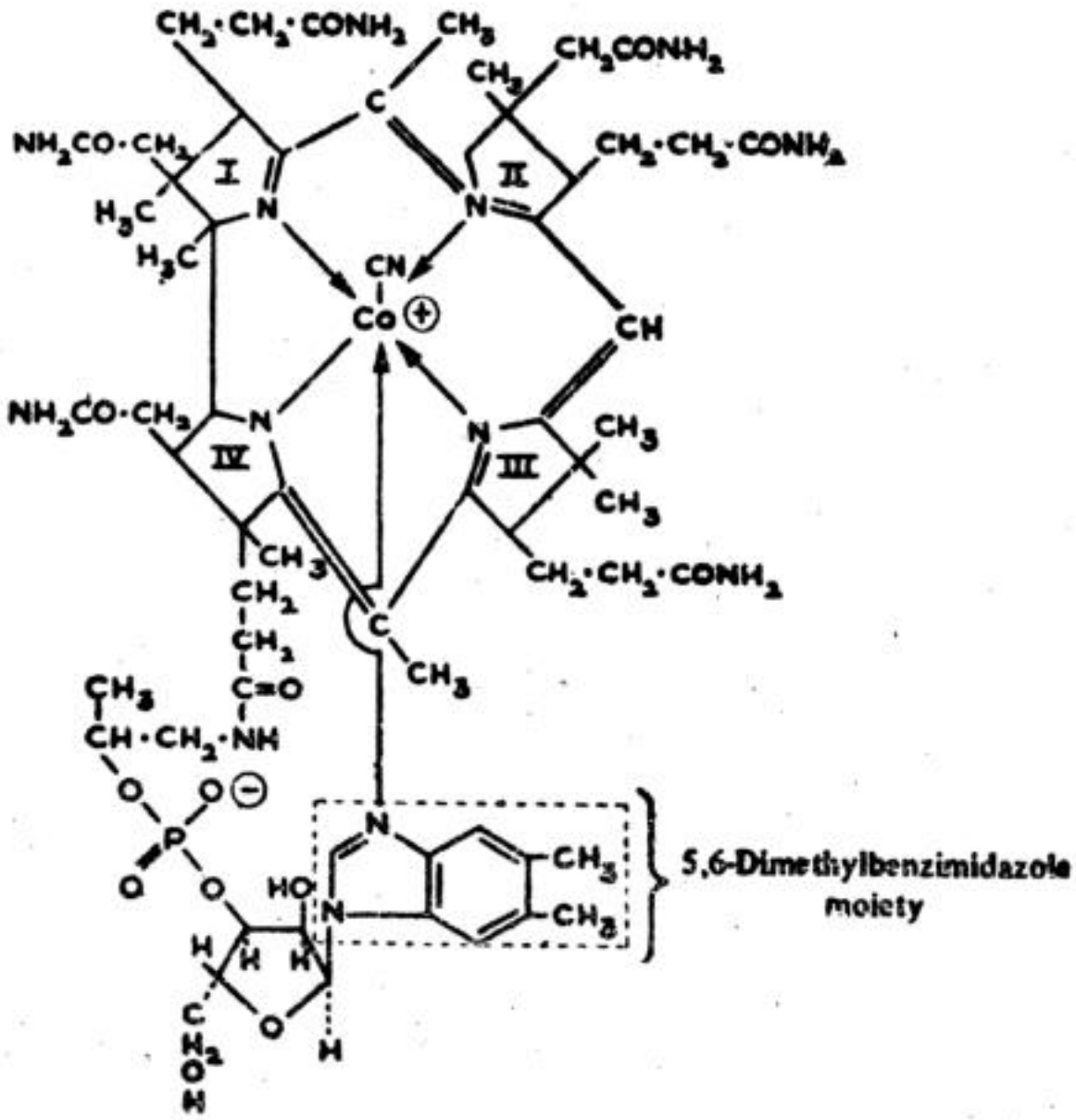
Foods of marine origin are very rich in iodine. Among common animal feeds, fish meal, meat and bone meal, molasses are the richest sources. Synthetic iodized salts are more commonly used by the farmers.

COBALT (Co at. wt. 59)

The first evidence that cobalt is an essential mineral nutrient for ruminants came from a group of Australian investigators, (Lines, 1935; Marston, 1935; Underwood and Filmer, 1935).

A number of disorders of cattle and sheep characterized by an emaciation and listness typical of mal-nutrition have been recognized for many years and have given a variety of local names, some of which are descriptive of the disease and some of which merely reflect the district or area in which the deficiency occurs. Thus the disease was known as *bush sickness* in New Zealand, *coast disease* in South Australia, *wasting disease* in western Australia, *nakuruitis* in Kenya, *pining* in Great Britain etc. The most appropriate scientific designation for all these conditions is *enzootic marasmus*. All these names clearly indicate the occurrence of cobalt deficiency in many areas of the world including Australia, New Zealand, U.S.A., Canada, middle and northern Europe, and many parts of Asia.

Progress in understanding the mode of action of cobalt in the animal organism was slow until after the discovery that the anti-pernicious anemia factor in liver, subsequently designated



Cobalt as a component of Vitamin B_{12} (Cyanocobalamin)



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5. Inhibit certain enzymes concerned with carbohydrate and lipid metabolism (e.g., glucose-6-phosphate dehydrogenase, ATPases, lipase, alkaline phosphatase).

Note. Mineral mixture containing rock phosphate might carry more than 0.1 per cent fluorine. Their use should be made after defluorination.

SELENIUM (Se at. wt. 34)

It has been confirmed in 1935 by the scientists of South Dakota Experiment Station, U.S.A. that selenium of forages causes toxicity by promoting alkali disease or blind staggers in cattle. Interest in selenium was enhanced greatly by the discovery in 1957 that selenium in traces (0.05 to 0.2 ppm) is an essential nutrient despite its toxicity in larger intakes. Animals grazing on certain soils suffered from retarded growth and reproduction troubles which could be overcome by the feeding of traces of the element. M.L. Scott and associate of Cornell University have confirmed that selenium at a level of approximately 0.15 ppm is required for prevention of dietary liver necrosis in vitamin E deficient rats, exudative diathesis in vitamin E deficient chicks, and also for pancreatic degeneration of chicks.

Types of Selenium Compounds

The most common inorganic forms of selenium are selenic acid, selenates and selenites, which are the selenium analogues of sulphuric acid, sulphurous acid, sulphates and sulphites. Plants and micro-organisms have been shown to be able to replace the sulphur in cystine, and methionine with selenium. thereby producing selenocystine and selenomethionine.

In ruminants a large percentage of the ingested selenium appears to be incorporated by the rumen micro-organisms into the selenoanalogues of cystine and methionine. These may be absorbed by the animals and deposited in the tissues in the form of selenoamino acids.

Absorption, Transport and Excretion of Selenium Compounds. Inorganic selenite and selenocystine are absorbed for the intestine by passive processes whereas selenomethionine is absorbed by an active transport mechanism.

After absorption the compound gets binded with α_2 and β_1 globulin fractions of the plasma. From this selenium binding protein, selenium is then transferred to erythrocytes (RBC). Uptake by the erythrocytes is influenced by adequate intracellular reduced glutathione.

Selenium intake in excess of that which can be bound by proteins are methylated. In mammals this methylation occurs in two steps: (1) formation of dimethyl selenide; and (2) further conversion of dimethyl selenide to trimethyl selenonium ion which is water soluble and represents the normal excretory product of moderate excess of dietary selenium. At the time of excess intake, the transformation of dimethyl to trimethyl stops at certain stage and then the dimethyl selenide, being a volatile compound is excreted through expired air imparting a garlic odour to the breath.

Physiological Functions

1. Acts as non-specific antioxidant,
2. Protects against peroxidation in tissues and membranes,
3. Participates in the biosynthesis of ubiquinone,
4. Participates in hydrogen transport along the respiratory chain.



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biochemical changes as well as to the anatomical lesions which are characteristic of the various vitamin deficiency states.

Before the chemical structures of the vitamins were known it was customary to identify these substances by letters of the alphabet (A, B, C, etc.). This system is gradually being replaced by a nomenclature based on the chemical nature of the compound or a description of its source or function.

The vitamins are generally divided into two major groups: fat soluble and water soluble. The fat soluble vitamins, which are usually found associated with the lipids of natural foods, include vitamins A, D, E, and K. The vitamins of the B complex and vitamin C comprise the water soluble group.

Vitamin C is the only member of the water soluble group that is not a member of the B family and its functions and characteristics are so different from the B vitamins that it requires special discussion. Consequently while making a differential study between fat and water soluble vitamins (Table 10.31)the consideration of Vitamin C has been excluded.

Table 10.32

Summary of the metabolic activities of vitamins

Vitamin	*Metabolic activity*	*Deficiency symptoms*
Lipid Soluble		
Vitamin A (Retinol, Retinal and Retinoic acid)	1. Oxidation-reduction activity, visual cycle 2. Necessary for normal synthesis of chondrotin sulphate	Cattle and pigs—skin conditions, xerophthalmia. Poultry—retarded growth, high mortality.
Vitamin D (D_2=ergocalciferol D_3=cholecalciferol)	1. Absorption of calcium from intestine 2. Necessary for calcification of bone matrix	Young animals—rickets; old animals—osteomalacia.
Vitamin E (α-tocopherol)	1. Inhibits autoxidation of unsaturated fatty acids	Most animals fail to reproduce; young cattie and lambs—muscle degeneration—chick — cerebral degeneration.
Vitamin K (Phylloquinine)	1. Necessary for the hepatic synthesis of proconvertin	Chicks—delayed clotting time of blood.
Water Soluble		
Thiamine (B_1)	1. Decarboxylation of pyruvic acid 2. Transketolase reaction of hexose-monophosphate shunt	Emaciation, weakness, and nervous disorders (polyneuritis of chicks and Chastek paralysis of foxes)
Riboflavin (B_2)	1. Biosynthesis of flavin nucleotide (FAD, FMN) 2. Used in oxidation-reduction reactions	Pigs—retarded growth, skin, conditions, eye diseases; chicks —curled toe paralysis.



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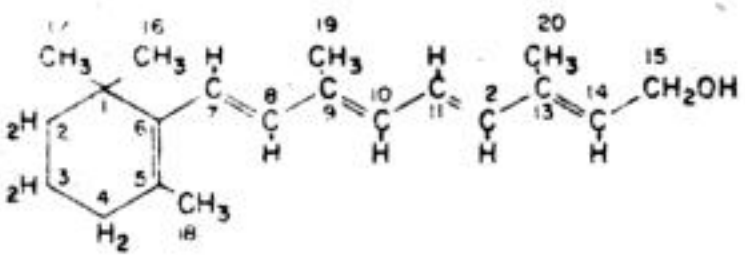


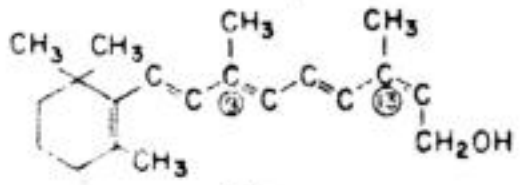
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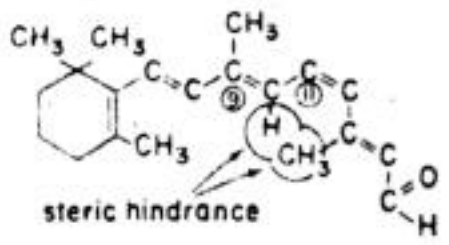


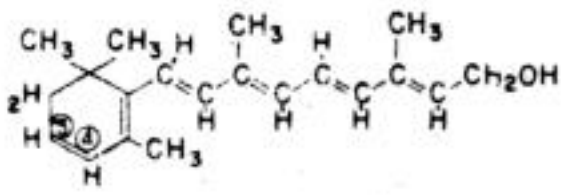
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Isomeric forms of vitamin A.









	Relative Biological Activity	
	CHICKS	RATS
Trans-Retinol	100	100
13-*cis* Retinol	50	75
11-*cis* Retinal (neo-b-retinene)	?	47
3-Dehydro-retinol (vitamin A_2, retinol$_2$)	?	40

Table 10.34 Vitamin A deficiency signs in animals.

Abnormality	Animals studied
General	
Anorexia	Rat, fowl, farm animals
Growth failure and weight loss	Rat, fowl, farm animals
Xerosis of membranes	Rat fowl
Roughened hair or feathers	Rat, birds, farm animals
Infections	Rat, birds, farm animals
Death	Rat, birds, farm animals
Eyes	
Night blindness	Rat, farm animals
Xerophthalmia	Rat, bovine
Keratomalacia	Rat
Opacity of cornea	Rat, bovine
Loss of lens	Rat, bovine
Papilloidema	Bovine
Constriction of optic nerve	Bovine, dog
Respiratory system	
Metaplasia of nasal passages	Fowl
Pneumonia	Rat, bovine
Lung abscesses	Rat
GIT	
Metaplasia of forestomach	Rat
Enteritis	Rat, farm animals
Urinary system	
Thickened bladder wall	Rat
Cystitis	Rat
Urolithiasis	Rat
Nephrosis	Rat
Liver	
Metaplasia of bile	Rat
Degeneration of Kupffer cells	Rat
Nervous system	
Incoordination	Rat, bovine, pig
Paresis	Rat, pig
Nerve degeneration or twisting	Rat, dog, rabbit, bovine, bird, pig
Constriction of optic foramina	Bovine, dog
Bone formation	
Defective modeling	Dog, bovine
Restriction of brain cavity	Dog
Reproduction	
Degeneration of testes	Rat
Abnormal estrus cycle	Rat, bovine
Resorption of fetuses	Rat
Congenital abnormalities	
Anophthalmia	Pig, rat
Microophthalmia	Pig, rat
Cleft palate	Pig, rat
Aortic arch deformation	Rat
Kidney deformities	Rat
Hydrocephalus	Rabbit, bovine
Miscellaneous	
Increased cerebro-spinal fluid pressure	Bovine, pig
Cystic pituitary	Bovine



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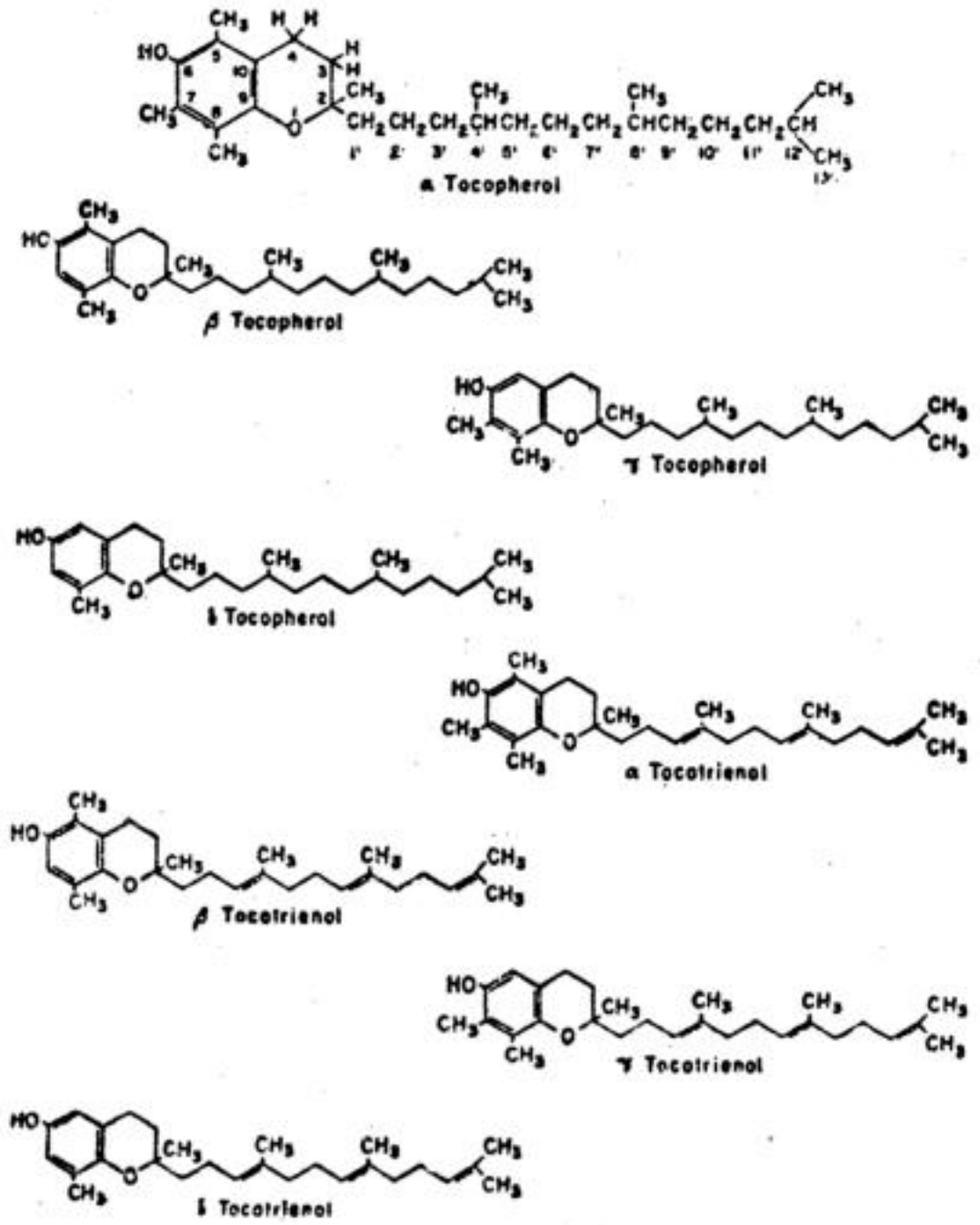
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Chemical structures of naturally occurring tocopherols and toco-trienols

tects coenzyme Q. Since coenzyme Q is involved in the transfer of electrons, additional studies on this relationship to vitamin E may serve to resolve a current controversy--whether α-tocopherol is an integral part of an enzyme system also.

The degradation of α-tocopherol in the animal body is presented in a diagramatic sketch as below. α-tocopherol is converted to tocopheryl quinone, its biological activity is then lost and the reaction is not ordinarily reversible. α-tocopheroxide apparently is reversibly converted to α-tocopherol to a limited extent in the presence of adequate ascorbic acid.

Absorption. Fat digestion produces are important in the absorption of the vitamin Es, the amount absorbed being proportional to the amount of lipids in the diet. The per cent absorption can range from 10 to 70%. The absorbed vitamin E is transported from intestine in chylomicrons; one of its storage sites are Ito cells in the liver. Further transport to most other tissues occurs by way of the lipoproteins, VLDL and LDL. There are many distribution pools with various biological half-lives, a relatively short-term pool in the plasma and liver, and a longer one in adipocytes (a major storage site) and muscle. The isomers have varying half-lives, with the α isomer lasting much longer than the γ. The major excretory route is through the bile in the faeces.



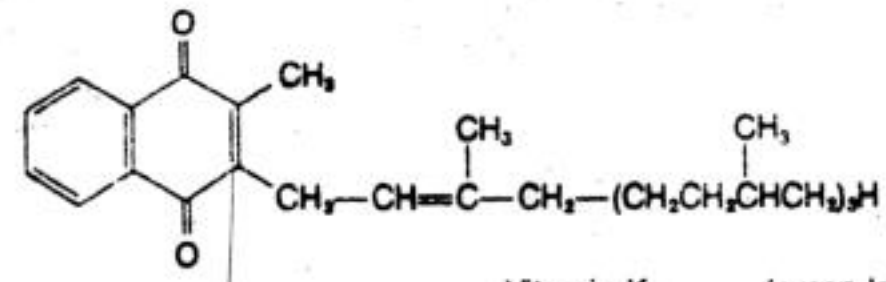
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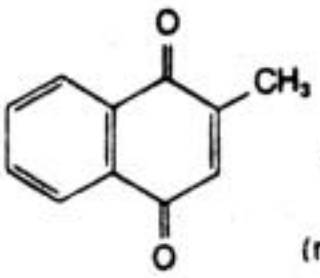


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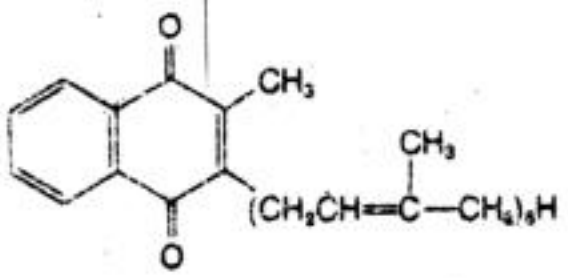
Vitamin K_1 (green leafy vegetables)

Phylloquinone



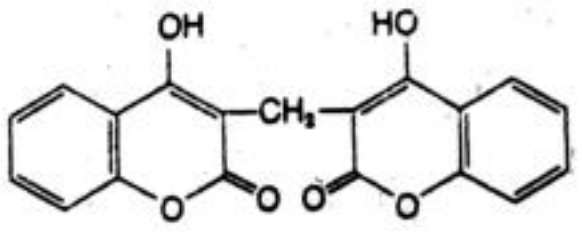
Vitamin K_3

(menadione)



Vitamin K_2 (intestinal bacteria)

Menaquinone-4

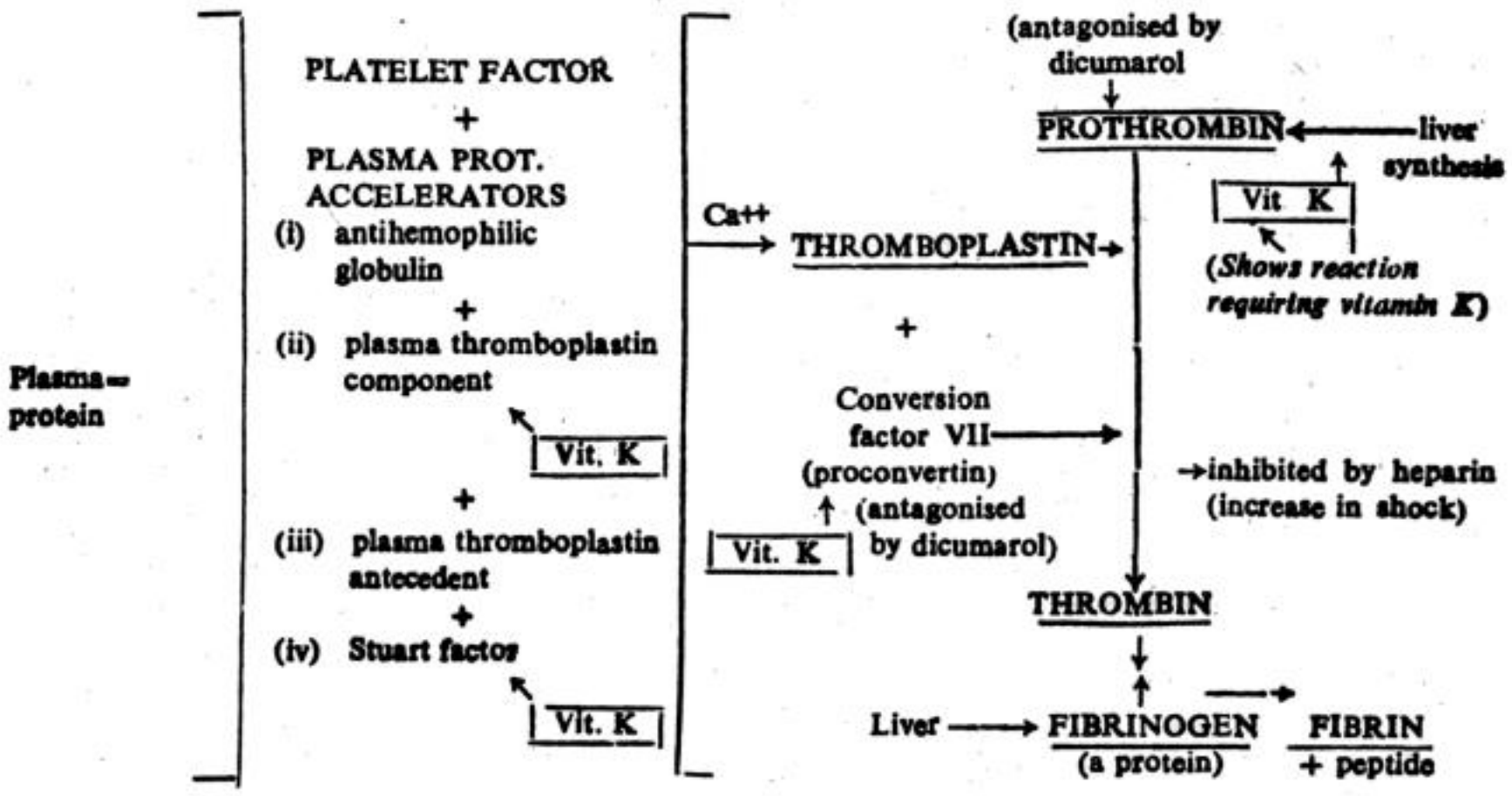


Dicoumarol

Absorption. The absorption of vitamin K requires bile and pancreatic juices and probably occurs by a passive mechanism, but K_1 may also have an active transport process in the distal small intestine. Vitamin K is transported from the intestine to the rest of the body in chylomicrons and later in very low density lipoproteins (VLDL) and low-density lipoproteins (LDL). The highest concentrations occur in the liver, spleen, and lungs, but even with a lower concentration the muscle is the largest storage site. Vitamin K has a short half-life, 2–3 hours, excreted primarily as lactones and glucuronides in the faeces through bile with a much smaller amount appearing in the urine.

Biochemical Function

Schematically it may be elaborated as follows:





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THE VITAMINS OF THE B COMPLEX

The vitamins included under this complex all have the property of being soluble in water and most of them are components of enzyme systems.

Complete agreement has still not been reached concerning which substances should be considered as B vitamins, but those listed here under B complex are generally accepted as members of the B complex. Many writers include choline, inositol and *p*-aminobenzonic acid with the B vitamins.

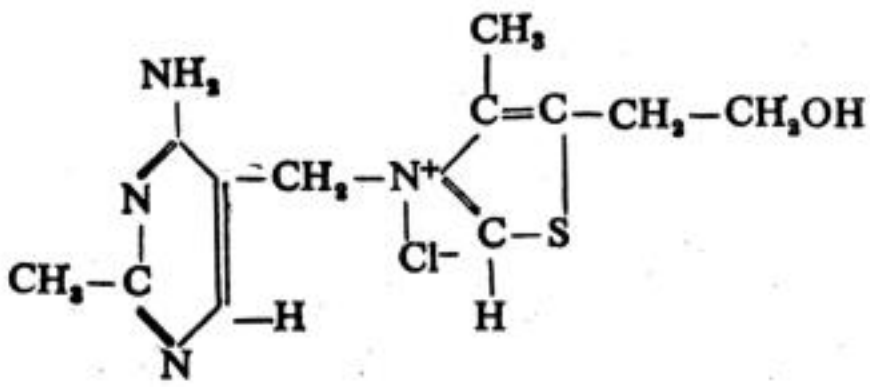
It is possible that the requirements of different animal species vary. In recent years it has become apparent that the activity of the intestinal flora in synthesizing vitamins of the B group explains species differences. In general we can say that microbial synthesis of the B complex in the digestive tract can supply part of the requirements of all monogastric animals. For ruminants the entire requirements of B vitamins are synthesised by the microbes in their digestive tract. Deficiency symptoms in farm animals do occur only in pigs and poultry.

THIAMINE (VITAMIN B_1)

The disease beriberi had been known for several centuries before its dietary origin was recognized. Beriberi is characterized by extensive damage to the nervous and cardiovascular system and may be accompanied by severe muscle wasting (dry beriberi) or edema (wet beriberi). In the late nineteenth century, Eijkmann, working in a hospital laboratory in Batavia, Dutch East Indies, discovered that a polyneuritis (characterized by a peculiar head retraction obviously of neurological origin) in chickens with symptoms similar to beriberi in humans was produced by feeding an experimental diet of polished rice. It did not occur when brown rice was substituted for polished rice or when rice polishings were added to the polished rice diet.

In 1926, Jansen and Donath, successors of Eijkmann succeeded in crystalizing vitamin B_1 in pure form. The identification of the structure of the vitamin and its synthesis was accomplished in 1936 by Williams and co-workers in the same laboratory.

Chemistry of Thiamine. Thiamine (aneurine, vitamin B_1) is a complex nitrogenous base composed of a pyrimidine and a thiazole ring; it is available commercially in hyrdochloride form.



Thiamine Chloride

Due to the presence of a hydroxyl group at the end of the side chain thiamine easily forms esters with phosphorus of ATP. In the esterified form the molecule becomes active and this active molecule is known as cocarboxylase (thiamine pyrophosphate or TPP). The structure of thiamine pyrophosphate is shown below:



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Metabolic Function

Riboflavin in the form of flavin mononucleotides (FMN) and flavin adinine dinucleotide (FAD) acts as the prosthetic group of several enzymes involved in biological oxidation-reduction reactions. These enzymes serve as bridges over which hydrogen atoms can pass between two other molecules. In its reduction and oxidation riboflavin alternately accepts and releases two hydrogen atoms. Reactions catalyzed by flavoproteins may be divided into three groups:

1. Reactions in which enzyme removes hydrogen, not from the primary substrate but from an intermediate carrier *e.g.*, from reduced pyridine nucleotide.
2. Reactions in which the enzyme removes hydrogen directly from substrate such as succinic and choline which are transformed to fumaric and betaine aldehyde respectively.
3. Catalyze the reactions of molecular oxygen *e.g.*, xanthine oxidase and oxygen to produce uric acid.

Source

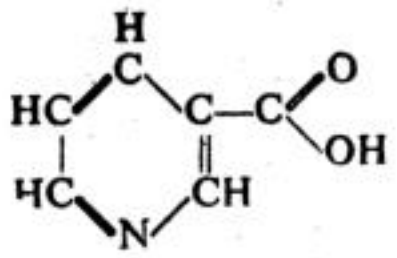
Riboflavin is widely distributed throughout the plant and animal kingdoms, with very rich sources in anaerobic fermenting bacteria. Milk, liver, kidney and heart are excellent sources. Many vegetables are also good sources, but the cereals are rather low in riboflavin content.

NIACIN AND NIACINAMIDE

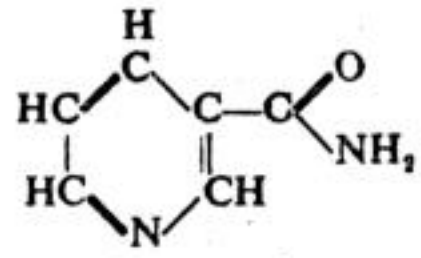
The terms niacin and niacinamide have replaced the older terms nicotinic acid and nicotinic acide amide (nicotinamide). The latter names were found to be undesirable because of confusion and the unwanted belief by many that they were physically related to nicotine.

Funk had isolated nicotinic acid from rice polishings as early as 1914, but he did not realize that it was a vitamin. In fact be was searching for an antiberiberi factor but discarded it when it was ineffective against beriberi! However, the discovery of niacinamide as component of coenzyme II (NADP) concerned in hydrogen transport (oxidation-reduction system) by Warburg and Christian (1935) suggested that the substance was of metabolic importance. When Elvehjem et al. (1938) were able to cure black tongue in dogs with niacinamide isolated from liver, niacin was firmly established as the pellagra-preventive factor (from the Italian *pelle agra* means rough skin). Subsequently curing of pellegrous humans with niacin in their ration became a common practice.

The structure of niacin and niacinamide is as follows:



(Nicotinic acid)



(Niacinamide)

Chemical Nature. There are two active forms of niacin: nicotinic acid (niacin) and nicotinic acid amide (nicotinamide) and four derivatives: NMV (nicotinic acid mononucleotide), NaMN (nicotinic) acid amide mononucleotide, a tryptophan metabolite), NAD, and NADP (phosphate on the ribose). Nicotinic acid is a pyridine-3-carboxylic acid; the reduced form is labile to acid, and the oxidized form is labile to alkali. Both are stable to heat and are stable as solids. Tryptophan can be converted



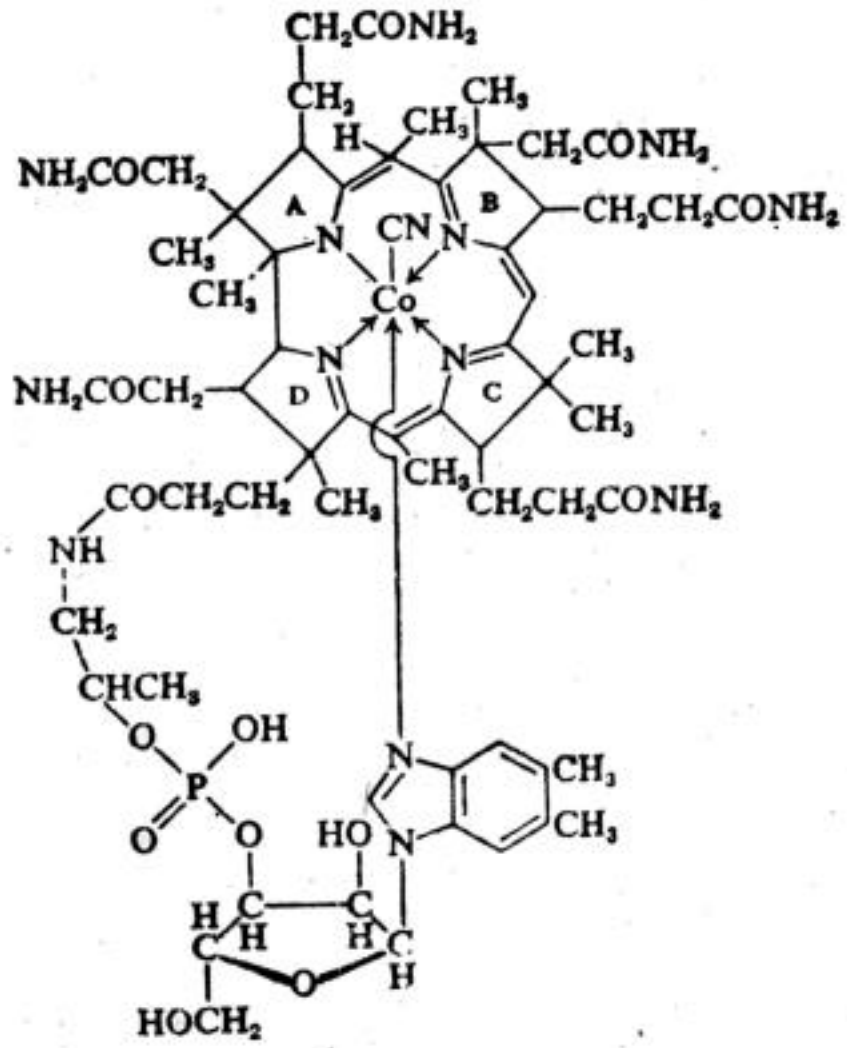
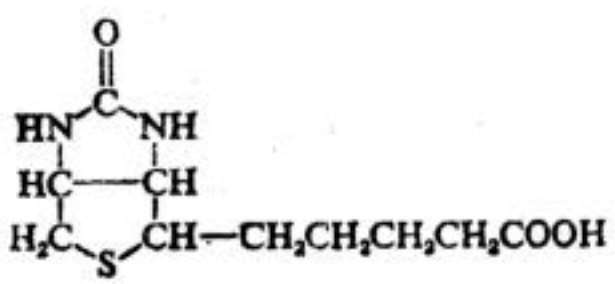
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Growth factor or vitamin	*Structure*	*Related prosthetic group of coenzyme*	*Function*
Cyanocobalamin (B_{12})		Cobamide coenzymes	1. Molecular rearrangements and formation of methyl groups. 2. The isomerisation of methylmalonyl CoA to succinyl CoA in fat metabolism requires a vitamin B_{12} coenzyme. This reaction is extremely important in the overall process of gluconeogenesis, especially in ruminants. 3. Vitamin B_{12} catalyzes the production of folacin from conjugated folates and aids in the formation of folacin coenzymes. 4. It sustains nerve function through its involvement in carbohydrate metabolism (it is known that vitamin B_{12} maintains glutathione in its biologically active reduced state).
Biotin			



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Deficiency Symptoms

Affects mainly on three tissues: (1) Nerve—lesions and demyelination. Norris found Riboflavin deficiency causes excessive swelling of nerves but Pantothenic deficiency causes degeneration of sheath, probably both maintain the normal condition of the nerve. (2) Adrenal gland—Acetyl CoA is precursor of cholesterol and thus of steroid hormones of adrenal gland. The anatomic changes of the adrenal gland are accompanied by evidence of functioning inefficiency. (3) Skin —severe dermatitis like biotin deficiency.

In chicks, retarded growth, dermatitis, fatty liver condition, severe edema, subcutaneous haemorrhage are the common symptoms. "*Goose step walk*," a typical nerve disease is found in case of pigs.

Sources

Excellent food sources include egg yolk, kidney, liver and yeast. Skimmed milk, sweet potatoes and molasses are fair sources.

FOLIC ACID (FOLACIN)

A deficiency disease found to be folic acid deficiency was first described by Wills (1931) as a "tropical macrocytic anemia" observed in pregnant women patients in Bombay, India, whose diet consisted primarily of white rice and bread. Since the anemia responded to yeast and could be produced in monkeys maintained on similiar monotonous diet it was apparent that the anemia was of nutritional origin.

The development of our present knowledge of folic acid resulted from studies of the nutritional needs of animals, on the one hand, and of bacterial requirements on the other. It is no wonder that this compound has been assigned to a wide variety of designations, since so many test animals and different bacteria have been employed. Also, a variety of symptoms were used as deficiency criteria in animals. Further complications surely resulted from the fact that the vitamin occurs in several chemical forms. A few of the names previously applied to this vitamin include vitamin M (a haematopoietic factor for monkeys), vitamin B_6 (chick growth factor), factor R (bacterial growth factor), vitamin B_{10} and vitamin B_{11}.

The name folic acid was proposed by Mitchell et al. (1941) for a compound isolated from spinach and shown to be necessary for growth of *Streptococcus faecalis* R. Eventually the structure and synthesis of pteroylglutamic acid were determined by investigators working at Lederle laboratories and Parke Davis Company. A few years later it was clear that all the factors were a form of the vitamin now known as folic acid or pteroylglutamic acid.

Chemical Nature

The vitamin consists of a pteridine nucleus, *p*-aminobenzoic acid, and glutamic acid, hence the name pteroylglutamic acid. The portion of the molecule containing pteridine and *p*-aminobenzoic acid is designated pteroic acid. At one time both *p*-aminobenzoic acid and pteroylglutamic acid were considered to be vitamins, but it is now apparent that the species requirement is for one or the other of the two. Pteroylglutamic acid is the vitamin for most mammals, whereas *p*-aminobenzoic acid is essential to certain bacteria that are able to synthesise the larger molecules.



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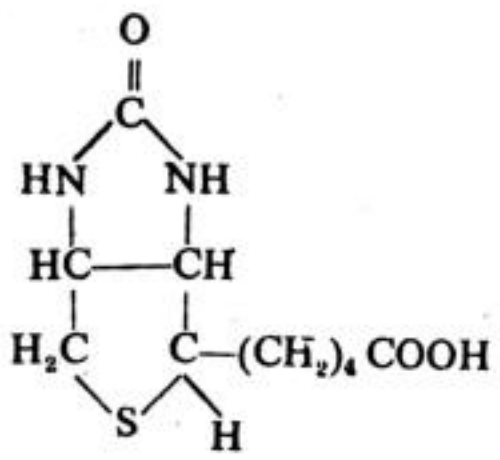
BIOTIN

Biotin was first described as the factor protective against "egg white injury". Rats fed large amounts of raw egg white developed an eczema-like dermatitis, paralysis of the hind legs, and a characteristic alopecia around the eyes, aptly termed *spectacle eye*. Cooked egg white was shown to be non-toxic to rats. This member of the group of B vitamins, has been known by a variety of names including bios factor, vitamin H, and coenzyme R. Duvigneaud and co-workers characterised biotin and published its structure in 1942. Harris and others announced the synthesis of *d*-biotin in 1943. Numerous improvements in synthesis of biotin have been made and at present biotin is readily available to the research worker.

Chemical Nature

From the structure it can be said that biotin is a relatively simple monocarboxylic acid. Unlike all other members of the B vitamins, biotin is very slightly soluble in water and alcohol.

In the free state biotin has the structure shown below:



Biotin

Biochemical Functions

In biological systems, biotin functions as the coenzyme for carboxylases, enzymes which catalyse carbon dioxide "fixation" or carboxylation. An important example is acetyl-CoA carboxylase, the enzyme which catalyses the reaction of carboxylation in the first step of non-mitochondrial pathway for the synthesis of fatty acids. Biotin also appears to be necessary for synthesis of dicarboxylic acids.

Deficiency Symptoms

Experimental biotin deficiency in man, which has been induced by feeding a biotin deficient diet together with large quantities of raw egg white, results in a syndrome characterised by a scaly dermatitis, greyish pallor, extreme lassitude, anorexia, muscle pains, insomnia and a slight anemia.

In chicks biotin deficiency results in dermatitis similar to that occurring in pantothenic acid deficiency. The bottoms of the feet become rough, contain fissures, which show some haemorrhaging. The toes may become necrotic and slough off.

Sources

Richest sources of biotin are royal jelly, liver, yeast, molasses peanuts and eggs. Most fresh vegetables are fairly good sources. Intestinal synthesis of biotin contributes a major portion, if not all of the daily requirements for rats and many other mammals.



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Extensive use is being made of synthetic and purified estrogens, androgens, progestogens, growth hormones and thyroxine or thyroprotein (iodinated casein) to stimulate the growth and fattening of meat-producing animals. There is concern, however, about possible harmful effects of any residues of these materials in the meat or milk for the consumers.

Hormones related to animal growth on the basis of their effect in body can be grouped into two major categories *viz.*, ANABOLIC and CATABOLIC. Somatotropin, thyroxine and androgens are anabolic while estrogen and glucocorticoids belong to catabolic group.

The hormones of the anabolic class by nature exert their effect on both skeleton and protein metabolism. Somatotropin stimulates growth of endochondral bone and epiphysis of long bones while in protein metabolism it ai ls in nitrogen retention and overall protein synthesis. Thyroxine also stimulates growth of long bones as well as protein synthesis. Testosterone at low dose increases the epiphyseal diameter, promotes muscle growtb by augmenting nitrogen retention.

The hormones belonging to catabolic group similarly exert their effect on both skeleton and protein metabolism. Estrogen inhibits skeletal growth although in ruminants it increases nitrogen retention. Glucocorticoids decrease growth of epiphysis and also aid in degrading protein and amino acids and thereby inhibit protein synthesis in extrahepatic tissue.

It is thought that the hormone alters the metabolism so as to increase muscle and bone formation at the expense of fat deposition. Since the energy required to synthesise protein or bone is less than that required to synthesise the same weight of fat, and the amount of water in muscle is greater than in body fat, it follows that a given amount of food will produce a higher live-weight increase due to hormone treatment.

It is an established fact that milk production in the cow will increase following the feeding of thyroprotein or L-thyroxine. The most effective daily dose appears to be about 15 gm per cow in the case of thyroprotein and 100 mg/cow daily for L-thyroxine. The addition of thyroxine or thyroprotein to the diet has increased milk production from 15 to 20 per cent above control animals, if a concomitant increase in energy intake was maintained. If additional feed is not given then the response is muted. A problem which has encountered is that sudden withdrawal of thyroprotein will cause milk production to drop below that of normal control cows, resulting no appreciable increase in the total milk produced in an entire lactation. University of Tennesse investigators found gradual withdrawing of thyroprotein caused milk production to drop only to the expected level or to that of controls. The indications are that feeding thyroprotein for short periods in successive lactation periods does not impair production; feeding the hormone for long periods in successive lactations may have an adverse effect on milk production but adequate proof for this is lacking. Some dairymen have experienced an increase in teat and other injuries and general excitability in thyroprotein fed herd. This is reasonable to expect. The overall seriousness of the problem will vary with a particular situation. During periods of extremely high environmental temperature, there should be some caution exercised in the artificial induction of a hyperthyroid state.

Some workers have reported increased rates of gain and improved feed efficiency as a result of feeding thyroprotein or thyroxine to growing pigs from the time of weaning to market weight. As in the cow, administration of thyroprotein to lactating cows has been recommended by some investigators, with additional energy intake, lactation would probably be increased.

Studies with fattening lambs have shown that feeding 2-5 mg of stilbesterol daily increased



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Digestible Energy (DE)

The gross energy of a food or other material provides no clue about the amount of energy available for livestock production. The amount of digestible energy is more useful for this purpose. Digestible energy is represented by that portion of feed energy consumed which is not excreted in the faeces. Then the total energy of the feed consumed (GE) is first measured in a bomb calorimeter. The total energy of the faeces is determined in the same way and the difference is called the apparently digestible energy. It can also be calculated from the digested nutrients by the use of the gross caloric factors: Protein 5 65; Carbohydrates 4.15; and Fat 9.45 or from the TDN values as will be described later on in this Chapter.

The method is a direct determination and is one of the most accurate analyses performed in the laboratory. The determination is not as time consuming as the TDN method. It does not account for any loss except that of faecal loss.

Metabolisable Energy (ME)

All of the digestible energy is not available for productive purposes and other energy losses

Table 10.42

Average Energy Requirements of Selected Species

Common Name	Energy Requirement (Growth) (kcal/day)		Energy Requirement (Pregnancy) (kcal/day)		Energy Requirement (Lactation) (kcal/day)		Output (kg/day)	Urine Output (ml/day)
Beef cattle	4200-31,000	ME	12,600-24,000	ME	15,900-27,500	ME	13-35	17-45/kg bw
Dairy cattle	1800-31,980	ME	13,000-25,600	ME	40,190-48,380	ME	13-35	17-45/kg bw
Horse	7430-19,200	DE	8700-19,950	DE	15,240-30,020	DE	20	—
Goat	2100-3300	ME	3100-4100	ME	3400-4300	ME	0.5-3.0	10-40/kg bw
Swine	2020-11,090	ME	6430	ME	15,840-17,420	ME	0.5-3.0	5-30/kg bw
Sheep	1980-2600	ME	2160-4620	ME	3580-6100	ME	1.0-3.0	10-40/kg bw
Rabbit	283	DE	283-635	DE	588	DE	—	65/kg bw
Chicken	319	ME	—	—	—	—	0.11	—
Turkey	769	ME	—	—	—	—	0.45	—

Source : *Handbook of Animal Sc.* (1991), Putman, P.A. (ed)., Academic Press, Inc. U.S.A.

Table 10.43

Some typical gross energy value
(kcal per gm. of dry matter)

Feed constituents		*Feed ingredients*	
Glucose	**3.76**	Maize	**4.43**
Starch	**4.23**	Oats	**4.68**
Cellulose	**4.18**	Oat straw	**4.43**
Casein	**5.86**	Grass straw	**4.43**
Lactic acid	**3.62**	Grass hay	**4.51**
		Urea	**2.53**



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glycolytic pathway. The principal reactions involved in glycolysis are depicted below. Reactions corresponding to numbers are described below:

1. Free glucose is phosphorylated to form glucose-6-phosphate which requires ATP.
2. Glucose-6-phosphate is isomerised to fructose-6-phosphate.
3. Fructose-6-phosphate is further phosphorylated by ATP at the first carbon to form fructose-1, 6-diphosphate.
4. Fructose-1, 6-diphosphate is split into two molecules of glyceraldehyde-3-phosphate, and dihydroxyacetone phospnate. From this point, carbohydrate metabolism proceeds from glyceraldehyde-3-phosphate, but, because this compound and dihydroxyacetone phosphate are interconvertible, in effect, two molecules of glyceraldehyde are formed from one hexose unit.
5. Glyceraldehyde-3-phosphate is then oxidised to glyceric acid-1, 3-diphosphate. The hydrogen thus released is taken up by NAD which may be reoxidised by the mitochondrial electron transport system leading to the synthesis of 3 moles of ATP. In the absence of oxygen (anaerobic glycolysis), NADH is utilised in the formation of lactic acid from pyruvic acid.
6. Glyceric acid-1, 3-diphosphate reacts directly with ADP to form ATP and glyceric acid-3-phosphate.
7. Glyceric acid-3-phosphate is converted to glyceric acid 2-phosphate, essentially migration of the phosphate group.

Table 10.45

Yield of ATP from Glucose in Glycolysis

			Moles of ATP gained (+) or loss (-) per initial glucose unit Steps	
	Steps		*Anaerobically*	*Aerobically*
1.	Glucose + ATP	Glucose -6 phosphate + ADP	-1	-1
2.	Fructose-6 phosphate + ATP	Fructose-1, -6-diphosphate + ADP	-1	-1
3.	Glyceraldehyde-3-phosphate (2 moles)	1,3-diphosphoglyceric acid	-	+6
4.	1,3-diphosphoglyceric acid + 2 ADP (2 moles)	3 phosphoglyceric acid (2 moles) + 2 ATP	+2	+2
5.	Phosphenol pyruvic acid + 2 ADP (2 moles)	Pyruvic acid (2 moles) + 2 ATP	+2	+2
	Net gain in ATP via Glycolysis		**+2**	**+8**

Note that Glycolysis can proceed in both aerobic and anaerobic conditions

8. Glyceric acid-2-phosphate is dehydrated to form phosphoenol pyruvic acid.
9. Phosphoenol pyruvic acid reacts with ADP, to form pyruvic acid and ATP.
10. Pyruvic acid, thus formed, enters the mitochondrion for further oxidation. When the oxygen supply is low, as in prolonged muscular activity, pyruvic acid may be used to oxidize NADH, forming NAD and lactic acid.

Lactic acid, so produced in anaerobic condition, is transported to the liver for resynthesis to glycogen since there is no enzymatic mechanism in muscle cells for the conversion of lactic acid to glycogen.



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seven residue segments of the amylose to terminal chains are transferred to a C-6 hydroxyl of a glucosyl residue that is four residue away for an existing branch. The initial terminal branch must be at least eleven residues in length before a segment is transferred from it. (Fig. 10.17).

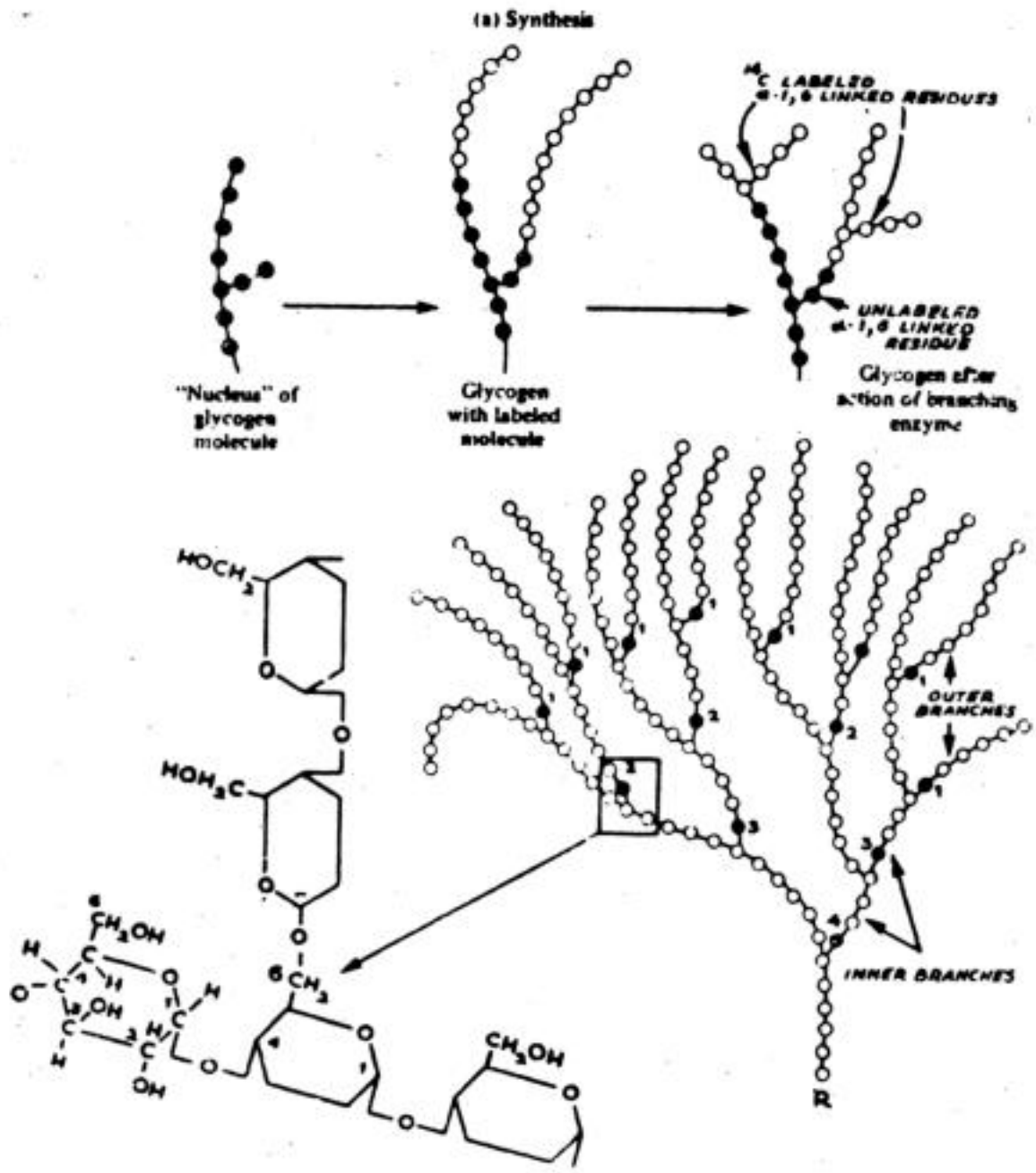


Fig. 10.17 The Glycogen molecule.

Open circles are glucose residues linked by α-1, 4-glucosidic bonds and solid circles are glucose residues linked by α-1, 6 bonds. Segments at the branch point is enlarged to show structure.

Regulation of Glycogenesis

1. The rate limiting step in glycogen formation is the addition of activated glycosyl units (derived from UDP-glucose) to an existing chain by glycogen synthetase—which again exists in two forms, e.g., dependent (D) and independent (I) forms.
   Interconversion of the D and I forms takes place by phosphorylation and is catalyzed by cyclic adenosine monophosphate-dependent. (C-AMP-dependent) protein kinase. The phosphorylated form is the inactive (D) form.

2. ***Hormonal Regulation***

   In Muscle: (a) Epinephrine promotes glycogenolysis and inhibits glycogenesis. The hormone stimulates the formation of (cyclic AMP) CAMP by activating adenylate cyclase. Thus in an emergency when epinephrene is released and acts upon the muscle cell membrane,



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Factors Controlling Output of Energy

It has already been mentioned that the foetus, and the lactating mammary gland impose obligatory demands for glucose on the adult cow.

Glucose is the major source of energy supplied to the foetus *in utero*. In sheep on advanced stage of pregnancy requirement may range between 8-9 g glucose/kg body weight daily. A single foetus may require 32 g of glucose daily depending on the size. In certain circumstances the total glucose requirement may amount to 70% of the glucose entry rate for the mother cow.

Lactose may impose even large burdens on glucose supply. Fortunately, there is a *"fail safe"* mechanism i.e., as blood glucose falls milk yield tends to fall in parallel. However, mammary gland has no power of gluconeogenesis for lactose synthesis so it must be supplied with preformed glucose. Between 1 and 1.5 kg of lactose may be secreted in milk daily in early lactation. Glucose is also needed for the synthesis of glycerol which is a vital component of the milk fat and also for oxidative purposes in the mammary gland itself, so that in all 70-90% of the animals total glucose entry may be taken up by lactation.

Endocrinological Control of Energy Metabolism

If the animal becomes hyperglycemic then the pancreas is stimulated to secrete insulin. This has several effects. It will tend to reduce blood sugar level by storing glucose in the liver and muscle as liver and muscle glycogen. *Insulin secretion in the ruminant is also stimulated by a rise in VFA concentration.* This is hardly surprising in view of the important part VFA's play in the energy metabolism in ruminants.

If the animal becomes hypoglycaemic, there will be increase in glucagon secretion. Moreover, hypoglycaemia will stimulate glucoreceptors in the hypothalamus to send impulses to the adrenal medulla for increased secretion of epinephrene. The combined effect of these will cause (1) more hepatic glycogenolysis, (2) will mobilise glycerol and FFA's from adipose tissue—the glycerol being used for gluconeogenesis and the FFA's as an alternative fuel for oxidation. In extreme cases it will also stimulate amino acid release from muscle for the production of glucose via gluconeogenesis.

FAT SYNTHESIS

Fat synthesis are continually renewed in order to provide not only of various multicomponent lipids (triacyl-glycerides, phospholipids, etc.), but also to meet the energy requirement of animals. The amount of energy that higher vertebrates can store in the form of carbohydrate is strictly limited and thus most of the surplus energy taken in as carbohydrate when food is plentiful is stored as fat (except in ruminants). Although carbon residues of the amino acids are readily transformed into citrate cycle intermediates, which may in turn be converted into fat, significant amounts are unlikely to be derived from dietary protein in normal circumstances.

Fat synthesis occurs in two stages: (1) fatty acid synthesis, and (2) Biosynthesis of triacylglycerides and incorporation of fatty acids.

Liver, mammary gland, and adipose tissue are the three major sites of biosynthesis of fatty acids and triacylglyceredes. In mouse and rat about half of the synthesis occurs in the liver, but in chicken and pigeon nearly all occurs in the liver; in the pig it is adipose tissue while in cow and sheep both liver and adipose tissue are important, although the latter predominates. In liver and adipose tissue the major product is palmitic acid. In the mammary gland, shorter chain fatty acids are produced.



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The reverse of the collection reactions can also occur. Glutamic acid acts as a "universal" donor of an amino group to keto acids (Page 597). The enzyme glutamic-pyruvic transaminase (GPT) is released from the liver into the blood in cases of severe liver damage.

The enzyme glutamic-oxaloacetic transaminase (GOT) is abundant in heart muscle. In myocardial infarction, the damaged heart muscle releases its transaminase into the blood.

Oxidative deamination *is the conversion of an amino acid into a keto acid with the release of an ammonium ion.*

$$\text{glutamic acid} + NAD^+ + H_2O \xrightarrow[\text{Glutamate dehydrogenase}]{} \alpha\text{-ketoglutaric acid} + NADH + NH_4^+$$

Method of Excretion of Circulatory NH_3 (Urea Cycle)

In ruminants, urea is one of the main microbial fermentation products of proteinous feed formed inside rumen, the large quantum of which are utilised by the microbes for the synthesis of their body protein and a good amount enters in the circulation by diffusion through ruminal wall. Apart from this urea, the liver of all mammals synthesise urea out of the excess ammonia formed by deamination of amino acids on the liver, which if allowed to accumulate in the system by virtue of their toxic property could be fatal for the species concerned. However, a very small amount of ammonia is otherwise utilised for the formation of some non-essential amino acids, purines, pyramidines, creatine and to other non-protein nitrogenous substances. The major portion thus remains unutilised and that is why all mammals have evolved biochemical reactions to remove excess ammonia rapidly in the form of urea—a comparatively non-toxic substance finally excreted out through urine.

Technique

The Krebs-Henseleit cycle (urea cycle) is a mechanism that explains the formation of urea. This is an energy requiring process. The ammonia combines with CO_2 (available from oxidation in the Kreb's cycle) and two molecules of ATP to form a *carbamyl phosphate*. (The compound provides the carbon atom and one of the two nitrogen atoms of the urea molecule at the final stage).

Carbamyl phosphate then reacts with a diamino acid *ornithine* in presence of an enzyme *ornithine transcarbamylase* resulting in the production of an amino acid *citrulline*, the other product being inorganic orthophosphate (Fig. 10.19)

A second amino group is then transferred from aspartic acid to carbamyl keto group of citrulline, to form the amino acid arginine.

In the presence of an enzyme, *arginase*, and magnesium, arginine yields one molecule of urea and of ornithine. Ornithine is thereby regenerated which can then participate in the next turn of the cycle.

The urea so produced leaves the liver by the blood stream, which carries it to the kidney for excretion. The amount present in the body and the rate of its excretion depend largely on protein content of the diet.

INTERCONVERSIONS OF THE MAJOR FOODSTUFFS

Upon feeding of liberal amounts of carbohydrate diet along with sufficient rest, domestic animals may soon become fattened. The fact demonstrates the eases of conversion of carbohydrate into fat. A most significant reaction in this respect is the conversion of pyruvate to acetyl CoA, as acetyl CoA is the starting material for the synthesis of long chain fatty acid. However, the pyruvate dehydrogenase reaction is essentially nonreversible, which prevents the direct



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(i) Post-ruminal infusion,
(ii) Heat treatment of the proteins
(iii) Tannic acid treatment
(iv) Chemical treatments including Formaldehyde.
(v) Protection of amino acids
  (a) By using amino acid analogue
  (b) By using encapsulated amino acids

Otherwise select feed proteins having very low solubility while computing rations for high yielders. billion dead microbes along with undergraded dietary protein (by pass protein) are brought to the abomasum. Af first the gastric juice which is highly acidic due to the presence of HCl, convert the proenzyme pepsinogen into pepsin by H^+ and also simultaneously denatures the protein and make the peptide bonds more susceptible to enzymatic hydrolysis. Pepsin catalyses the hydrolysis of only certain peptide bonds and as a result peptides (not amino acids) are formed. About 15% of the ingested proteins are thus partially hydrolyzed in.

14. High concentrations of rumen ammonia obviously do not necessarily indicate ammonia toxicity ; high rumen ammonia concentration commensurate with high rumen pH, however, would indicate toxicity because the free NH_3 concentration would be much higher at high pH. Ammonia exists as free NH_3 at high pH but as the ammonium ion (NH_4^+) at lower pH. Because tissue membranes are permeable to the lipid soluble NH_3 form but impermeable to the charged NH_4+ form, more ammonia is absorbed at high pH than at low pH.

The significance of this is that a large ammonia pool can be maintained in the rumen for microbial protein sysnthesis by maintaining low rumen pH. Readily available starch, such as cooked starch in *Starea*, is rapidly fermented to volatile fatty acids, which help to maintain low rumen pH.

15. High concentration of ammonia in the rumen does not stop normal bacterial growth, it is only that the excess amount of free NH_3 are absorbed through the rumen wall and most of these get lost through urine.
16. It is apparent that the rate at which energy is released from the carbohydrate material is crucial for conversion of ammonia to microbial protein. If it is released too slowly, as from cellulose, or if it released too rapidly as from glucose, ammonia conversion to microbial body in either case be poor. Starch has been considered the ideal source for supplying not only energy but also for carbon skeleton as well as production of VFA and thereby lowering pH value of rumen contents. Cooked starch gives more encouraging results than uncooked form.
17. Various types of microorganisms are present in the rumen, viz., Bacteria (5.4 to 31.4) x 10^{10}/ml ; Protozoa (0.3 to 19.7) x 10^6/ml ; Oscillospira (6.1 to 8.5) x 10^4/ml ; Yeast (0.0 to 10.0) x 10^3/ml and Bacteriophage which exceeds bacteria in the ratio of 2:1 to 10:1. Rumen protozoa which are mostly of ciliate types although are present in small numbers than bacteria, but because of their greater size can occupy little less than 50% of the biomass.

Absorption of Amino Acids. It has been emphasised earlier that rumen amino acid concentrations are very low, except soon after feeding a diet containing much of soluble protein. In general when a continuous normal feeding programme is followed, the concentrations of all free amino acids are very low and the rate of dissimilation by rumen microorganisms are so high that it would be surprising if significant absorption takes place. Interestingly enough, a definite transport of glycine across rumen epithelium and an increase in blood glycine following glycine addition to the rumen, has been demonstrated in goat and sheep.

It is very unlikely that there is any significant absorption of amino acids in general from the rumen and in most circumstances it must be negligible. But when we consider the fact that



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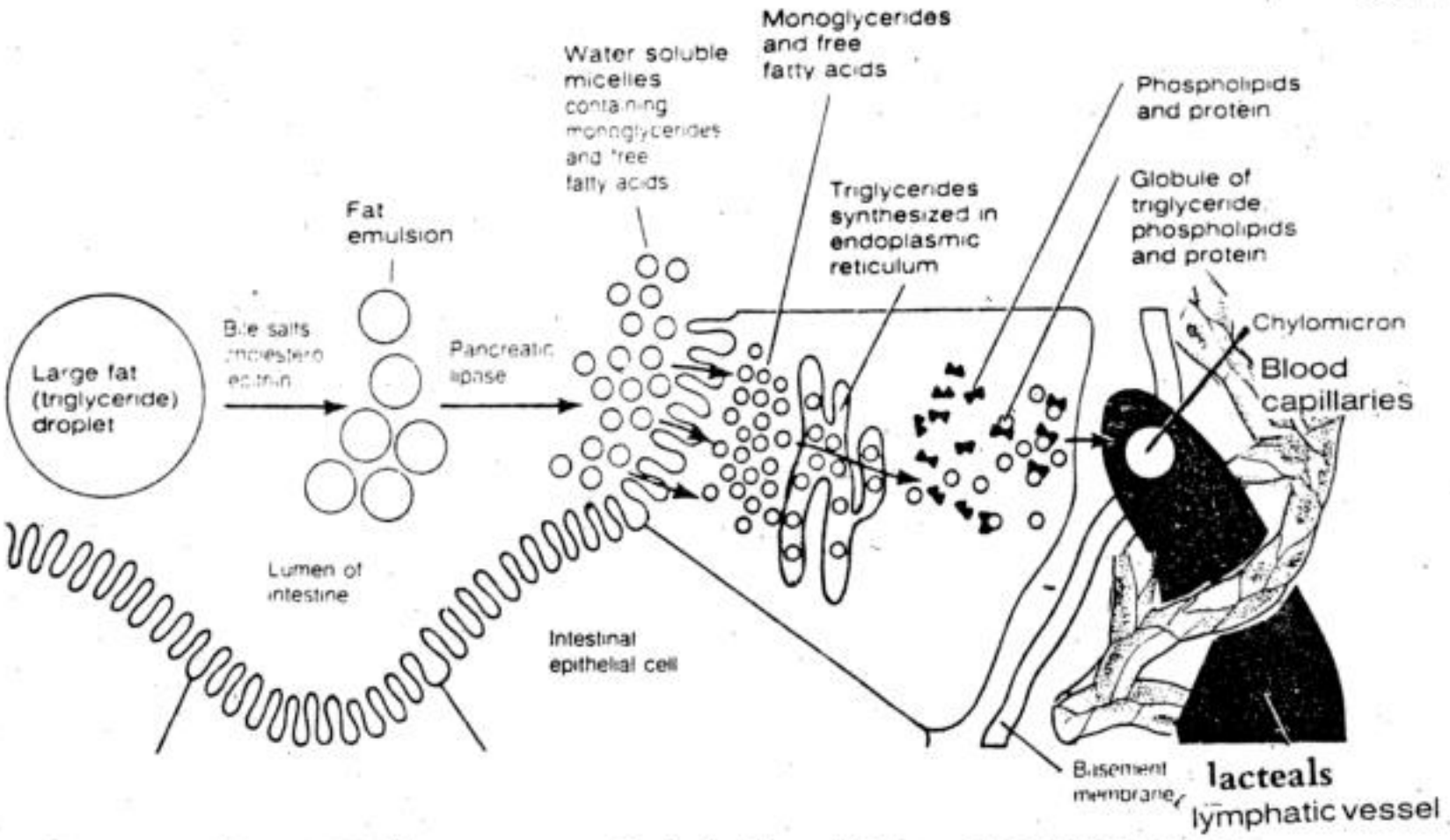


Fig. 10.27 Processes of fat digestion, absorption and chylomicron formation.

form the fatty acids and the monoglycerides are readily brought into contact with the microvilli. Each intestinal epithelial cell contains approximately 1000 microvilli which increase the surface area of the intestinal epithelial membrane by 15 to 25 fold. Monoacylglyceride and fatty acids

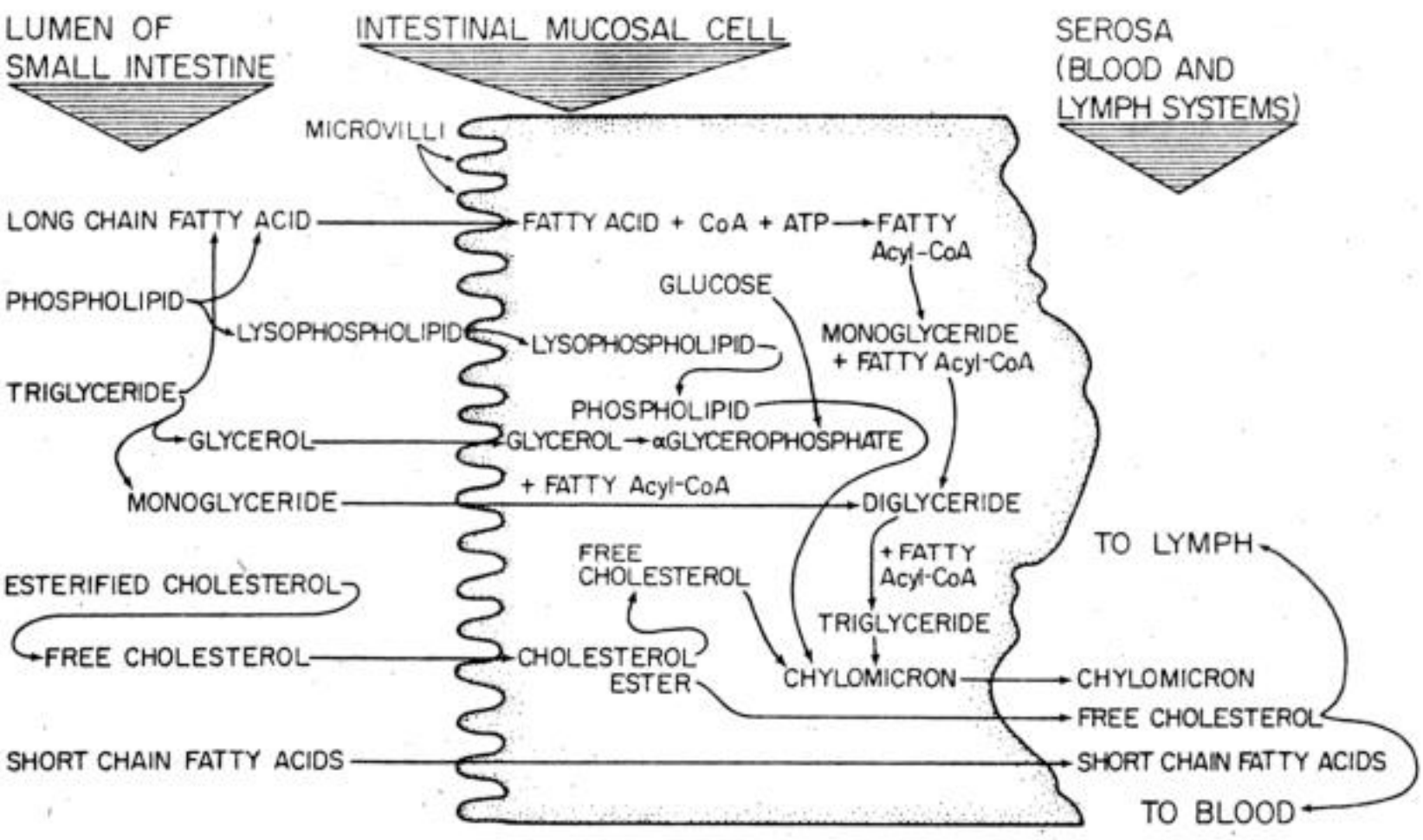


Fig. 10.28. Schematic diagram of the major conversions that occur in transport of lipids across the intestinal mucosal cell during absorption.



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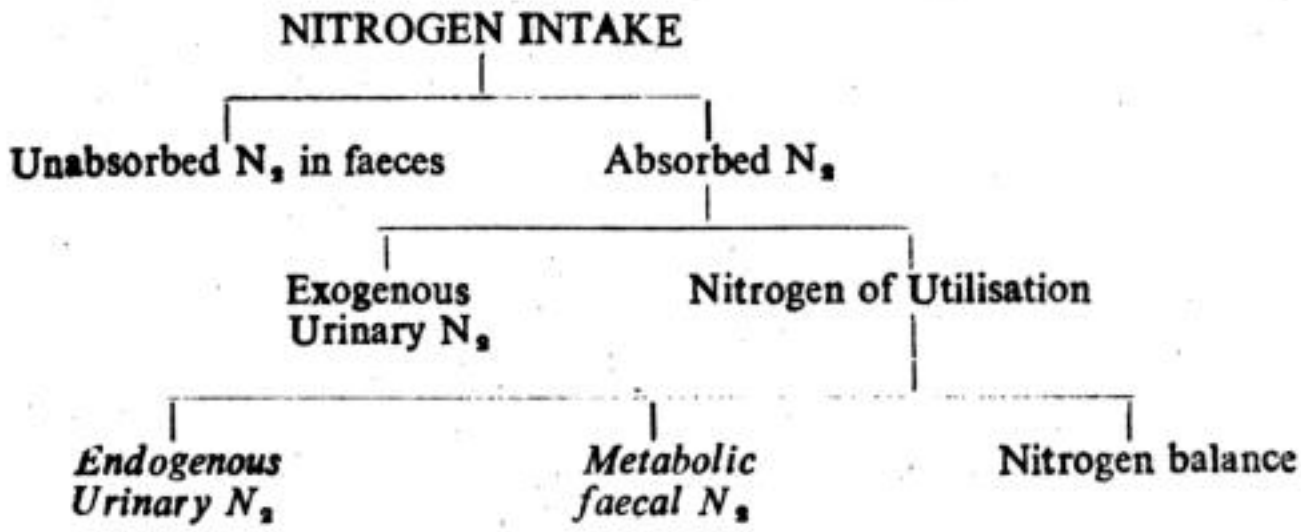


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The method involves determination of the amount of endogenous urinary as well as that of metabolic faecal nitrogen, both of which either may by calculated from the existing formulae (See Protein Metabolism) or may be obtained by conducting actual trials which are time consuming. Feed is withheld from animals so that their bodies enter into a catabolic condition. The nitrogen excreted in the urine and faeces during this period represents the nitrogen lost through metabolic process, the values thus obtained are accordingly known as *endogenous urinary nitrogen* (EUN) and *metabolic faecal nitrogen* (MFN)



These values are then substracted from the total nitrogen values obtained in the collection of the urine and faeces during the collection period of the balance trial. Exogenous urinary nitrogen and faecal nitrogen from feed are determined by the following equations :

1. Exogenous Urinary Nitrogen = total urinary nitrogen minus endogenous urinary nitrogen
2. Faecal Nitrogen from feed = total faecal nitrogen minus metabolic faecal nitrogen

When the daily nitrogen intake is less than the total outgo from the body, the animal in that case, is in *negative nitrogen balance*. If the nitrogen intake equalled the outgo, the animal is in *nitrogen equilibrium*.

In practice, this condition can hardly be observed. An excess of intake over outgo will represent a *positive nitrogen balance*, involving a deposition and storage of protein in the body.

To measure the quality of protein of a particular feed, care must be taken that the protein is fed at an adequate amount but not at an extra high level since with a higher protein intake (than the required), there will be more of excretion. Thus it will be difficult to compare the protein quality of various feeds.

THE NEW CONCEPT TO DETERMINE REQUIREMENTS OF PROTEINS IN RUMINANTS

The method most widely used for expressing the ruminant's requirement for protein and the extent to which a certain feed could meet these requirements is one based on the measurement of *digestible crude protein* (DCP). Since this method was considered to give too much weight to non-protein nitrogen, another concept of *protein equivalent* (PE) introduced in 1925, where non-protein nitrogen fraction was assumed to be fully digestible but to have half the value of digestible true protein.

$$\text{PE} = \frac{\% \text{ Dig. Crude Protein} + \% \text{ Dig. True Protein}}{2}$$



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Requirement of Dry Matter (DM)

The requirement of the quantity of dry matter depends on the body weight of the animal and also with the nature of its production. Cattle will generally eat daily 2.0 to 2.5 kg dry matter for every 100 kg of live weight. Buffaloes and crossbred animals are slightly heavy eaters and their dry matter comsumption varies from 2.5 to 3 kg daily per 100 kg body weight. This means that the animal in question should consume only so much. Naturally, all its requirements whether organic nutrients like carbohydrate, protein and fat or minerals or vitamins should come from the total dry matter that has to be allotted. Under Indian conditions, while computation of ration is made, the amount of grazing, is neglected as it is extremely poor. Since the bulk is essential, the dry matter allowance should be divided as follows:

- Total dry matter (DM)
  - ⅔ (as roughages)
    - ⅔ dry roughages or 3/4 if sufficient legume is available
    - ⅓ green roughages (If the green fodder is legume, this proportion may be only 1/4 of the total roughage ration.)
  - ⅓ (as concentrates)

Illustration 1

For a cross-bred cow weighing 400 kg, the dry matter requirement will be provided as indicated below·

Total DM requirement (kg) (@ 2.5 kg per 100 kg body weight)	=(4×2.5)=10
DM as concentrates (kg)	=(10×1/3)=3.33 or say 3.5
DM as roughages (kg)	=(10×2/3)=6.66 or say 6.5
DM as dry roughages (kg)	=(6.6×3/4)=4.95 or say 4.9
DM as green roughages (kg) (When legume will be available)	=(6.6×1/4)=1.65 or say 1.6

Requirement of Digestible Protein & Energy (DCP & TDN)

While calculating the total requirements of DCP and TDN one has to consider the physiological needs, or say, the purpose for which the animal has to be fed, i.e., whether the animal is just to maintain itself or in addition to carry out the advanced stage of pregnancy or whether the animal is under production. In later case it is also necessary to consider the quantity and quality of milk. The requirement of DCP and TDN requirement for all these purposes separately may be obtained from the appropriate Tables. What one has to do is to add up the additional requirements on top of maintenance requirement as per physiological condition.

Illustration 2

Find out the total requirements of DCP and TDN for a cow weighing 400 kg and yielding 10 litres of milk having 4.5 % fat.



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Animal Husbandry

(Eighth Edition)

G.C. Banerjee

Animal Husbandry with various domesticated species of livestock is an important sector of the rural economy of India for the past hundreds of years. Its role in augmenting income and employment, specially of the weaker sections of the society and in improving the nutritional status of our population needs to be promoted untiringly. With these objectives in view the book was first published in 1964 and since then it has gone through seven revised editions.

A spectacular reputation of the 7th edition entrusted further responsibility to enhance the quality of this 8th edition. Most of the chapters have undergone significant revisions, rewritings, reorganizations and discussions with updated informations and thereby enriched the latest edition. Three new Chapters viz., An introduction to Microbiology, Rabbit and Yak have been incorporated. Inclusion of Glossary, new photographs, diagrammes, necessary tables, along with important biochemical formulae will positively attract the interested readers. The revised edition is a real comprehensive integrated text to provide educational concepts and self study guide for students, researchers, teachers, livestock extension specialists and administrators interested in the study of Animal Husbandry.

The in-depth scientific documentation on the rearing aspects of all the important species of farm animals in one single volume is the main highlight of the book.

Dr. G.C. Banerjee graduated in 1956 in Agriculture from the University of Agra. He also obtained his Master's degree in Animal Science from the same University. Thereafter, for a period of two years, on an Indian Council of Agricultural Research Fellow, he was associated with the National Dairy Research Institute, Karnal for conducting research work in Microbiology. Thus completing his formal education, he proceeded to Cornell University in Ithaca, U.S.A. with a fellowship from the same University and did his Ph.D. in 1970 majoring in Animal Nutrition and minoring in Physiology and Biochemistry.

Dr. Banerjee has been associated with undergraduate and postgraduate teaching in the University of Kalyani and the Bidhan Chandra Krishi Viswavidyalaya (Agricultural University) for nearly two decades. He worked as Dean, Faculty of Veterinary & Animal Sciences for about two years and as Dean, Postgraduate Studies for about a decade. He has to his credit ninety scientific papers published in reputed journals in India and abroad. He retired from his long teaching career in 1996.

He is also the author of Poultry, a book for undergraduate students and also for all progressive farmers of the country. Feeds and Principles of Animal Nutrition is his other significant contribution.

Prof. Banerjee has been appointed as examiners of M.V.Sc. and Ph.D. candidates by over fifteen Universities of the country. For over a decade he is also closely associated with National level committees and examinations.

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