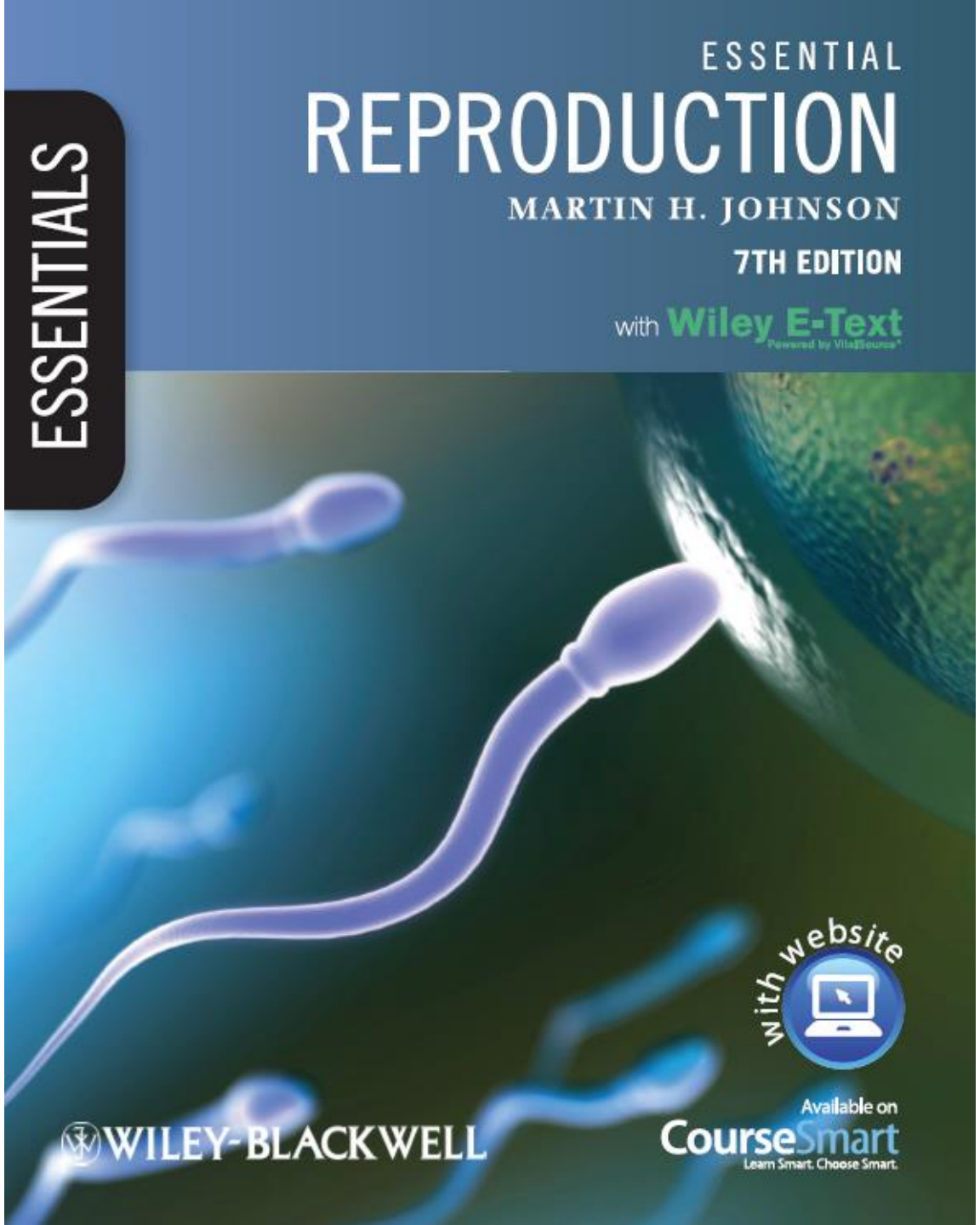
Essential Reproduction

黃 步 敏

BU-MIIN HUANG

02-19-2025



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Seventh edition

18 weeks

每週課程內容 weekly scheduled contents
Week 1 (2025-02-19)：What is Reproduction? (Chapter 1)
Week 2 (2025-02-26)：Sex (Chapter 2)
Week 3 (2025-03-05)：Sexual Maturation (Chapter 3)
Week 4 (2025-03-12)：Gender (Chapter 4)
Week 5 (2025-03-19)：Sexual Selection (Chapter 5)
Week 6 (2025-03-26)：Making Sperm (Chapter 6) and Men (Chapter 7)
Week 7 (2025-04-02)：Spring Break
Week 8 (2025-04-09)：Making Egg (Chapter 8) and Women (Chapter 9)
Week 9 (2025-04-16)：Midterm Examination
Week 10 (2025-04-23)：Sperm and Eggs (Chapter 10) and Fertilization (Chapter 11)
Week 11 (2025-04-30)：Initiation Pregnancy (Chapter 12) and Supporting the Embryo plus Fetus (Chapter 13)
Week 12 (2025-05-07)：Growing the Fetus (Chapter 14) and Fetal Challenges (Chapter 15)
Week 13 (2025-05-14)：Preparing for Birth (Chapter 16) and Giving Birth (Chapter 17)
Week 14 (2025-05-21)：Lactation (Chapter 18) and Postnatal (Chapter 19)
Week 15 (2025-05-28)：Regulating Fertility (Chapter 20) and Restoring Fertility (Chapter 21)
Week 16 (2025-06-04)：Society and Reproduction (Chapter 22)
Week 17 (2025-06-11)：Review
Week 18 (2025-06-18)：Final Examination

16 weeks

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Week 1 (2025-02-19)：What is Reproduction? (Chapter 1)
Week 2 (2025-02-26)：Sex (Chapter 2)
Week 3 (2025-03-05)：Sexual Maturation (Chapter 3)
Week 4 (2025-03-12)：Gender (Chapter 4)
Week 5 (2025-03-19)：Sexual Selection (Chapter 5)
Week 6 (2025-03-26)：Making Sperm (Chapter 6) and Men (Chapter 7)
Week 7 (2025-04-02)：Spring Break
Week 8 (2025-04-09)：Making Egg (Chapter 8) and Women (Chapter 9)
Week 9 (2025-04-16)：Midterm Examination
Week 10 (2025-04-23)：Sperm and Eggs (Chapter 10) and Fertilization (Chapter 11)
Week 11 (2025-04-30)：Initiation Pregnancy (Chapter 12) and Supporting the Embryo plus Fetus (Chapter 13)
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Week 13 (2025-05-14)：Preparing for Birth (Chapter 16) and Giving Birth (Chapter 17)
Week 14 (2025-05-21)：Lactation (Chapter 18) and Postnatal (Chapter 19)
Week 15 (2025-05-28)：Regulating Fertility (Chapter 20) and Restoring Fertility (Chapter 21) plus Chap 22
Week 16 (2025-06-04)：Final Examination
Week 17 (2025-06-11)：
Week 18 (2025-06-18)：
核心能力 core competencies

Let me know which schedule you prefer!

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Grade (100%) =

50% Midterm examination

and

50% Final examination

CHAPTER 1

What is Reproduction?

Reproduction is the biological process by which new organisms known as the offsprings are produced by their parents.

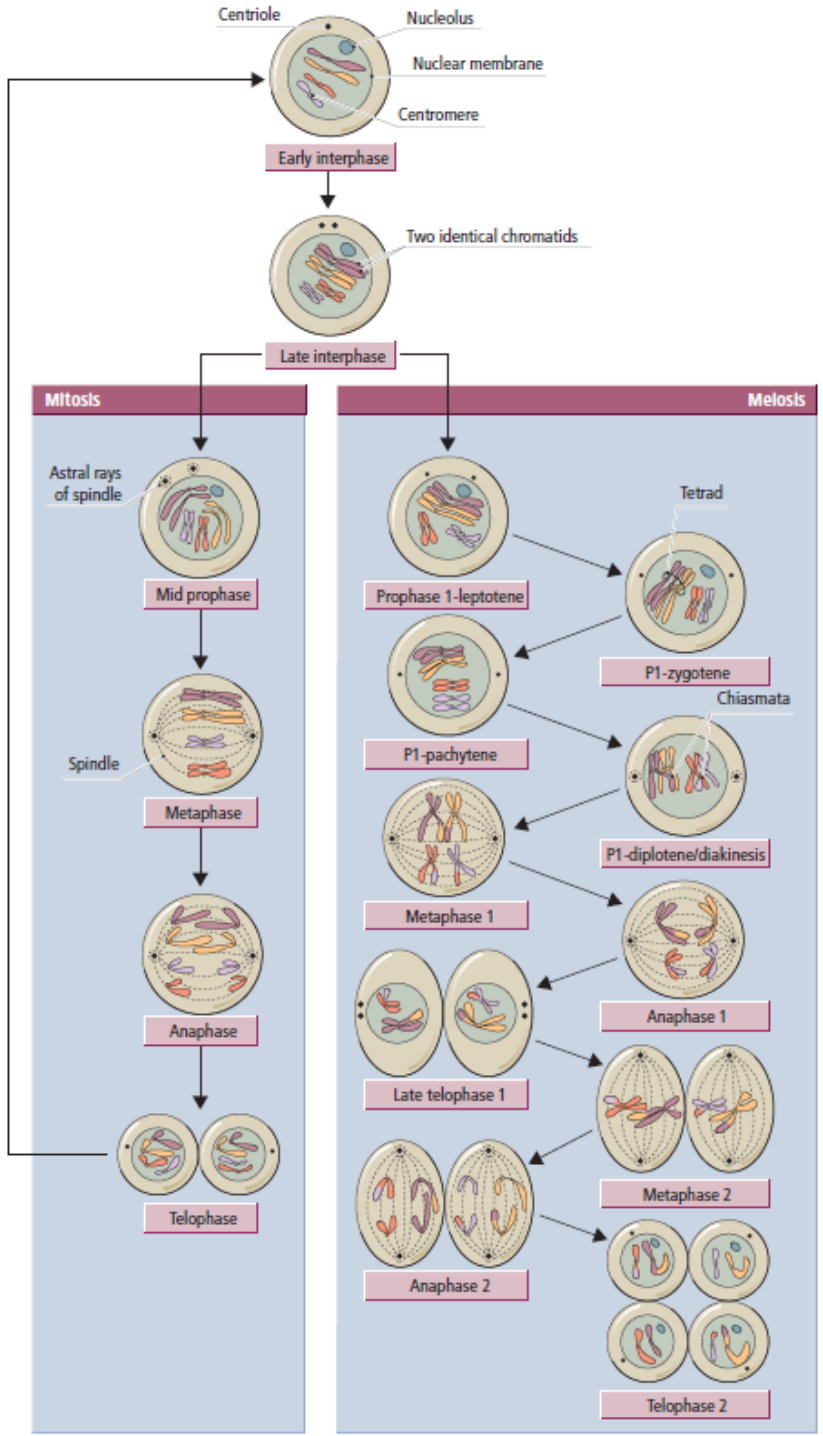
The ability to reproduce is a defining feature of all living organisms. Through reproduction, genes are passed to a new generation.

Reproductive strategies

Asexually

Mitosis

A single parent can give rise to the offspring.



Sexually

Meiosis

Two parents (male and female) are required to give rise to the offspring.

Asexually – Mitosis

Binary Fission -- Bacteria

Budding -- Echinodermata and hydra

Parthenogenesis – Reptile (lizard)

Fragmentation – Starfishes

(natural selection)

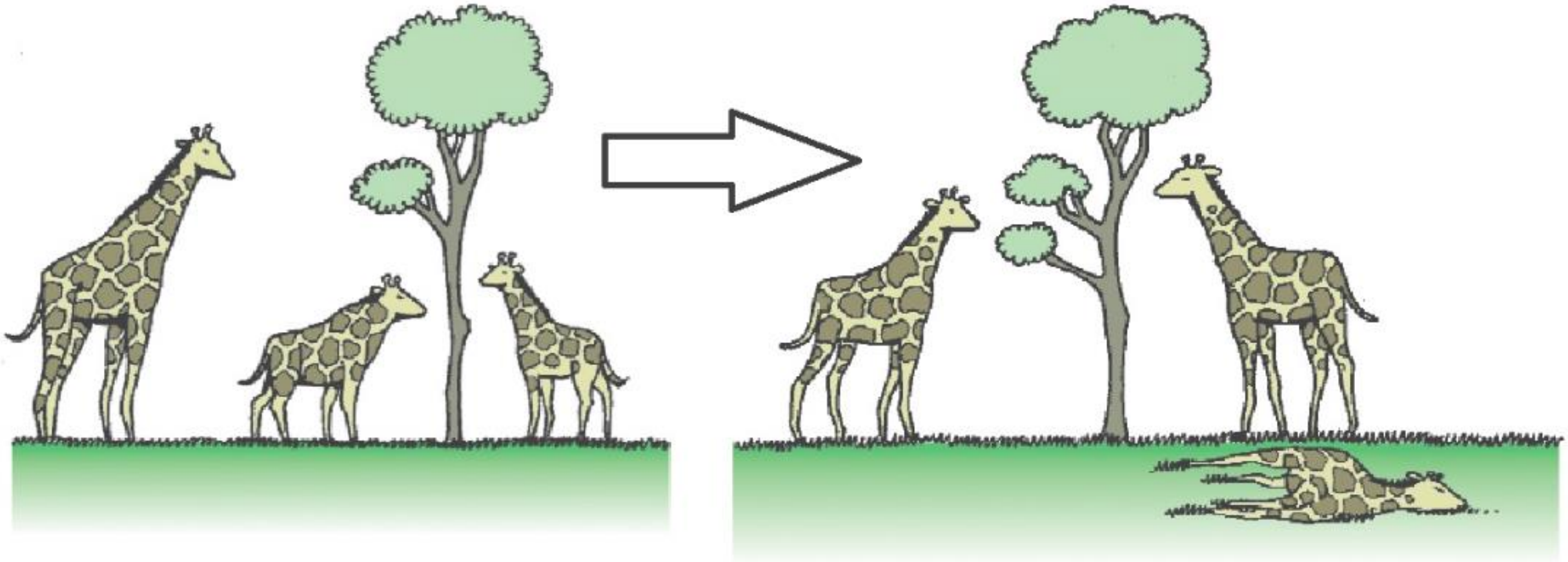
Sexually – Meiosis: Two parents () are required to give rise to the offspring.

(natural selection + sexual selection)

→ Fitness to Survive

Natural selection is the differential survival and reproduction of individuals due to differences in phenotype. It is a key mechanism of evolution, the change in the heritable traits characteristic of a population over generations.

Charles Darwin popularised the term "natural selection", contrasting it with artificial selection, which is intentional, whereas natural selection is not.



Natural Selection in action

Sexual Reproduction

Each new individual receives its **chromosomes** in two equal portions:
half carried in a **male gamete**, the **spermatozoon** (see Chapter 6), and
half in a **female gamete**, the **oocyte** (see Chapter 8).

These gametes come together at **fertilization** (see Chapter 11) to form the genetically novel **zygote**.

Sexual Selection

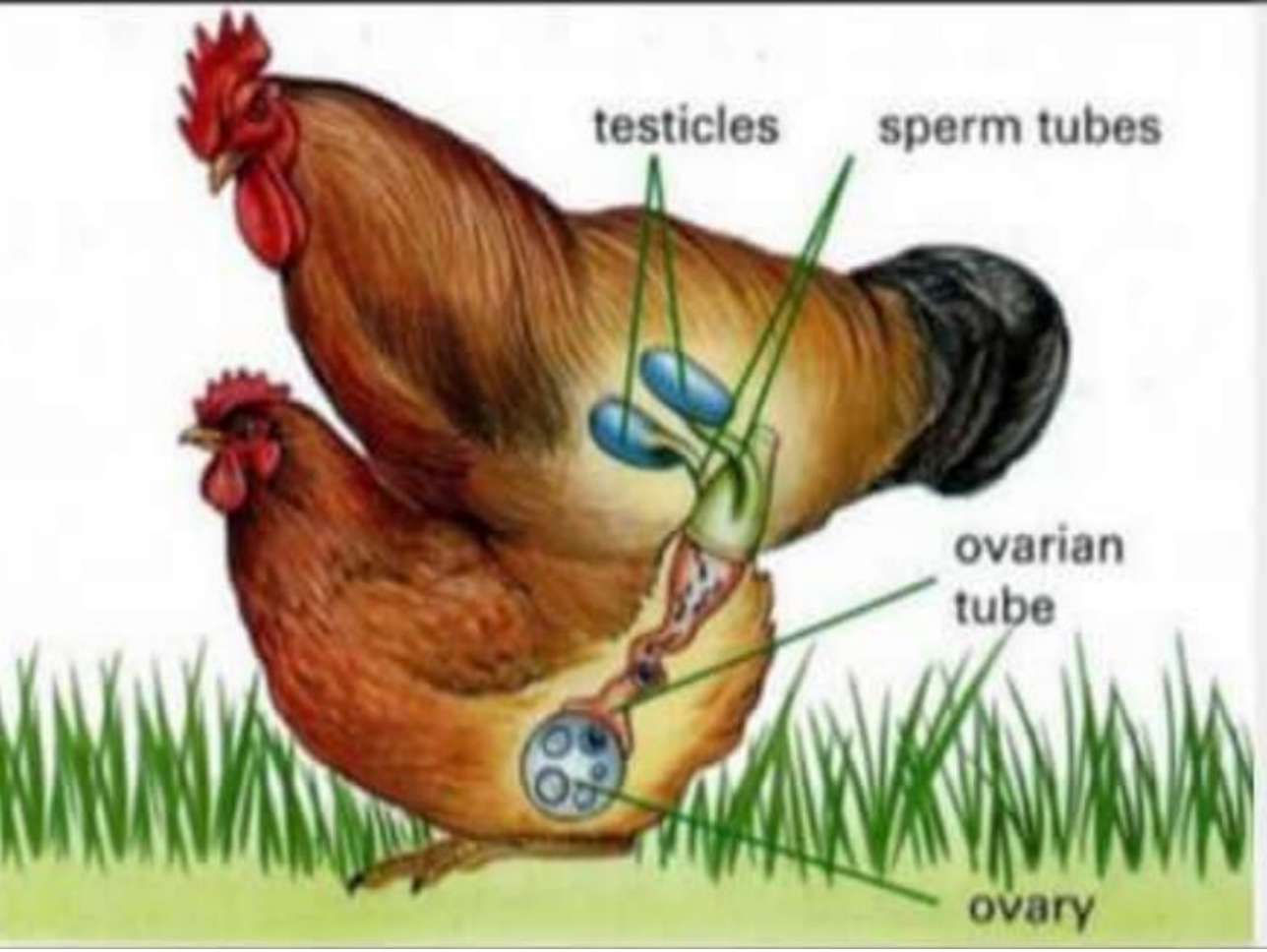
One biological sex chooses mates of the other sex to mate with (intersexual selection), and compete with members of the same sex for access to members of the opposite sex (intrasexual selection).

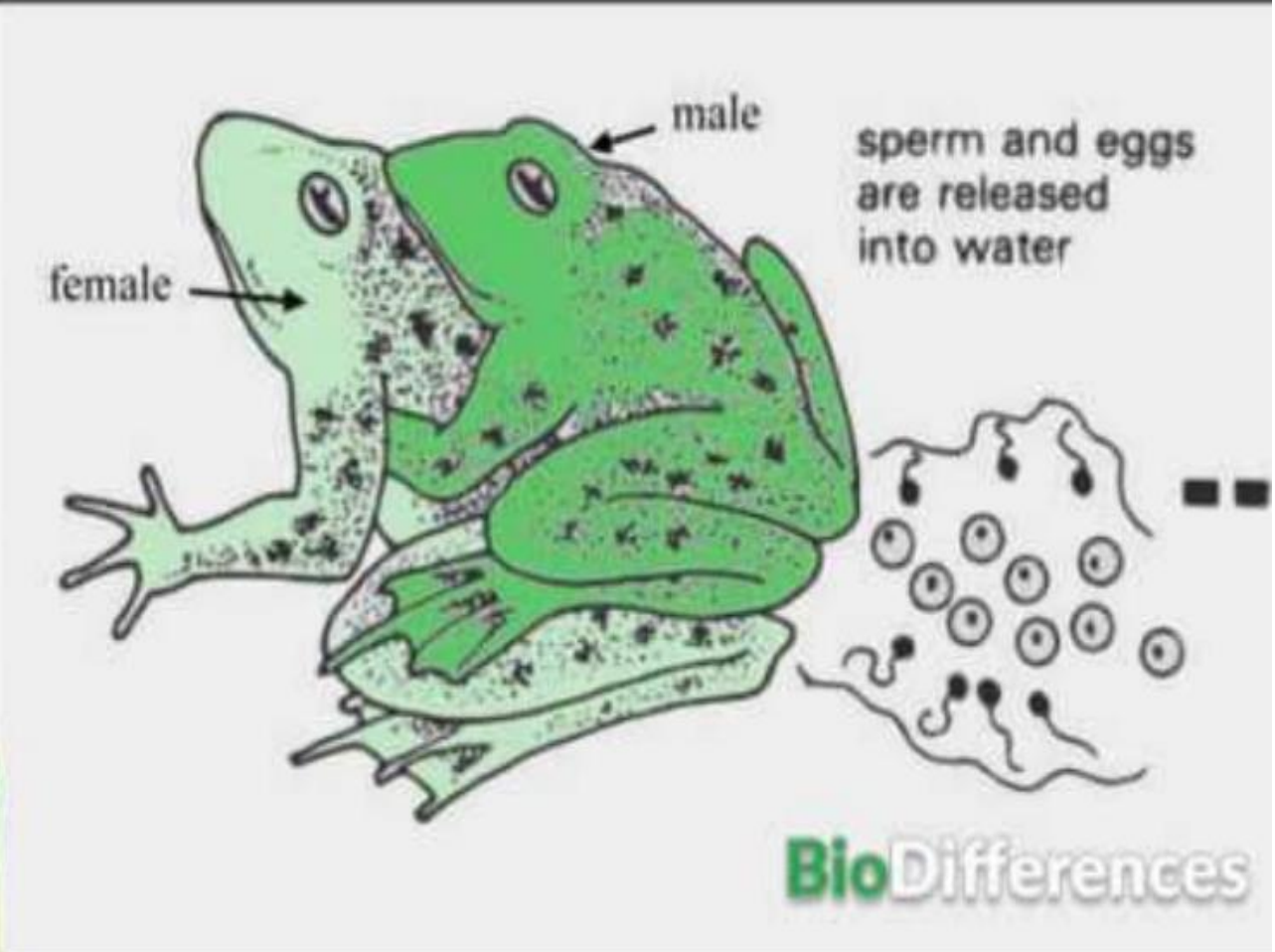
These two forms of selection mean that some individuals have greater reproductive success than others within a population, for example because they are more attractive or prefer more attractive partners to produce offspring.

Successful males benefit from frequent mating and monopolizing access to one or more fertile females. Females can maximise the return on the energy they invest in reproduction by selecting and mating with the best males.

Cost of sexual selection: it involves considerable energy expenditure in locating, attracting and keeping a sexual partner, and also can expose both partners to increased risk of death – from sexual competitors or predators preying on the sexually occupied!

Internal Fertilization VS External Fertilization



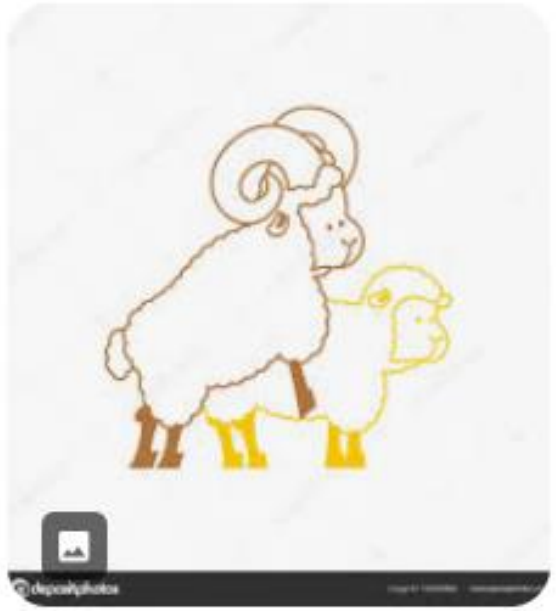


Internal fertilization is a reproduction process that occurs inside the body of the female organism.

This type of fertilization is mostly seen in land animals, birds, reptiles, and **mammals**.

For internal fertilization to take place, the male sperm has to fuse with the female oocyte in the female reproductive tract.

Fertilization in mammals is internal



Oviparity versus viviparity

FEMALE TRACT HAS EVOLVED A DUAL ROLE IN MAMMALS: IT TRANSPORTS SPERMATOZOA TO THE SITE OF FERTILIZATION, AND THEN NOURISHES THE DEVELOPING EMBRYO. THIS DUAL ROLE IMPOSES COMPLEX FUNCTIONAL CHANGES ON THE TRACT, THE SUBJECT OF CHAPTERS 9 AND 10.

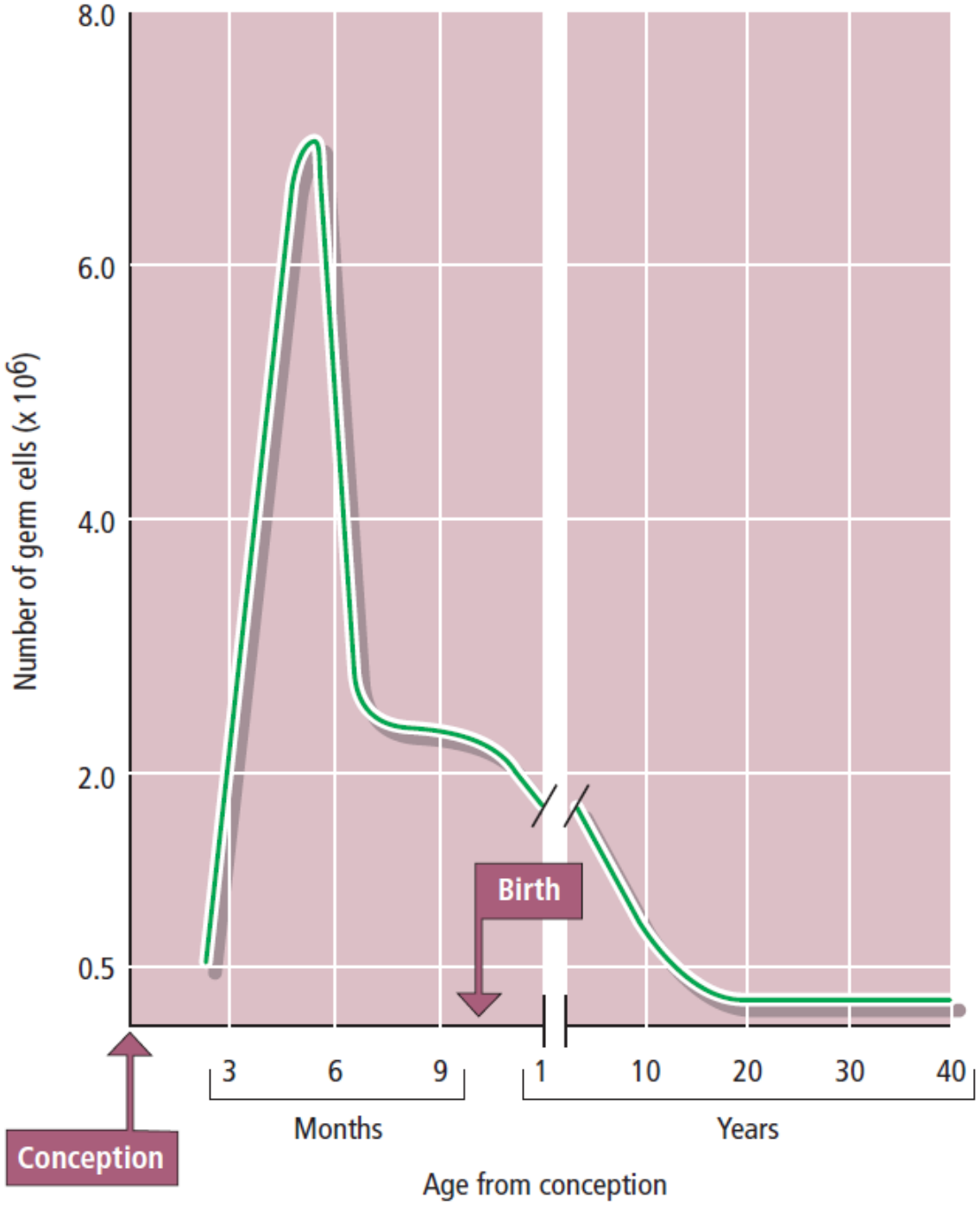
CORRESPONDING CHANGES HAVE EVOLVED IN THE DEVELOPING EMBRYO TO OPTIMIZE ITS NUTRITION. THESE INCLUDE THE DEVELOPMENT OF **SPECIALIZED MEMBRANE SYSTEMS** AND **PLACENTAE** FOR TAPPING INTO MATERNAL

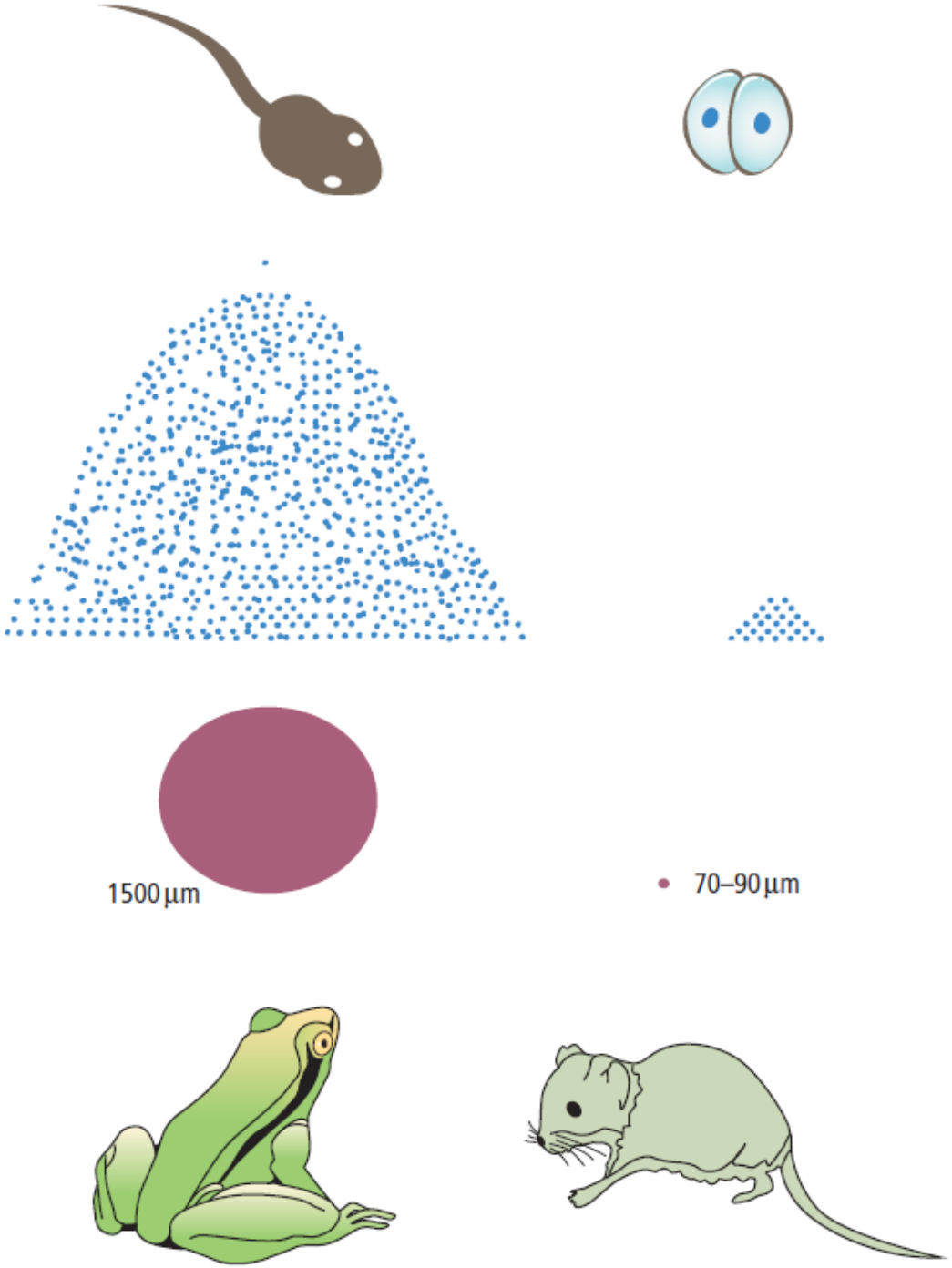
VIVIPARITY INVOLVES RELATIVELY PROLONGED PERIODS OF **GESTATION**, WHICH MAKE MAJOR DEMANDS ON THE **PREGNANT** FEMALE, WHOSE METABOLISM AND PHYSIOLOGY ARE MODIFIED TO MEET THE NEEDS OF THE DEVELOPING **EMBRYO** AND **FETUS** (SEE CHAPTER 14).

PREGNANCY CAN OFTEN GO WRONG – A CONSIDERABLE SELECTIVE COST TO THE SPECIES (SEE CHAPTERS 15 AND 16).

INDEED, A MAJOR SOURCE OF EVOLUTIONARY

Numbers of ovarian germ cells during the life of a human female from conception.





Differences between mammalian and frog eggs.

Frog eggs must carry with them most of what they need to transform into swimming tadpoles that can then feed themselves, something that they do very rapidly!

Mammalian eggs in contrast gain their nutrients for growth from the mother: largely through the placenta

Fecundity (繁殖力) vs. Fertility (生育力)

Fecundity is the capability of an individual or population to produce offspring whereas fertility is the number of offspring produced by the population or the individual.

Fertility is the actual number of offspring produced. The individual capable of reproducing is known as fertile.

Fecundity is the natural ability of a person to reproduce and that depends on the health and availability of healthy and genetics.

On the other hand, fertility is the number of offspring per couple in a population.

Fertility is dependent on various factors, such as lifestyle, stress, emotional and reproductive health, willingness, availability of a potential mating partner, and preventive measures being taken.

Fecundity is not equivalent to fertility as the translation of the ability to reproduce is further dependent on a number of societal, environmental, and physiological factors.

Parental care

THE UNIVERSAL FEATURE UNIQUE TO ALL MAMMALS, AND THROUGH WHICH THEY ARE NAMED, IS THE PRODUCTION OF MILK FROM 'MAMMAE' OR **NIPPLES** TO NURTURE THE NEONATE (SEE CHAPTER 18).

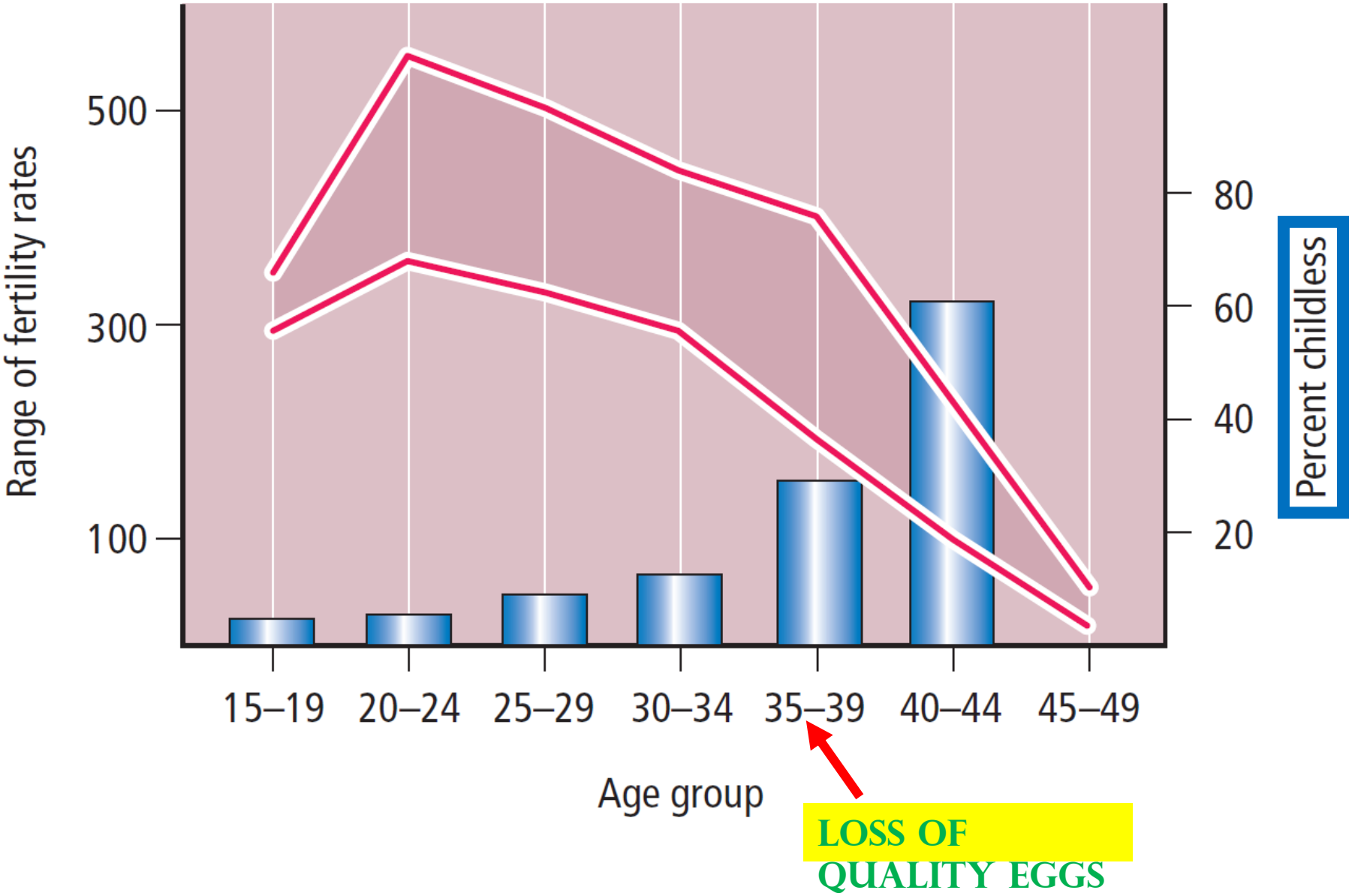
MILK production is just one aspect of the extended period of **parental care** shown by mammals – a further energy investment in just a few young (see Chapter 19).

Reproductive life cycles

WE ARE BORN PHYSICALLY AND SEXUALLY **IMMATURE**. WE THEN SPEND THE 1ST DECADE OF OUR LIFE GROWING AND MATURING PHYSICALLY AND ESTABLISHING AN INDIVIDUAL IDENTITY. SHORTLY THEREAFTER, AT ADOLESCENCE, WE MATURE SEXUALLY AT **PUBERTY** (SEE CHAPTER 3).

BY THE EARLY- TO MID-TEENS, WE ACHIEVE THE CAPACITY TO PRODUCE FERTILE EGGS OR SPERM (SEE CHAPTERS 6–11) AND, IN WOMEN, TO CARRY A PREGNANCY (SEE CHAPTERS 12–17). THIS REPRODUCTIVE CAPACITY, OR **FECUNDITY**, THEN CHARACTERIZES MUCH OF OUR ADULT LIFE.

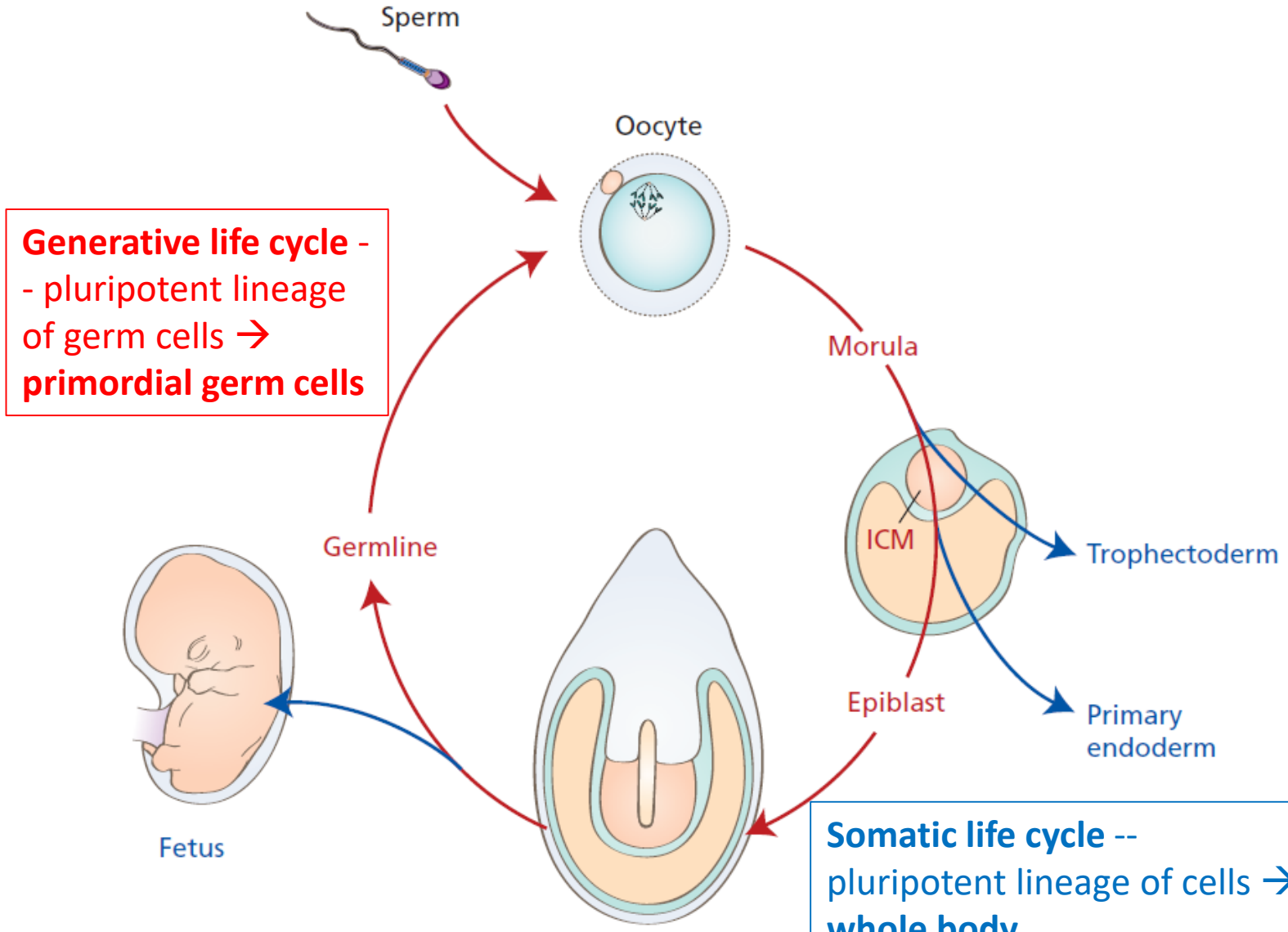
HOWEVER, THERE ARE **DISTINCT DIFFERENCES BETWEEN MEN AND WOMEN IN THEIR LIFE-TIME FECUNDITY** PATTERNS. MALE FECUNDITY, ONCE ACHIEVED, PERSISTS THROUGHOUT LIFE, ALBEIT



Female fecundity is ‘time limited’. Rates of fertility (red range) and childlessness (blue bars) by age of woman.

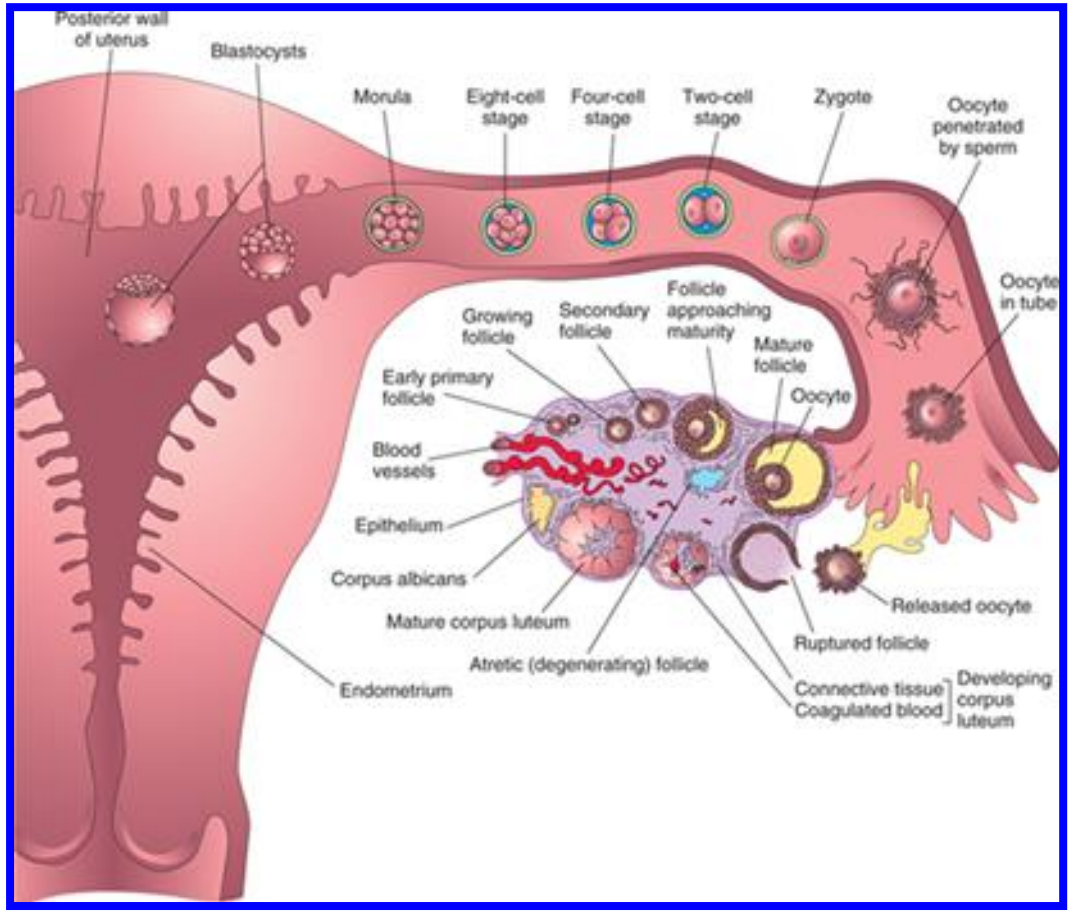
MALE FECUNDITY, ONCE ACHIEVED, PERSISTS THROUGHOUT LIFE, ALBEIT

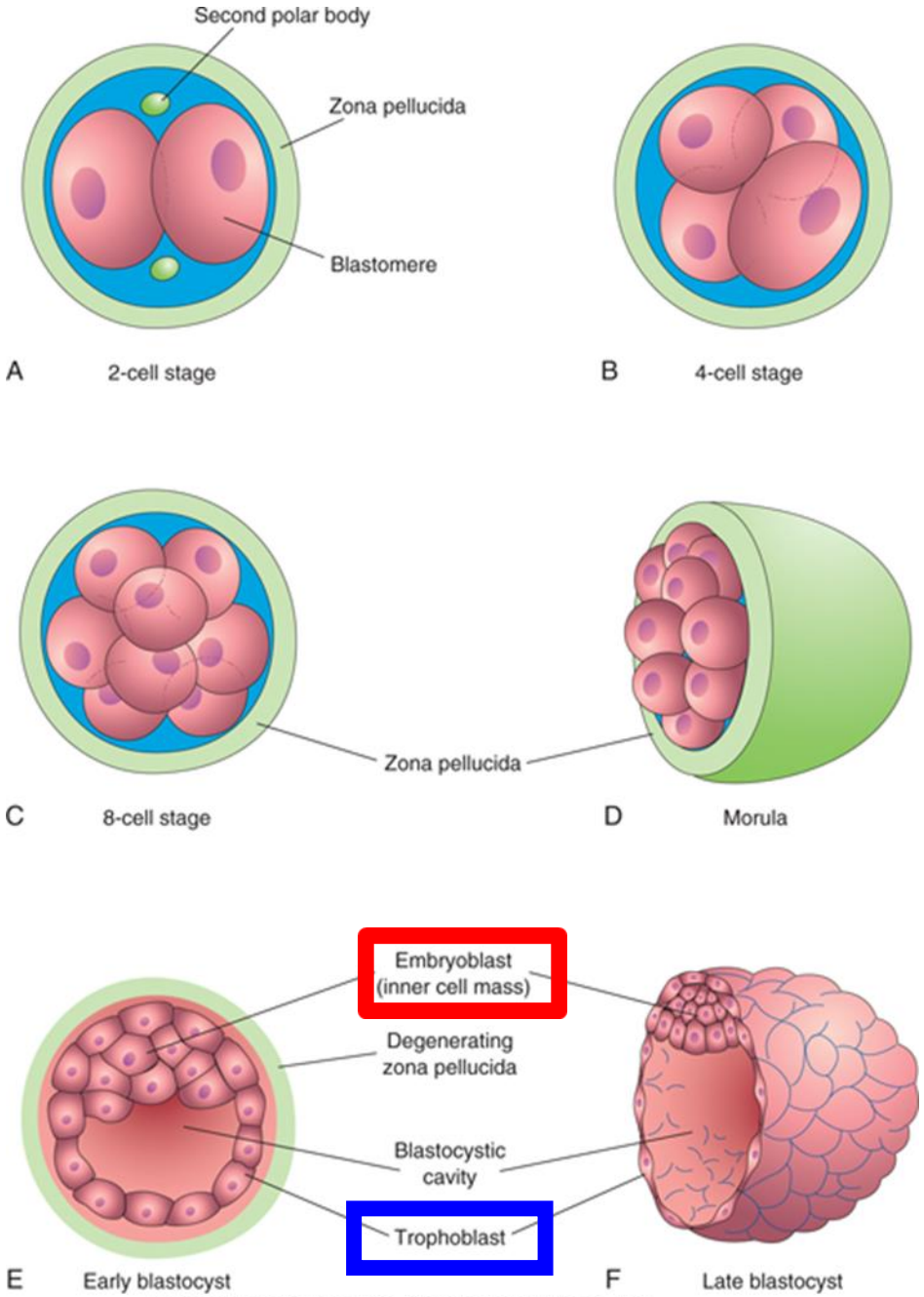
Reproductive life cycles

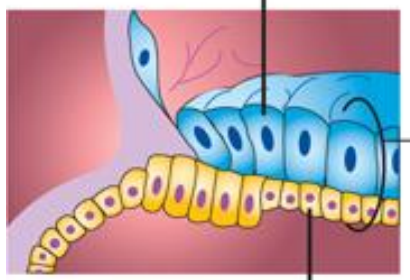


Generative life cycle -- pluripotent lineage of germ cells → **primordial germ cells**

Somatic life cycle -- pluripotent lineage of cells → **whole body**







Bilaminar embryonic disc

Epiblast

Ectoderm of amnion

Embryonic ectoderm

Primitive streak (see Chapter 4)

Extraembryonic mesoderm

Embryonic mesoderm

Notochordal process

Embryonic endoderm

Hypoblast

Endoderm of umbilical vesicle

Extraembryonic mesoderm

ECTODERM (outer layer of embryo)

- Epidermis of skin and its derivatives (including sweat glands, hair follicles)
- Nervous and sensory systems
- Pituitary gland, adrenal medulla
- Jaws and teeth

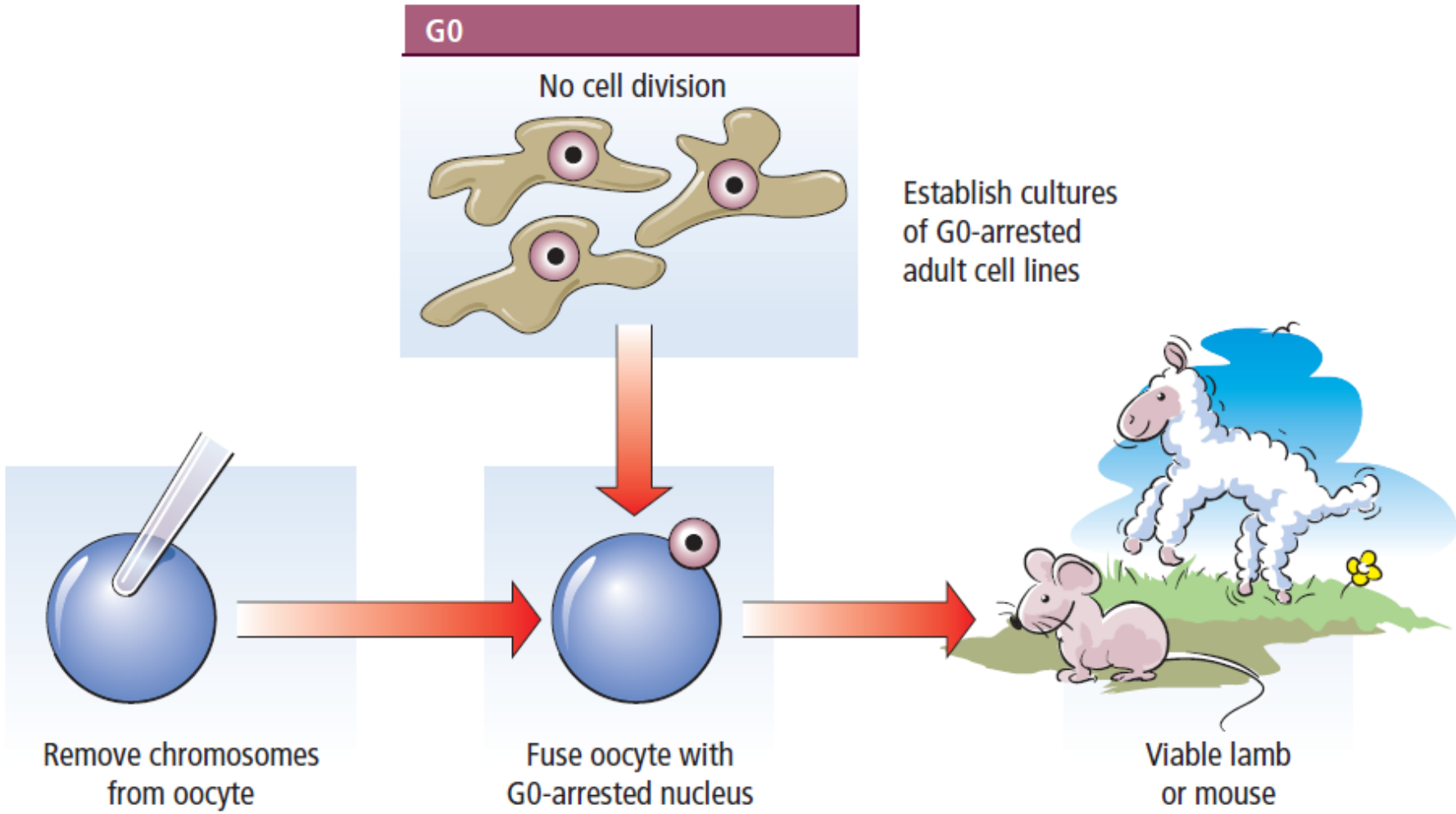
MESODERM (middle layer of embryo)

- Skeletal and muscular systems
- Circulatory and lymphatic systems
- Excretory and reproductive systems (except germ cells)
- Dermis of skin
- Adrenal cortex

ENDODERM (inner layer of embryo)

- Epithelial lining of digestive tract and associated organs (liver, pancreas)
- Epithelial lining of respiratory, excretory, and reproductive tracts and ducts
- Thymus, thyroid, and parathyroid glands
- Germ cells

SOMATIC CELL NUCLEAR TRANSFER (SCNT) IS ALSO KNOWN AS '**reproductive cloning"; Dolly Sheep (**(SEE CHAPTERS 21 AND 22**)! T**he same chromosomal and genetic composition (give or take a few atypical cells) and, moreover, all these genes are functionally competent. We know this because you can take a nucleus from an adult somatic cell and inject it into an enucleated oocyte, where it can then direct the formation of a new individual.



The epigenetic cycle

ALL CELLS HAVE AN IDENTICAL GENETIC MAKE UP, HOW DO CELLS FROM THE PLURIPOTENT LINEAGE DIFFER FROM SOMATIC CELLS?

HUMANS HAVE BETWEEN 20 000 AND 25 000 GENES. OUR GENES, THROUGH THEIR CODE OF DNA TRIPLETS, ENCODE PROTEINS AND IT IS PROTEINS THAT LARGELY MAKE US WHO WE ARE – **GENOTYPE ENCODES PHENOTYPE**.

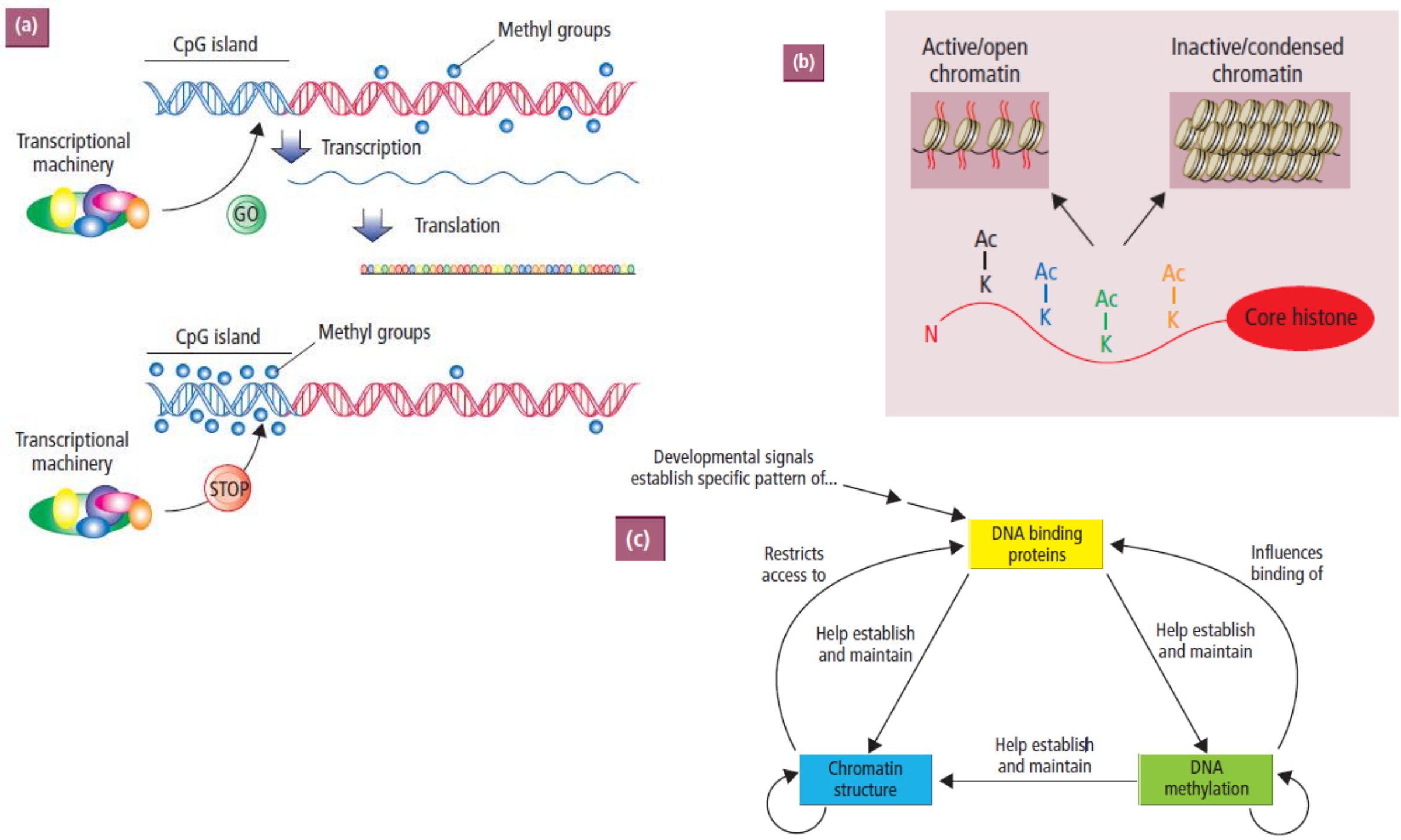
However, only a restricted subset of genes is expressed in any one cell, and that subset is characteristic for each cell type at particular times in its life cycle. Thus, muscle, nerve, skin and gut cells each express different combinations of genes.

They differ in 3 ways:

1. **Th**ey differ in the pattern of chemical modification to certain cytosine bases in the DNA, lacking methyl groups that are present on non-expressing genes: changes in the **DNA methylation patterns** (Figure 1.7a).

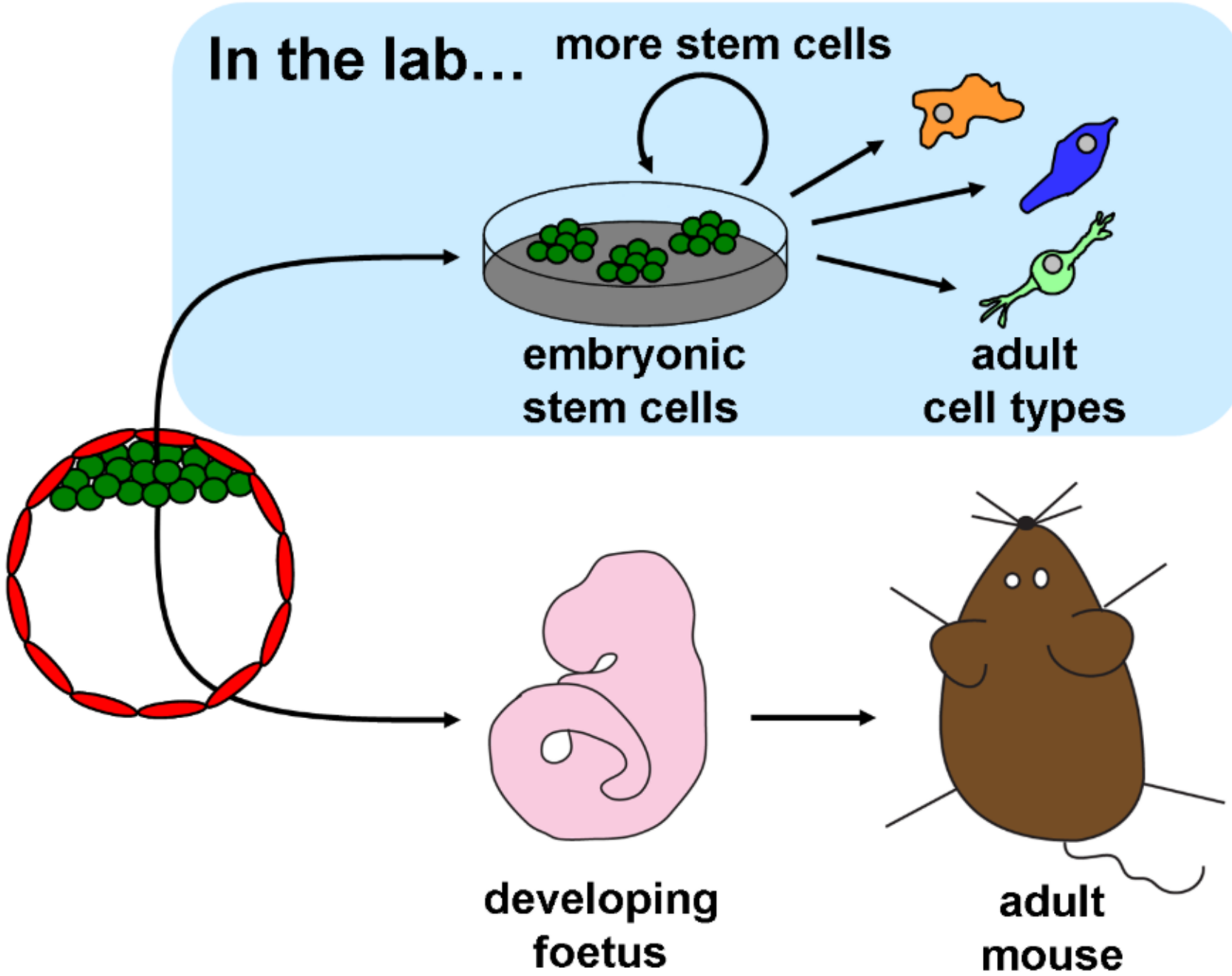
2. **Th**ey are wrapped up in a distinctive subset of associated proteins called **histones** that give the chromatin a distinctive looser **euchromatin structure**.
3. **Th**ese **histones** themselves show characteristic patterns of post-translational modification by **acetylation, methylation**, etc. (Figure 1.7b).

These three processes are each the result of **epigenetic influences** (from *epi* = outside of the genes), which are so called because they do not affect the genetic code itself (which would be a genetic change), but only the gene organization in ways that affect the **capacity of those genes to be expressed** (Figure 1.7c).


(a)
CpG island
Methyl groups
Transcriptional machinery
Transcription
GO
Translation
CpG island
Methyl groups
Transcriptional machinery
STOP
(b)
Active/open chromatin
Inactive/condensed chromatin
Ac
K
Ac
K
Ac
K
Ac
K
N
Core histone
(c)
Developmental signals establish specific pattern of...
DNA binding proteins
Restricts access to
Influences binding of
Help establish and maintain
Help establish and maintain
Help establish and maintain
Chromatin structure
DNA methylation

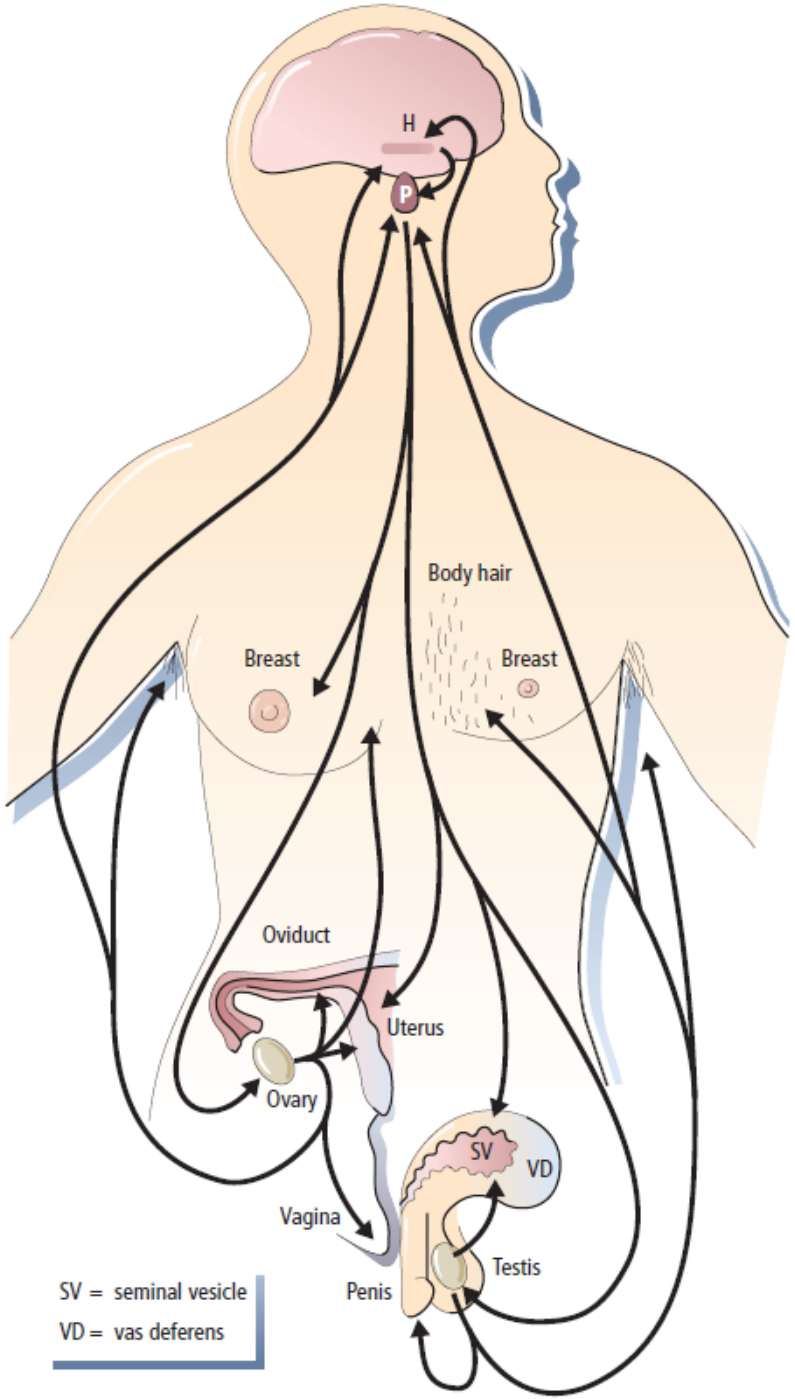
THE PLURIPOTENT GERM CELL LINEAGE ARE CHARACTERIZED BY QUITE DISTINCTIVE EPIGENETIC PATTERNS FROM THOSE IN NON-PLURIPOTENT SOMATIC CELLS.

HOW THIS DISTINCTIVE cycle of epigenetic patterning IS CONTROLLED IS THE SUBJECT OF INTENSE STUDY.


In the lab…
more stem cells
embryonic stem cells
adult cell types
developing foetus
adult mouse

THESE PLURIPOTENT CELLS CAN NOW BE ISOLATED AND PERSUADED TO GROW INDEFINITELY *in vitro* AS **EMBRYONIC STEM CELLS (ESCS)**. ESCS, GIVEN THEIR PLURIPOTENCY, HAVE MEDICAL PROMISE AS SOURCES OF REPAIR FOR DAMAGED TISSUES (SEE CHAPTERS 21 AND 22).

The reproductive body



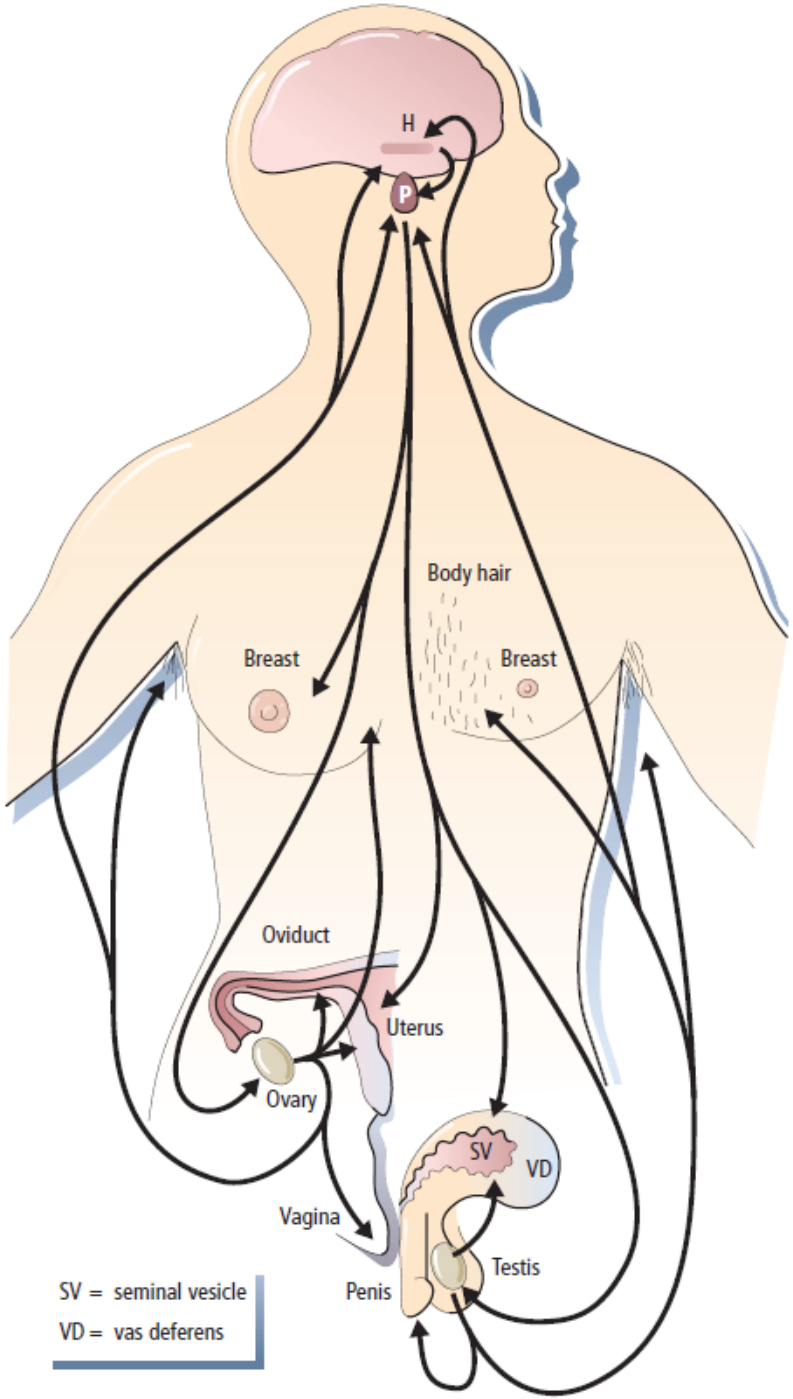
HUMAN FEMALE **OOCYTE** AND THE MALE **SPERMATOZOON:**

HUMAN MALE (FIGURE 1.8) DEVELOPS OBVIOUS **EXTERNAL GENITALIA** AND A SYSTEM OF INTERNAL DUCTS AND GLANDS THAT CONVEYS THE SPERMATOZOA IN **SEMINAL FLUID** FROM THE TESTIS TO THE **PENIS** AND THENCE REPRODUCTIVELY TO THE **VAGINA** (SEE CHAPTERS 9 AND 10), BUT HAS AN INTERNAL SYSTEM OF DUCTS THAT ACCOMMODATE THE ERECT PENIS AND ITS EJACULATED SPERMATOZOA AND TRANSPORT SOME OF THEM THROUGH THE **CERVIX** AND **UTERUS** TO THE **OVIDUCT** (OR **FALLOPIAN TUBE**).

FEMALE DEVELOPS LESS PROMINENT EXTERNAL GENITALIA (SEE CHAPTERS 9 AND 10), BUT HAS AN

7 AND 10)

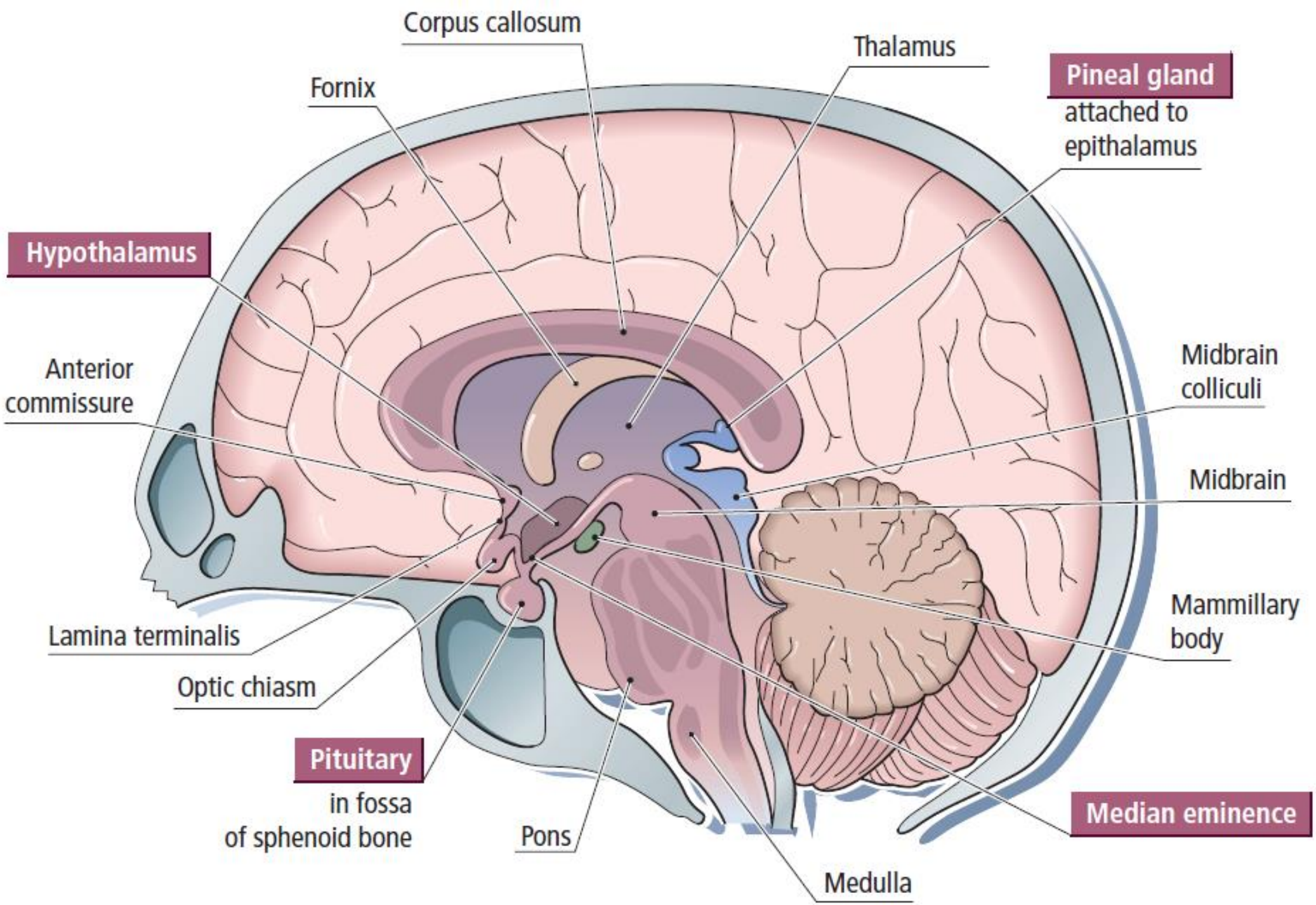
The oviduct is the site of fertilization, but the fertilized oocyte must then pass back to the uterus to **implant** and **gestate** until delivery through the cervix and vagina (see Chapters 11–17).

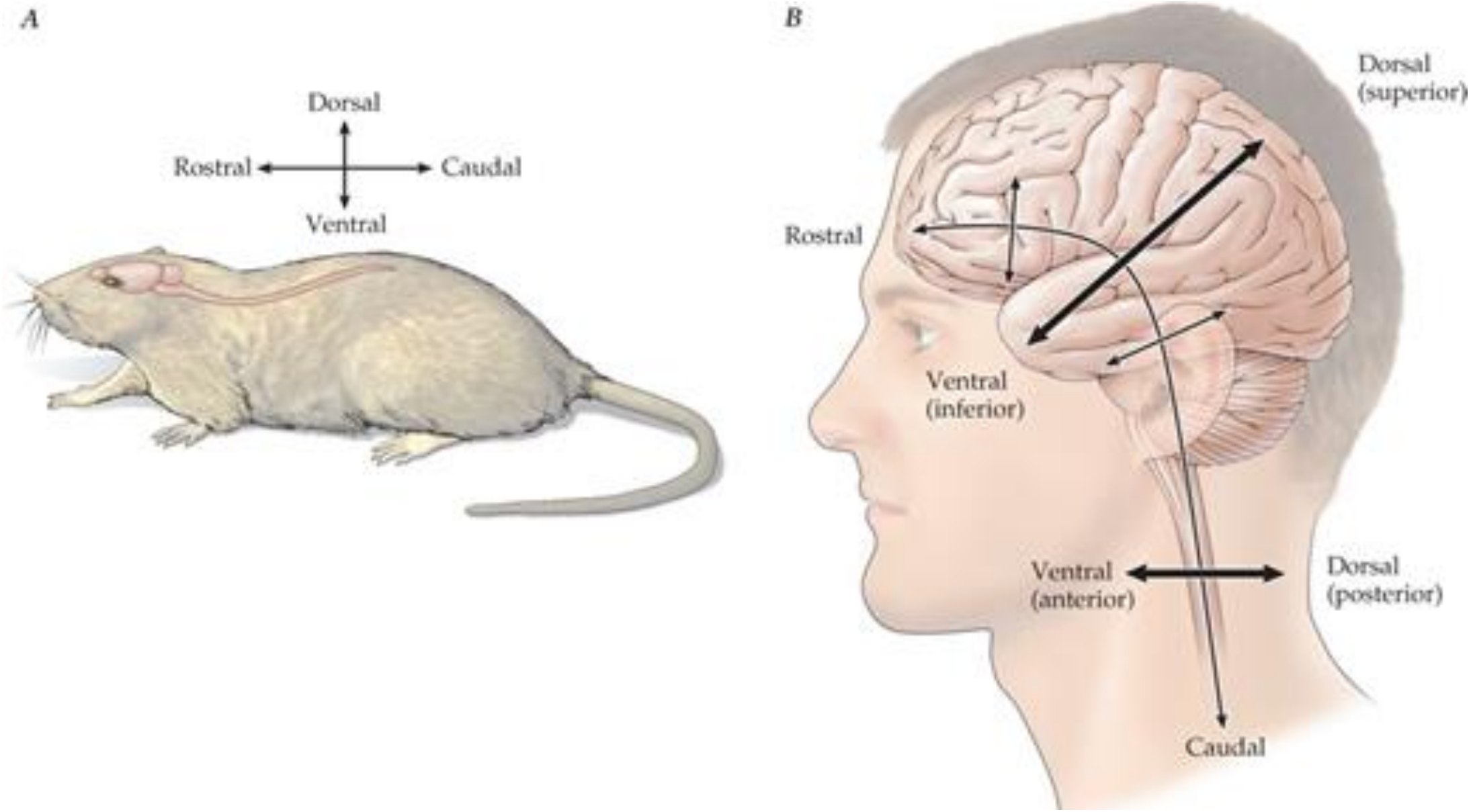


THE BASIC ANATOMICAL DIFFERENCES BETWEEN MEN AND WOMEN ARE ROOTED IN THEIR DIFFERENT REPRODUCTIVE ROLES. IN ADDITION TO THE PRODUCTION OF DIFFERENT GAMETES, EACH GONAD ALSO HAS A DISTINCTIVE PATTERN OF HORMONE PRODUCTION, NOTABLY OF THE **SEX STEROID HORMONES**.
HOWEVER, THE SEX STEROIDS DO NOT ACT ALONE BUT IN CONJUNCTION WITH A RANGE OF OTHER HORMONES AS WELL AS WITH THE NERVOUS SYSTEM.

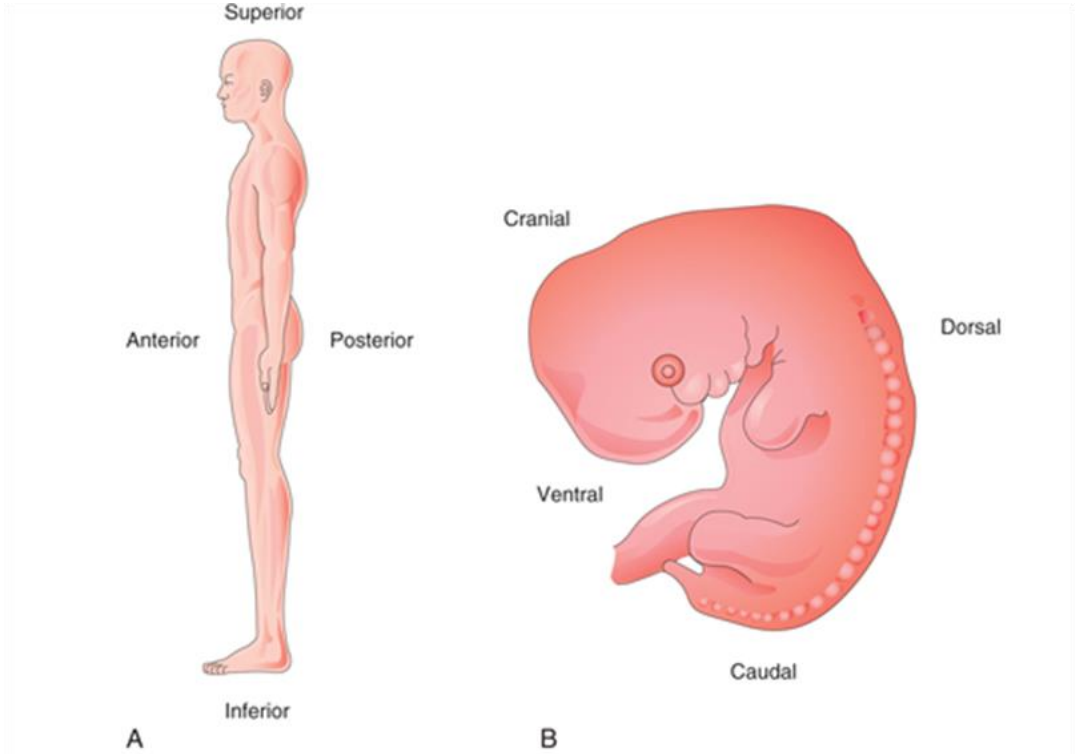
KEY HORMONES AMONGST THESE ARE THE **GONADOTROPHINS AND PROLACTIN**, LARGE PROTEINACEOUS HORMONES PRODUCED BY THE **PITUITARY GLAND**, AND SOME SMALLER HORMONES PRODUCED BY THE **HYPOTHALAMUS – OXYTOCIN, GONADOTROPHIN**

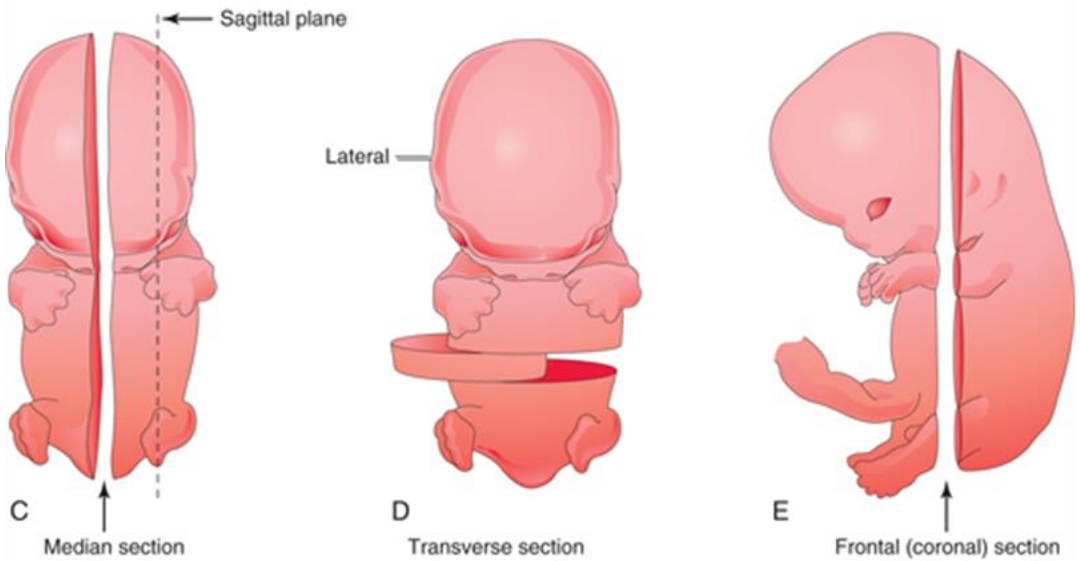
Brain, Hypothalamus and Pituitary


Corpus callosum
Thalamus
Fornix
Pineal gland
attached to
epithalamus
Hypothalamus
Anterior
commissure
Midbrain
colliculi
Midbrain
Lamina terminalis
Mammillary
body
Optic chiasm
Pituitary
in fossa
of sphenoid bone
Pons
Median eminence
Medulla



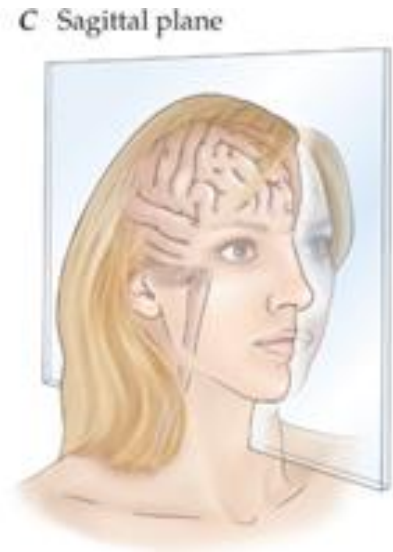
Textbook FIGURE 1–16.
The axes of the central nervous system are illustrated for the rat (A), an animal whose central nervous system is organized in a linear fashion, and the human (B), whose central nervous system has a prominent flexure at the midbrain. (Reproduced with permission from Martin JH. Neuroanatomy: Text & Atlas, 2nd ed. Stamford, CT: Appleton & Lange; 1996.)

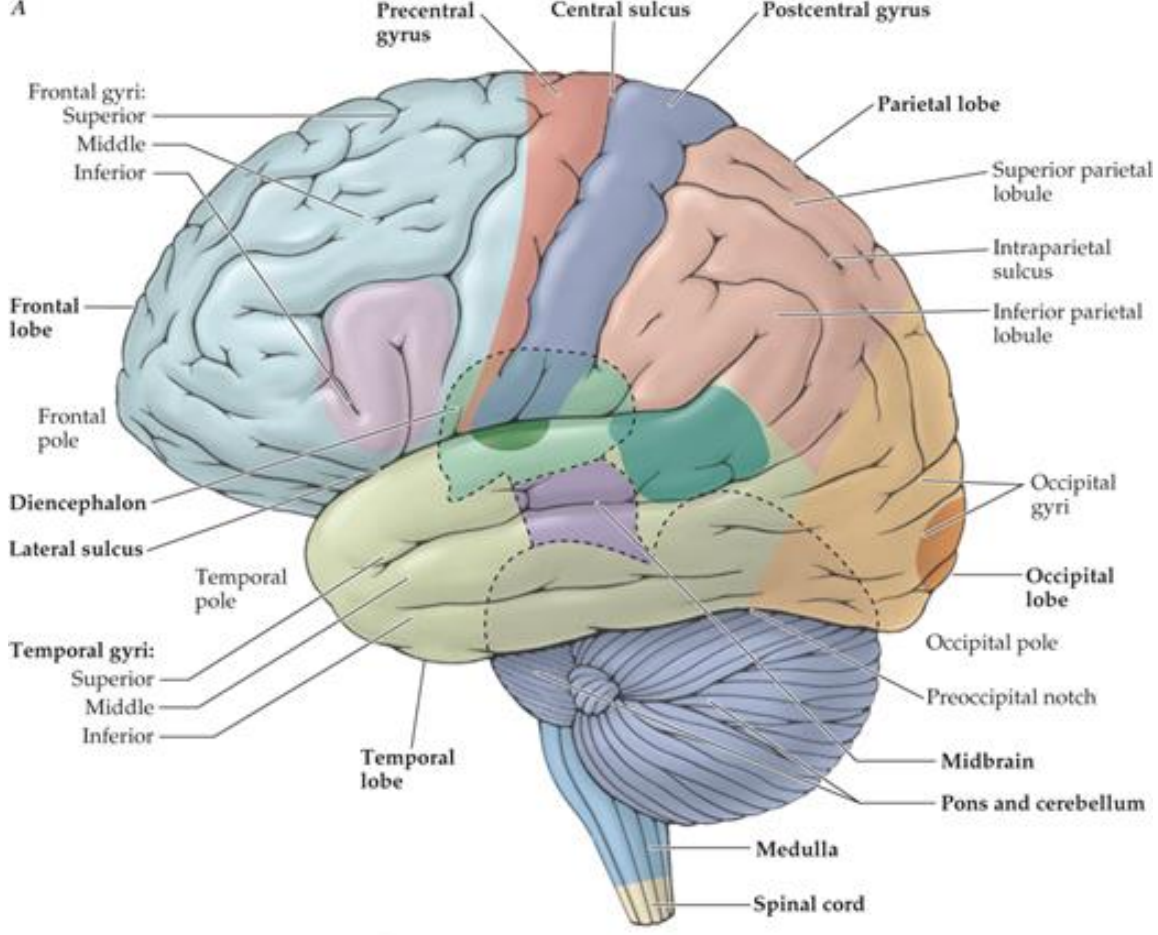

Superior
Anterior
Posterior
Inferior
A
Cranial
Dorsal
Ventral
Caudal
B

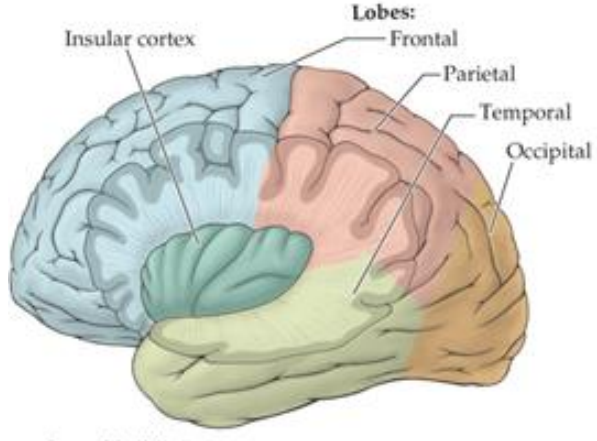

Sagittal plane
C
Median section
Lateral
D
Transverse section
E
Frontal (coronal) section

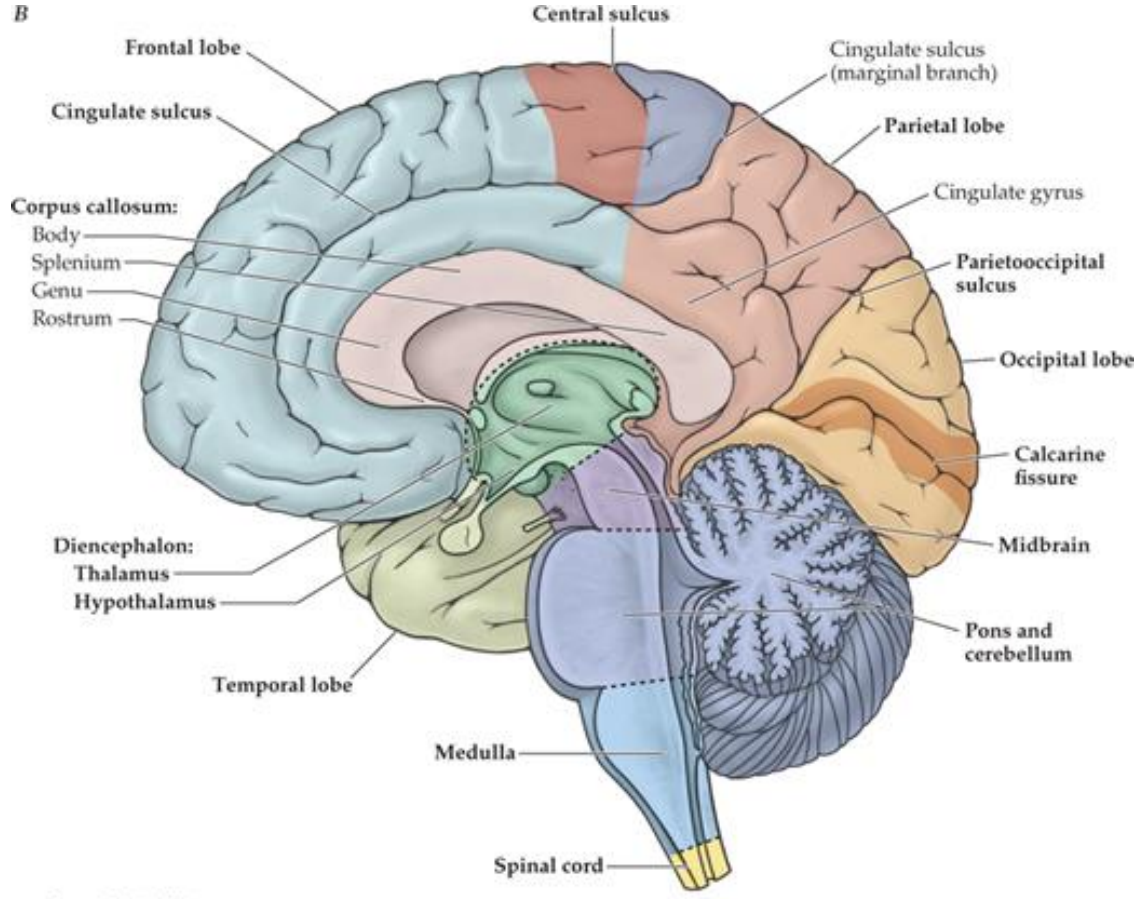

A Horizontal plane

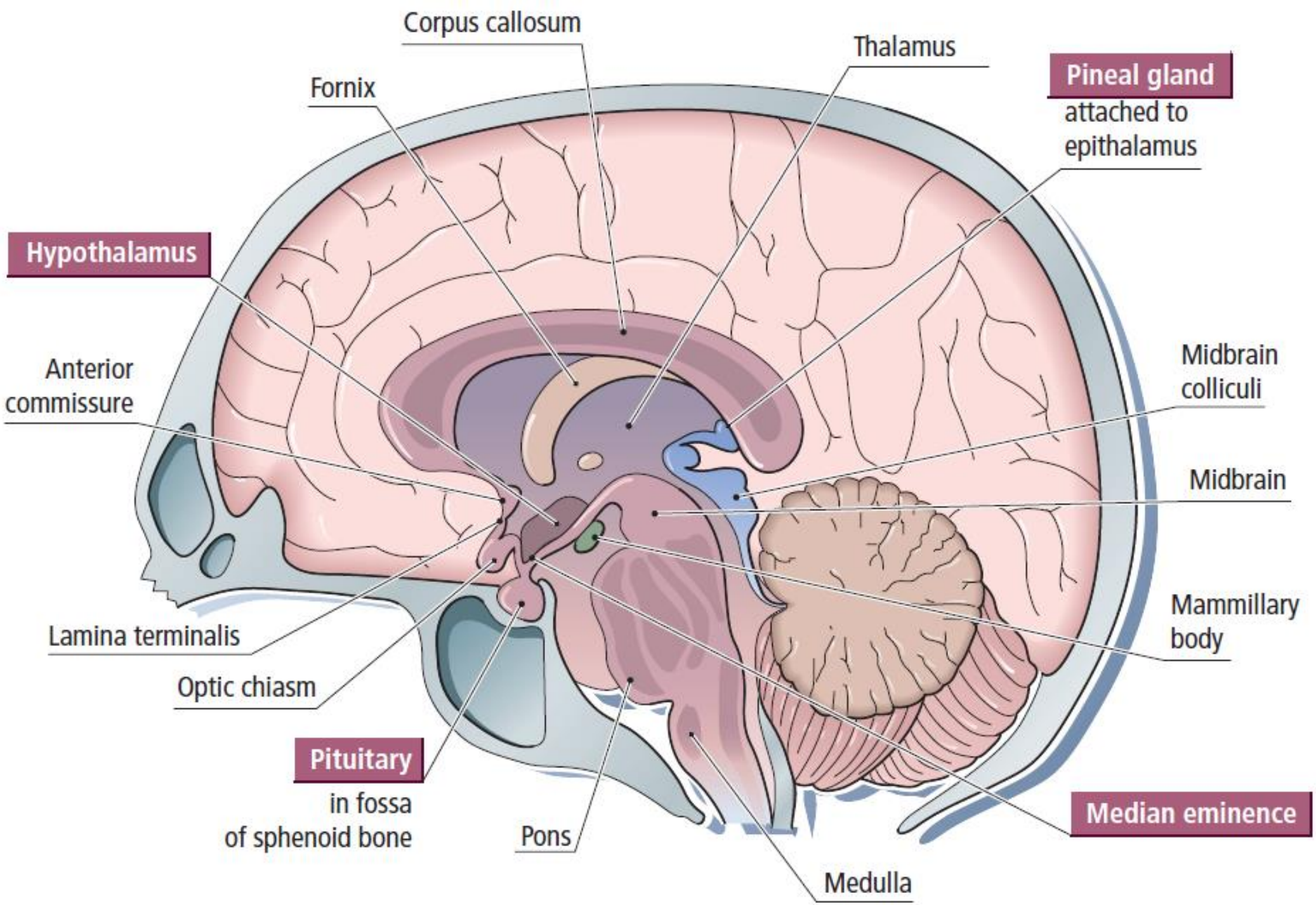

B Coronal plane


C Sagittal plane








Corpus callosum
Thalamus
Fornix
Pineal gland
attached to
epithalamus
Hypothalamus
Anterior
commissure
Midbrain
colliculi
Midbrain
Lamina terminalis
Mammillary
body
Optic chiasm
Pituitary
in fossa
of sphenoid bone
Pons
Median eminence
Medulla

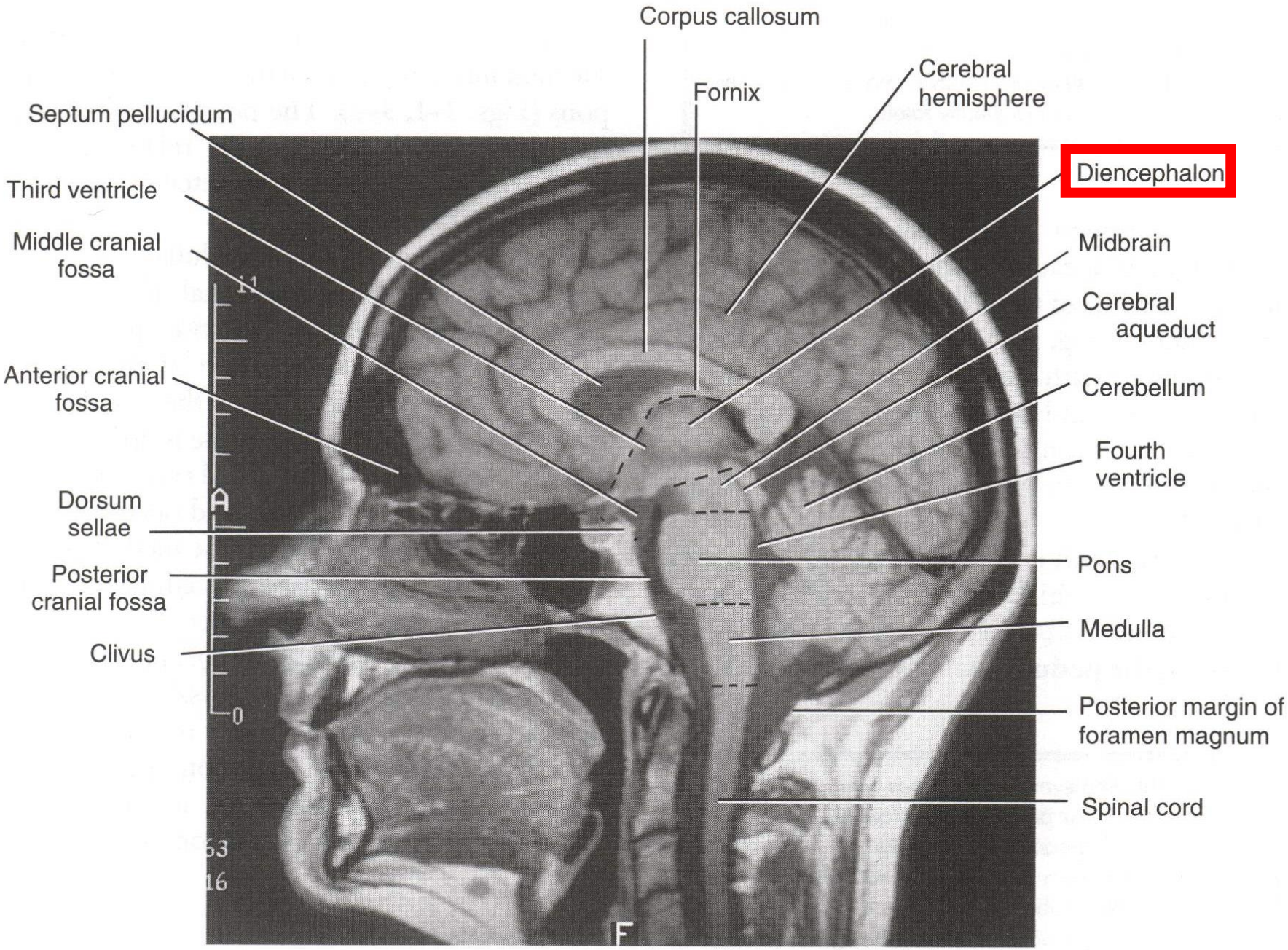
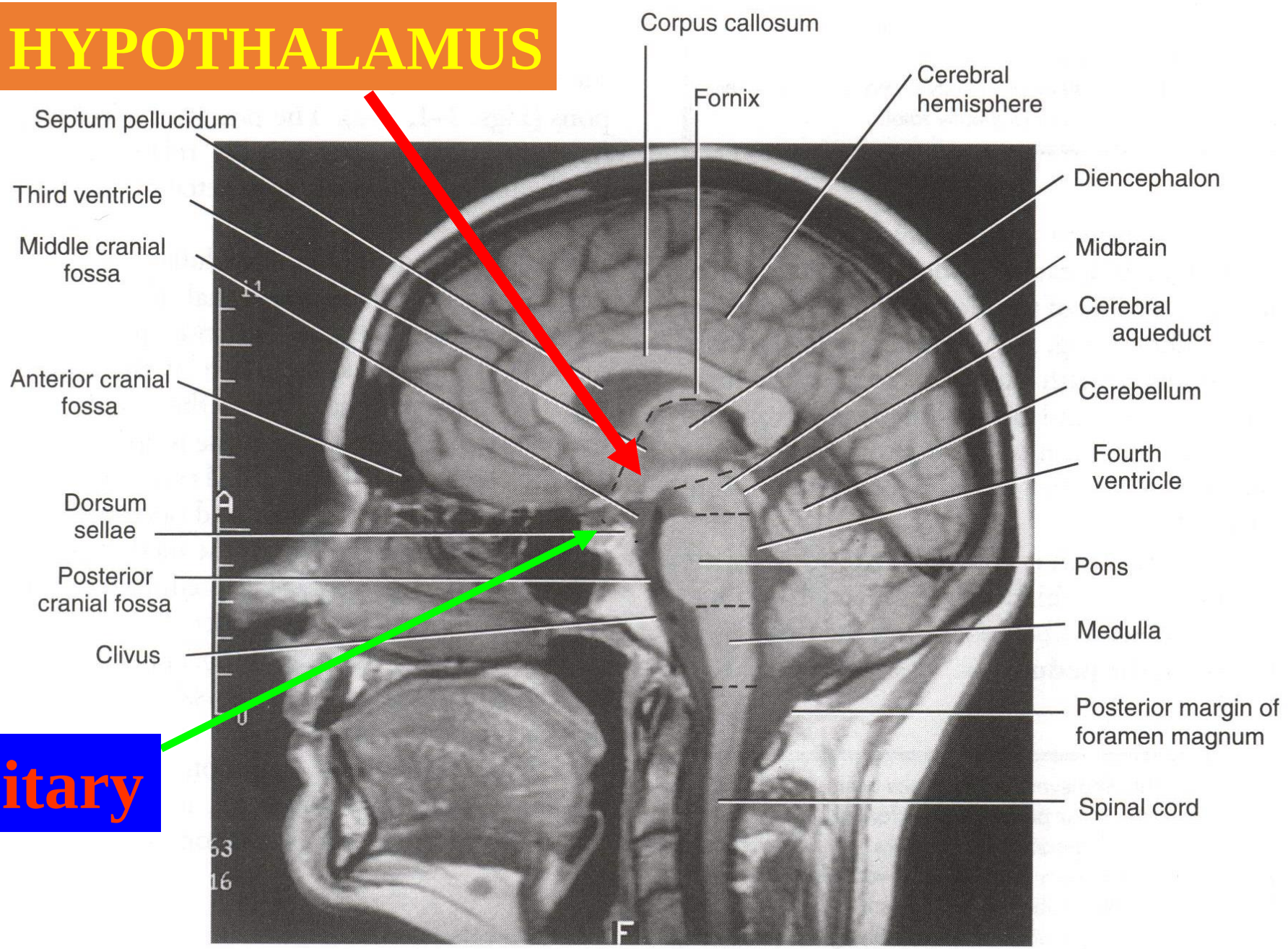


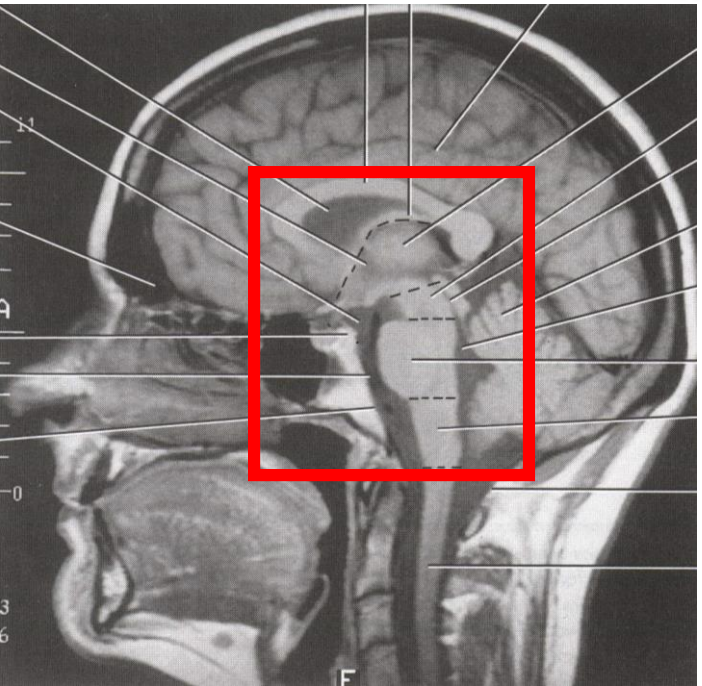
FIGURE 3–2. MRI median view of right half of brain.

HYPOTHALAMUS



Pituitary

FIGURE 3–2. MRI median view of right half of brain.



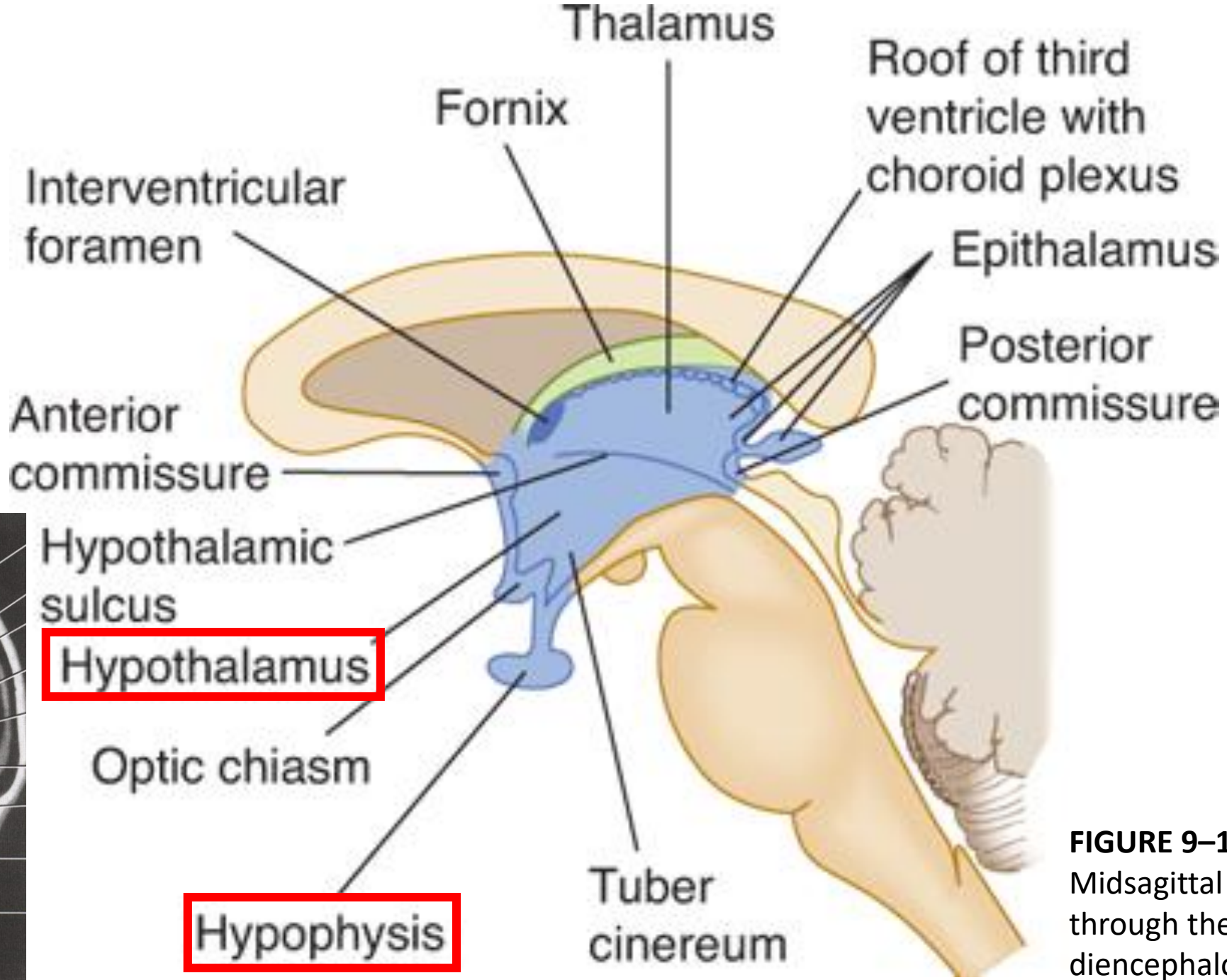
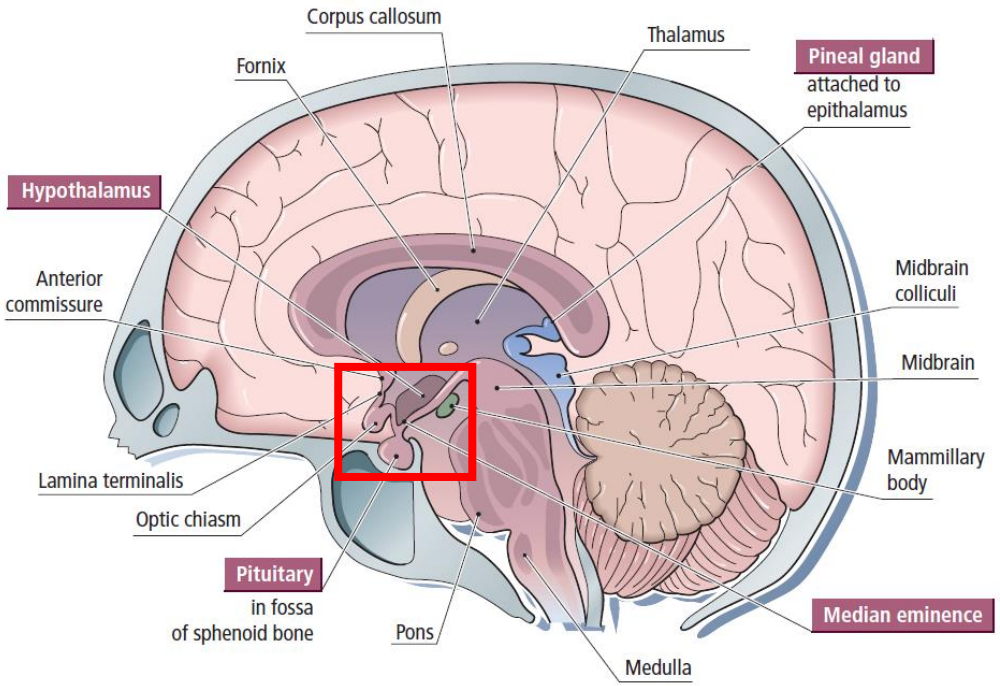
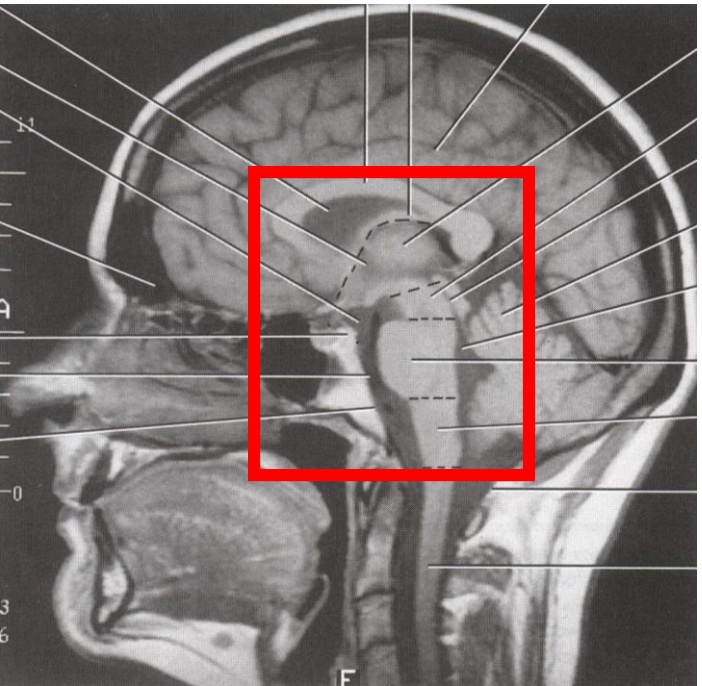
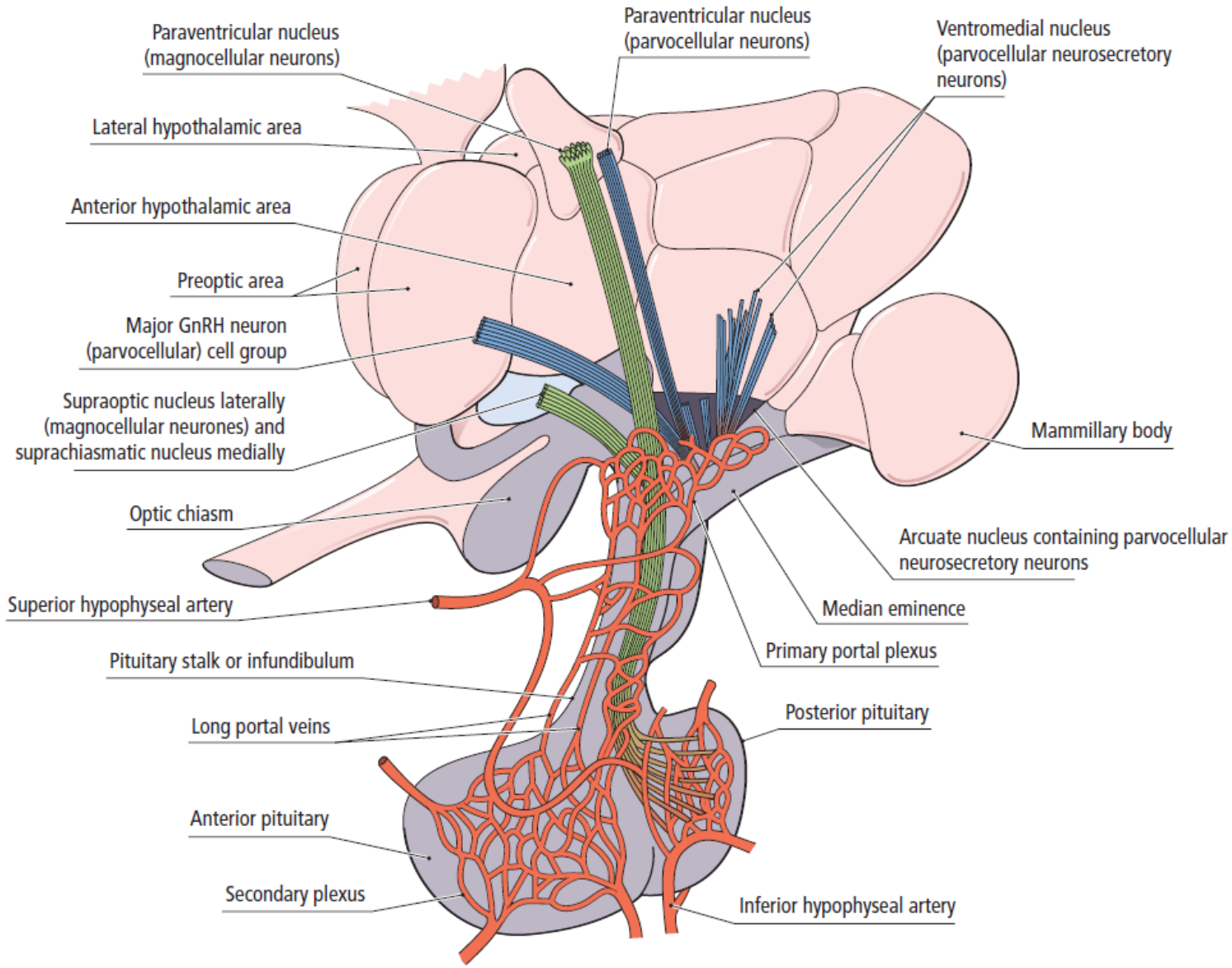
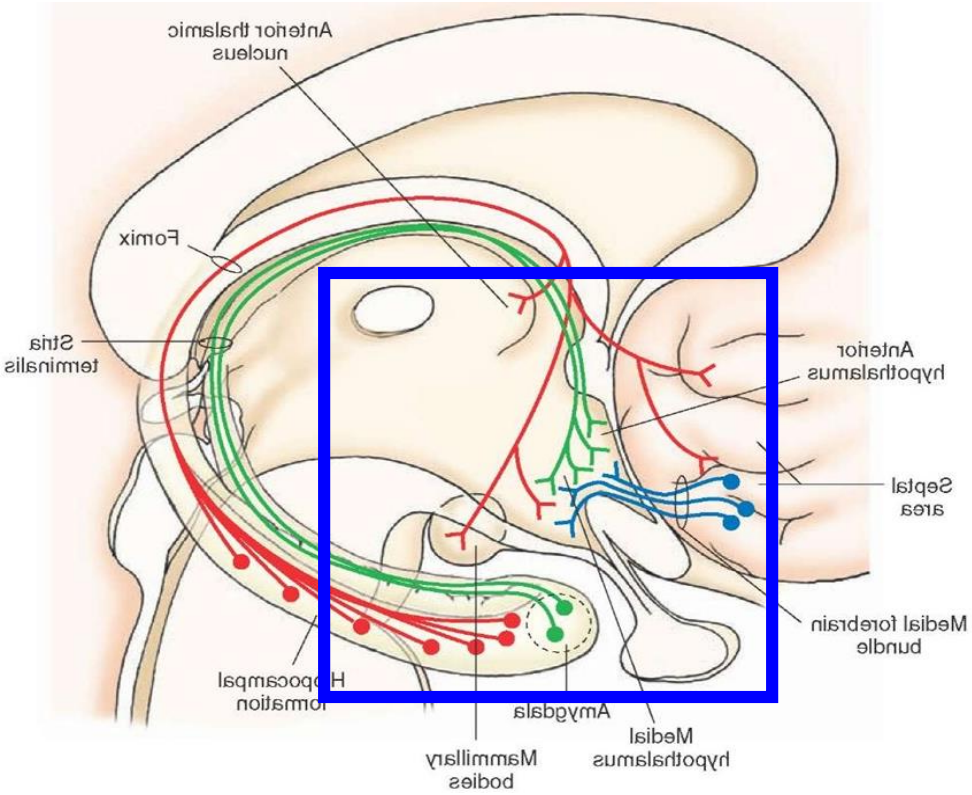


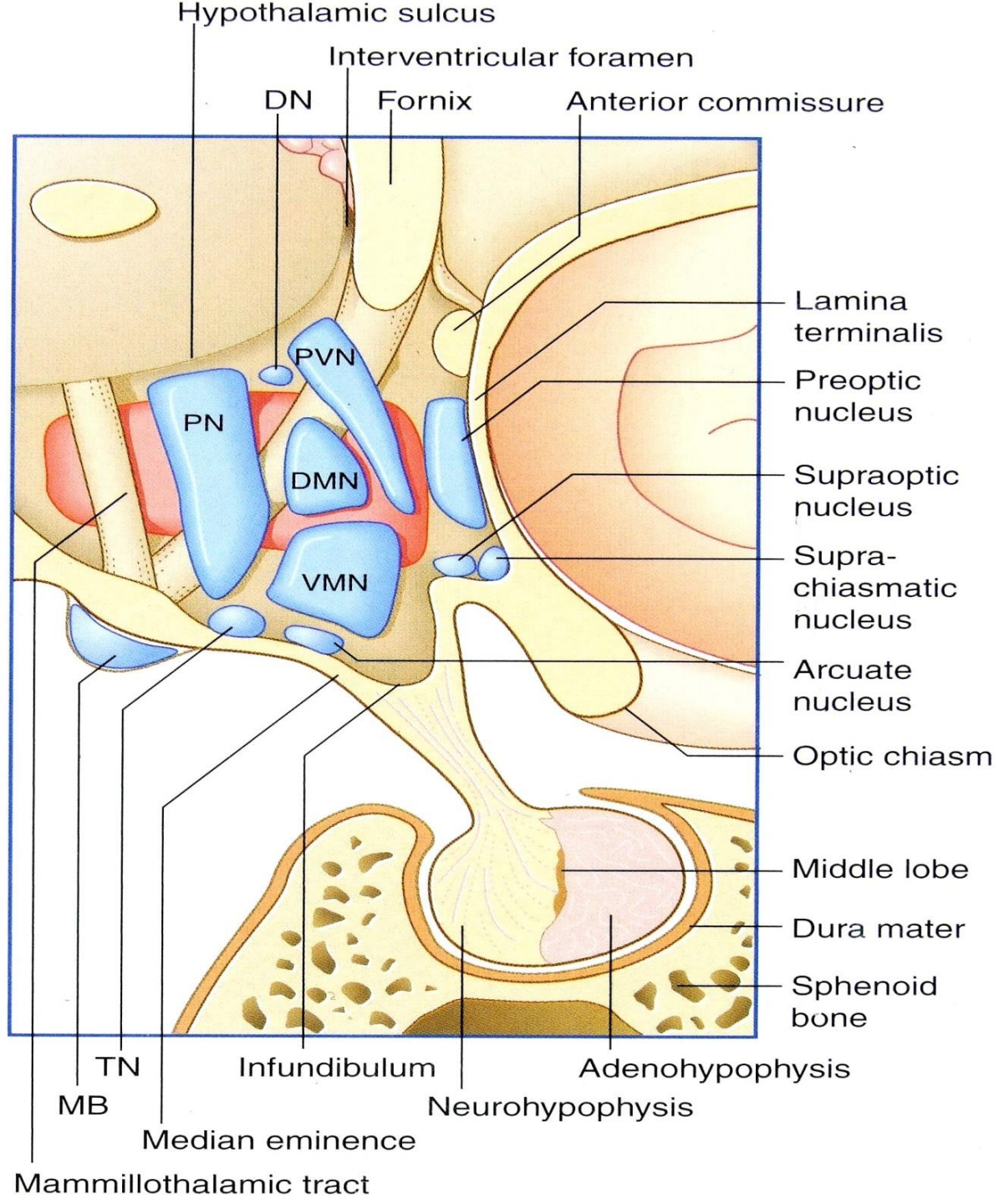
FIGURE 9–1
Midsagittal section through the diencephalon.

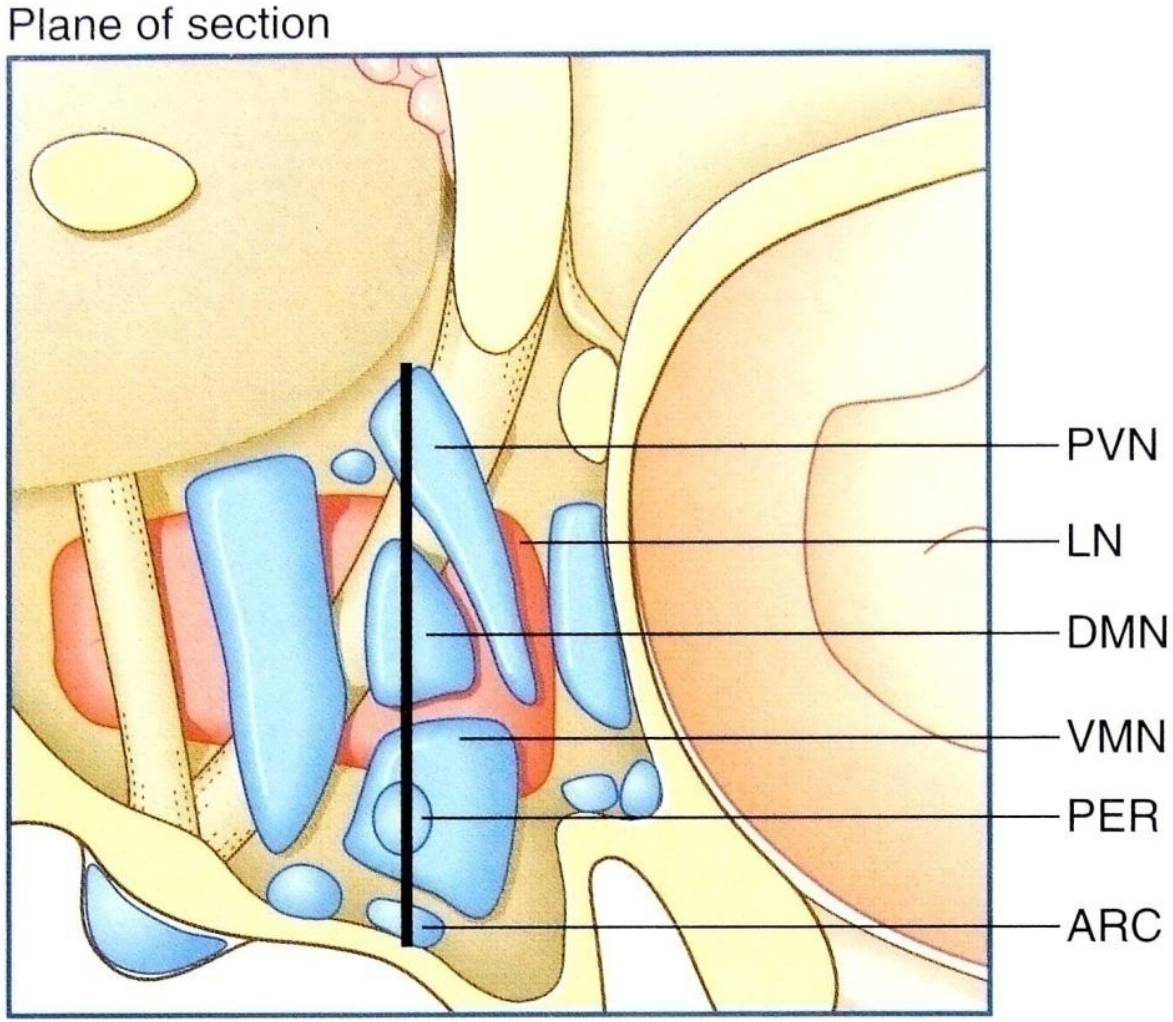

Corpus callosum
Thalamus
Fornix
Pineal gland
attached to
epithalamus
Hypothalamus
Anterior
commissure
Midbrain
colliculi
Midbrain
Mammillary
body
Lamina terminalis
Optic chiasm
Pituitary
in fossa
of sphenoid bone
Pons
Median eminence
Medulla

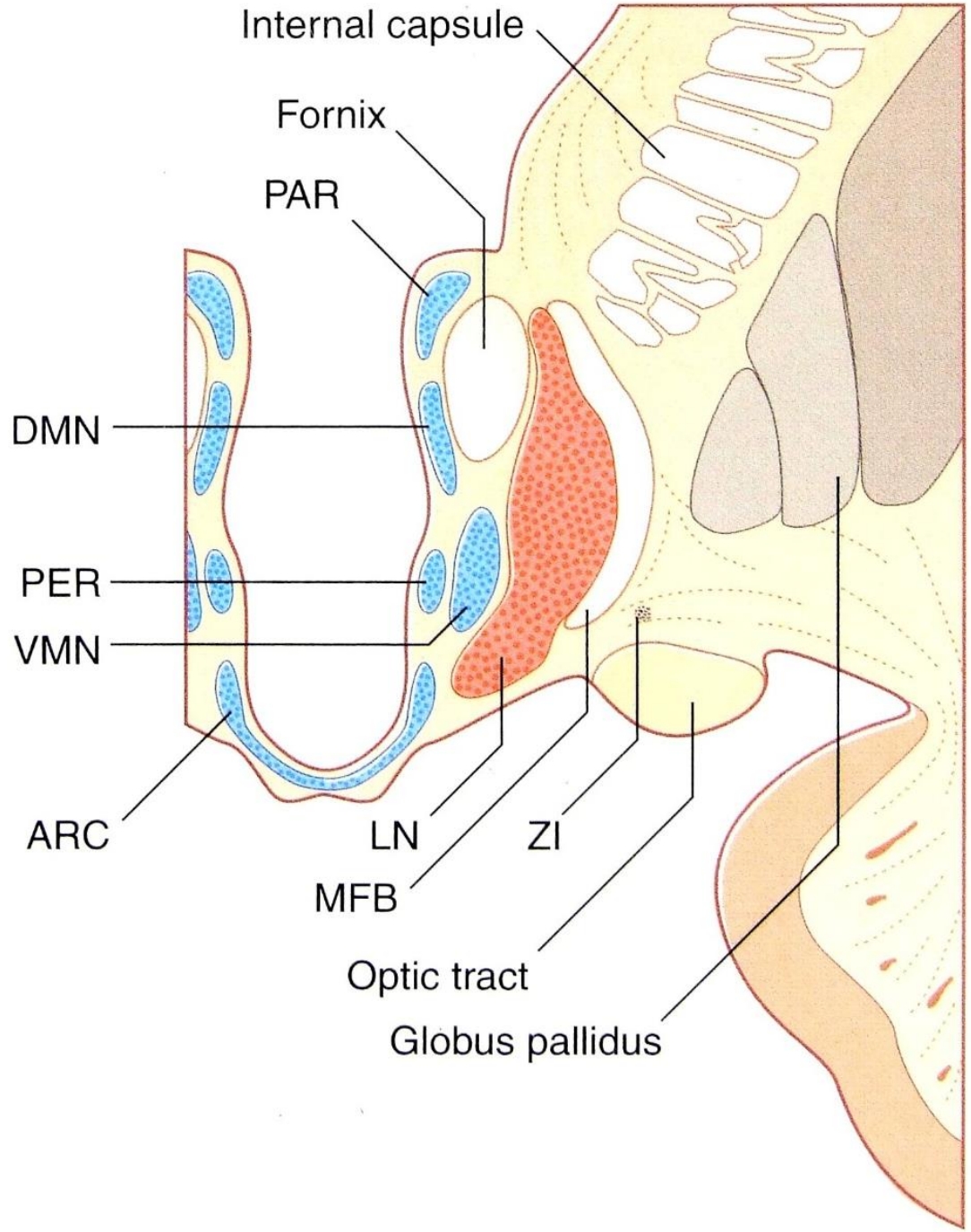


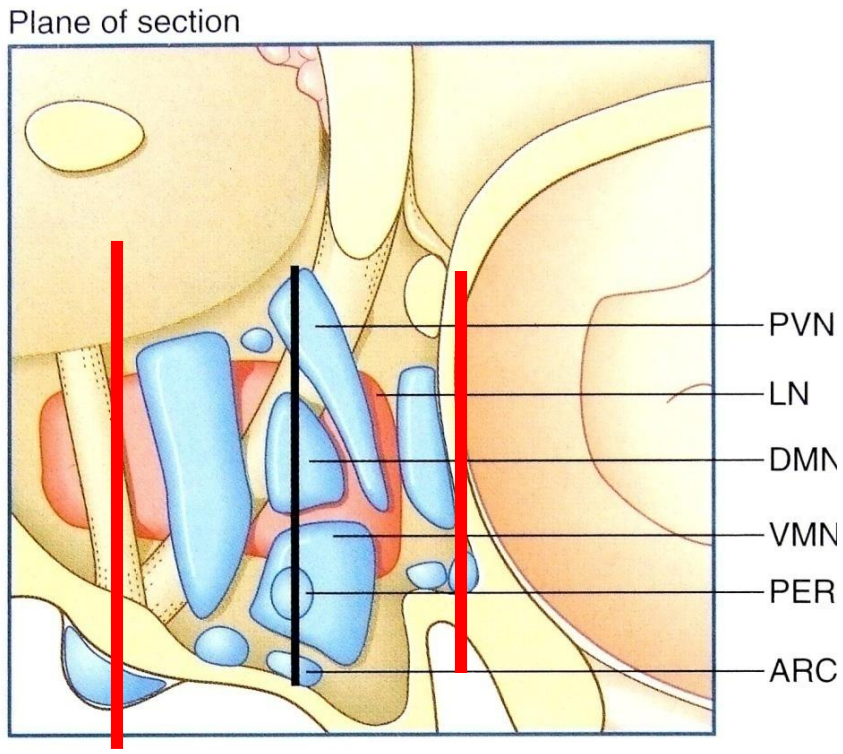

Paraventricular nucleus
(magnocellular neurons)
Paraventricular nucleus
(parvocellular neurons)
Ventromedial nucleus
(parvocellular neurosecretory
neurons)
Lateral hypothalamic area
Anterior hypothalamic area
Preoptic area
Major GnRH neuron
(parvocellular) cell group
Supraoptic nucleus laterally
(magnocellular neurones) and
suprachiasmatic nucleus medially
Optic chiasm
Mammillary body
Arcuate nucleus containing parvocellular
neurosecretory neurons
Median eminence
Primary portal plexus
Superior hypophyseal artery
Pituitary stalk or infundibulum
Posterior pituitary
Long portal veins
Anterior pituitary
Secondary plexus
Inferior hypophyseal artery

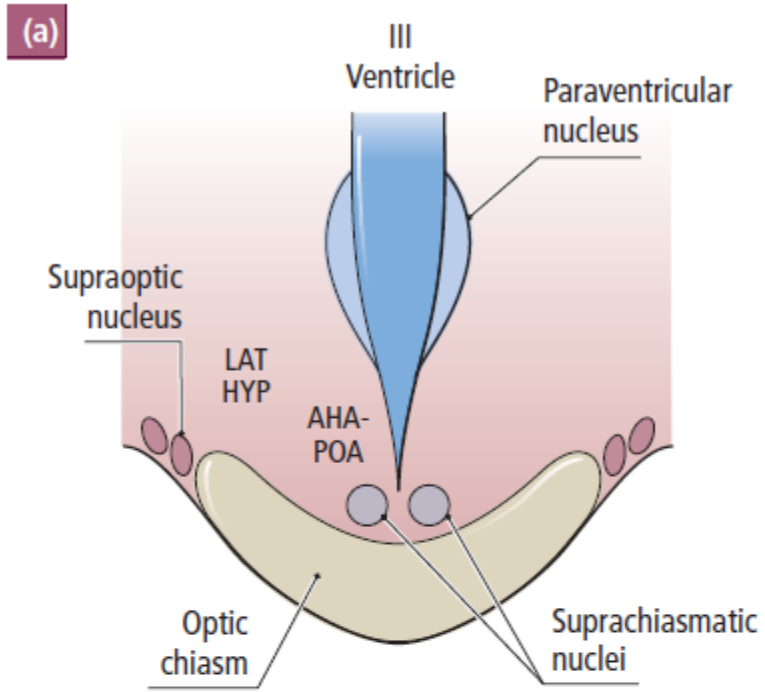

Anterior thalamic nucleus
Fornix
Stria terminalis
Anterior hypothalamus
Septal area
Medial forebrain bundle
Hippocampal formation
Amygdala
Mammillary bodies
Medial hypothalamus

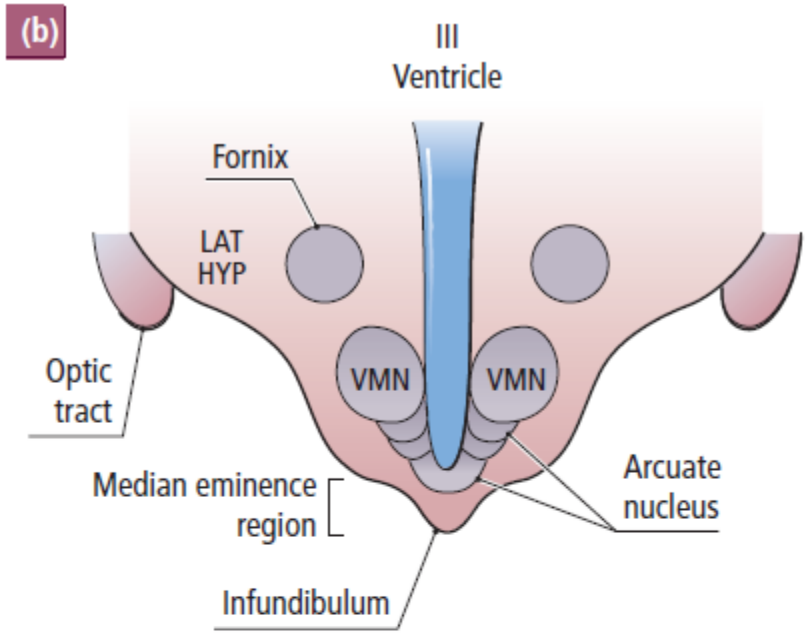

Hypothalamic sulcus
Interventricular foramen
DN
Fornix
Anterior commissure
PVN
PN
DMN
VMN
Lamina terminalis
Preoptic nucleus
Supraoptic nucleus
Supra-chiasmatic nucleus
Arcuate nucleus
Optic chiasm
Middle lobe
Dura mater
Sphenoid bone
TN
MB
Infundibulum
Adenohypophysis
Neurohypophysis
Median eminence
Mammillothalamic tract

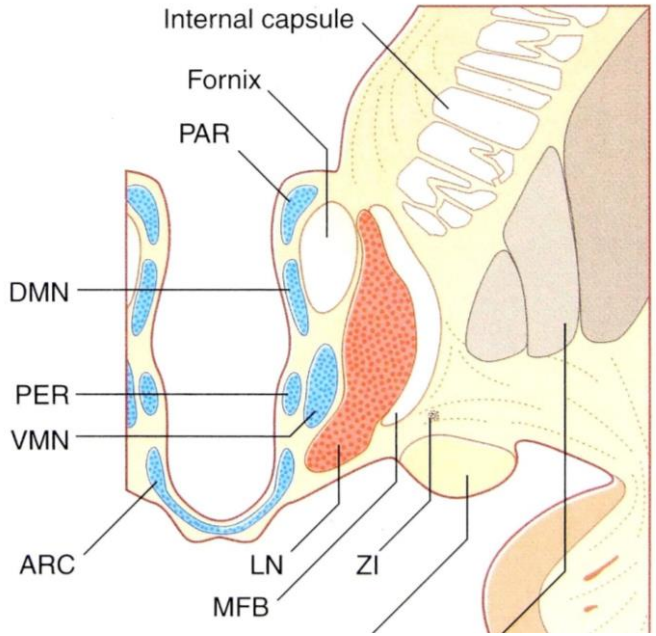

Plane of section
PVN
LN
DMN
VMN
PER
ARC

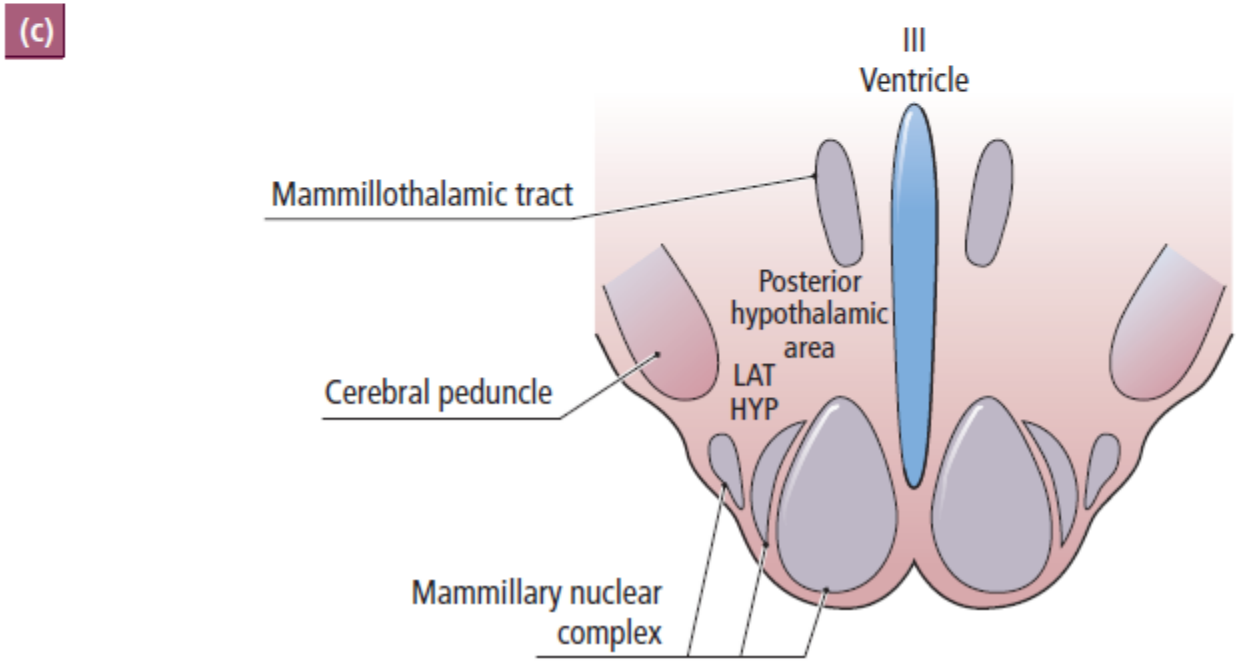

Internal capsule
Fornix
PAR
DMN
PER
VMN
ARC
LN
ZI
MFB
Optic tract
Globus pallidus

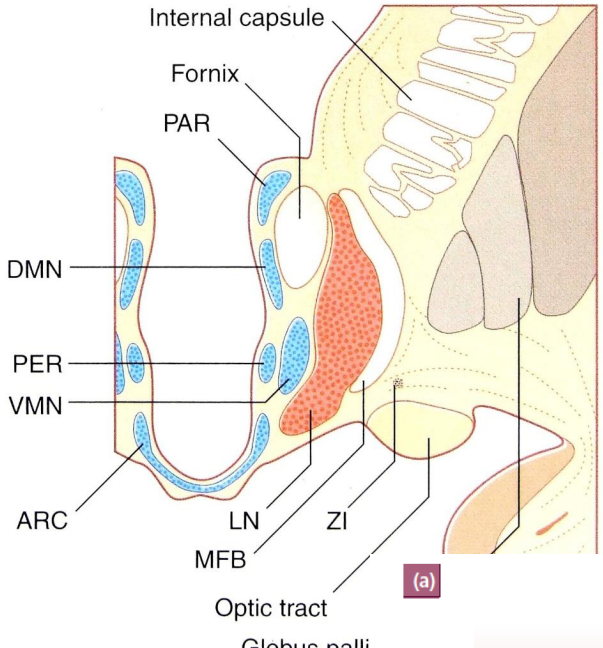

Plane of section
PVN
LN
DMN
VMN
PER
ARC

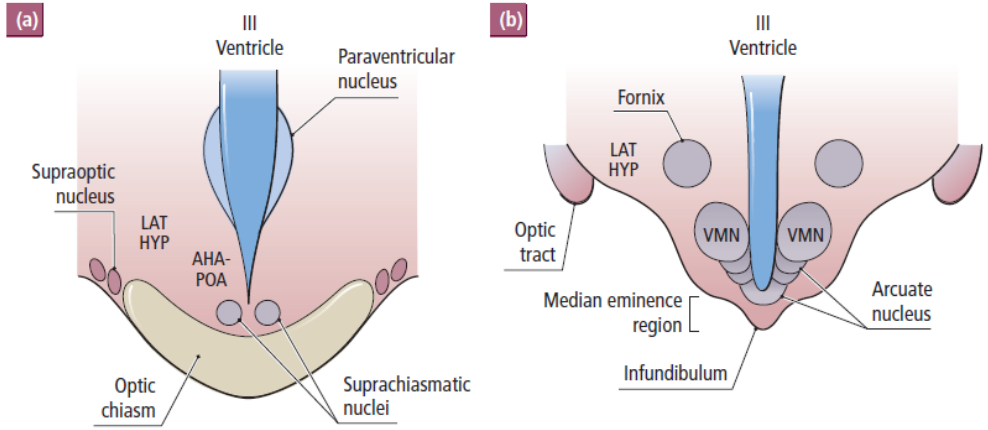

(a)
III Ventricle
Paraventricular nucleus
Supraoptic nucleus
LAT HYP
AHA-POA
Optic chiasm
Suprachiasmatic nuclei

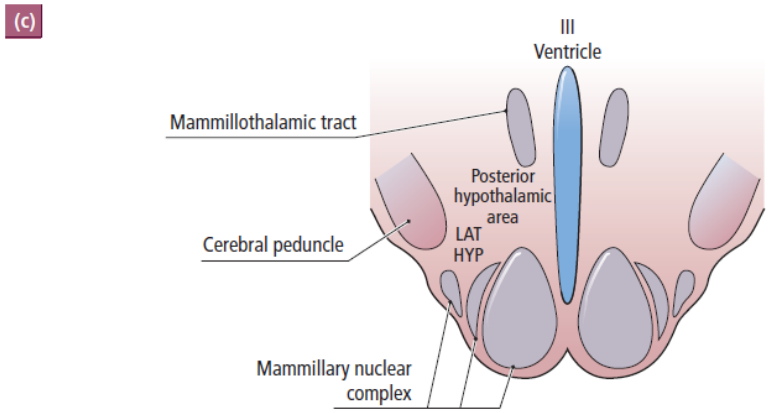

(b)
III Ventricle
Fornix
LAT HYP
Optic tract
VMN
VMN
Median eminence region
Arcuate nucleus
Infundibulum

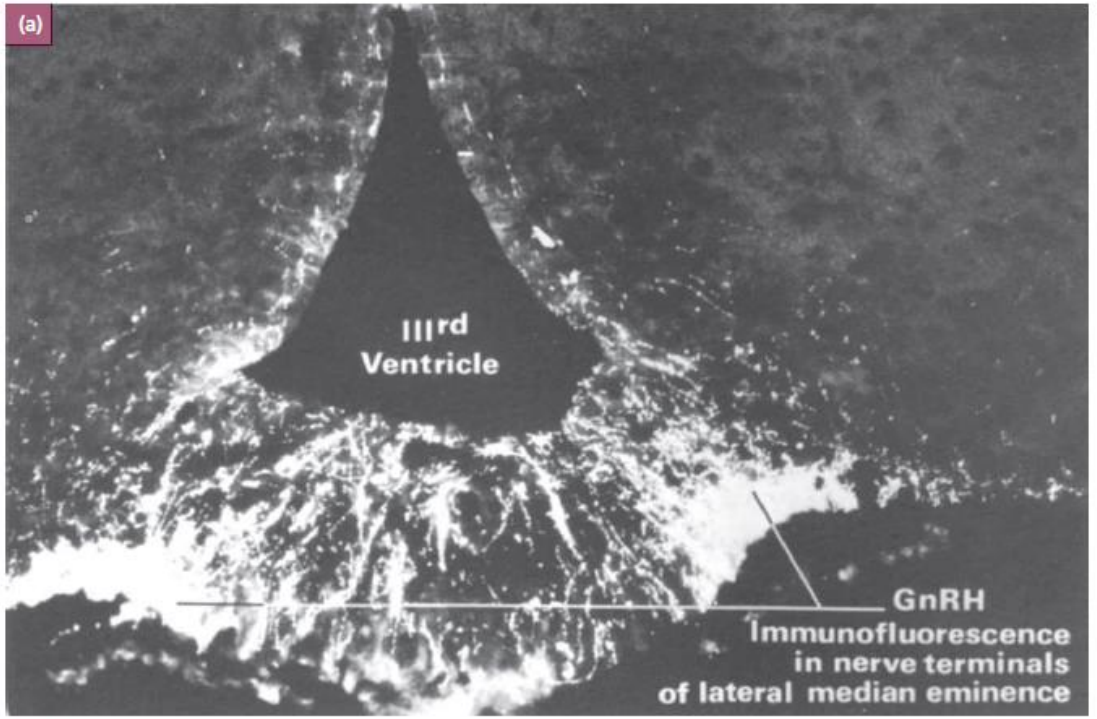

Internal capsule
Fornix
PAR
DMN
PER
VMN
ARC
LN
ZI
MFB

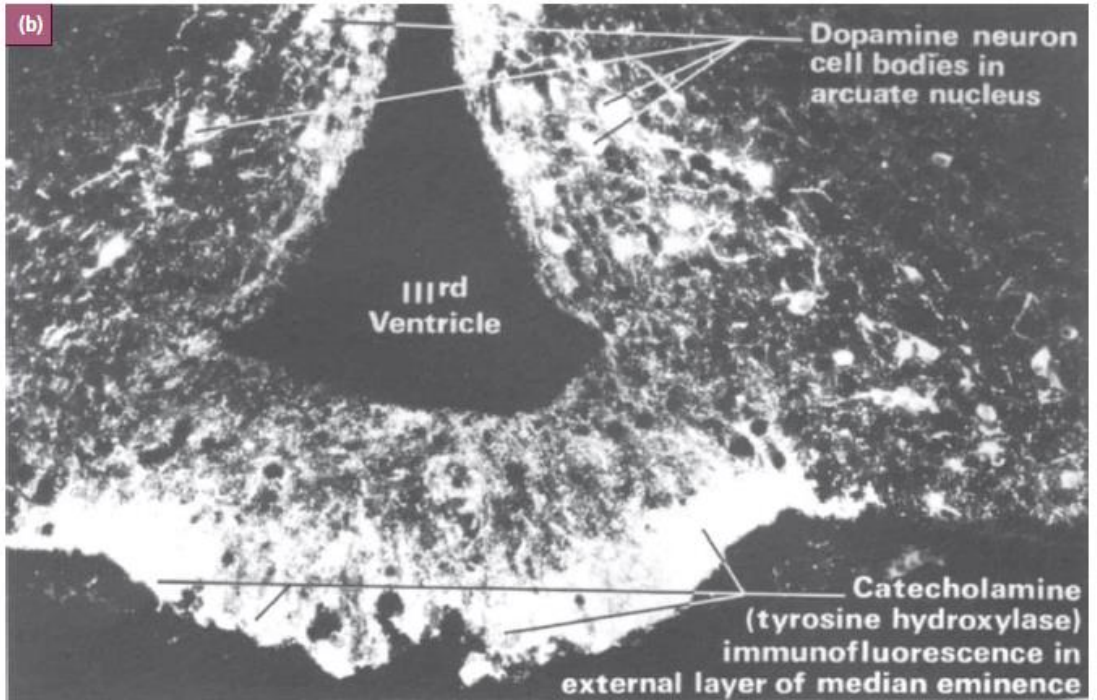

(c)
III Ventricle
Mammillothalamic tract
Posterior hypothalamic area
LAT HYP
Cerebral peduncle
Mammillary nuclear complex


Internal capsule
Fornix
PAR
DMN
PER
VMN
ARC
LN
ZI
MFB
Optic tract
Globus palli

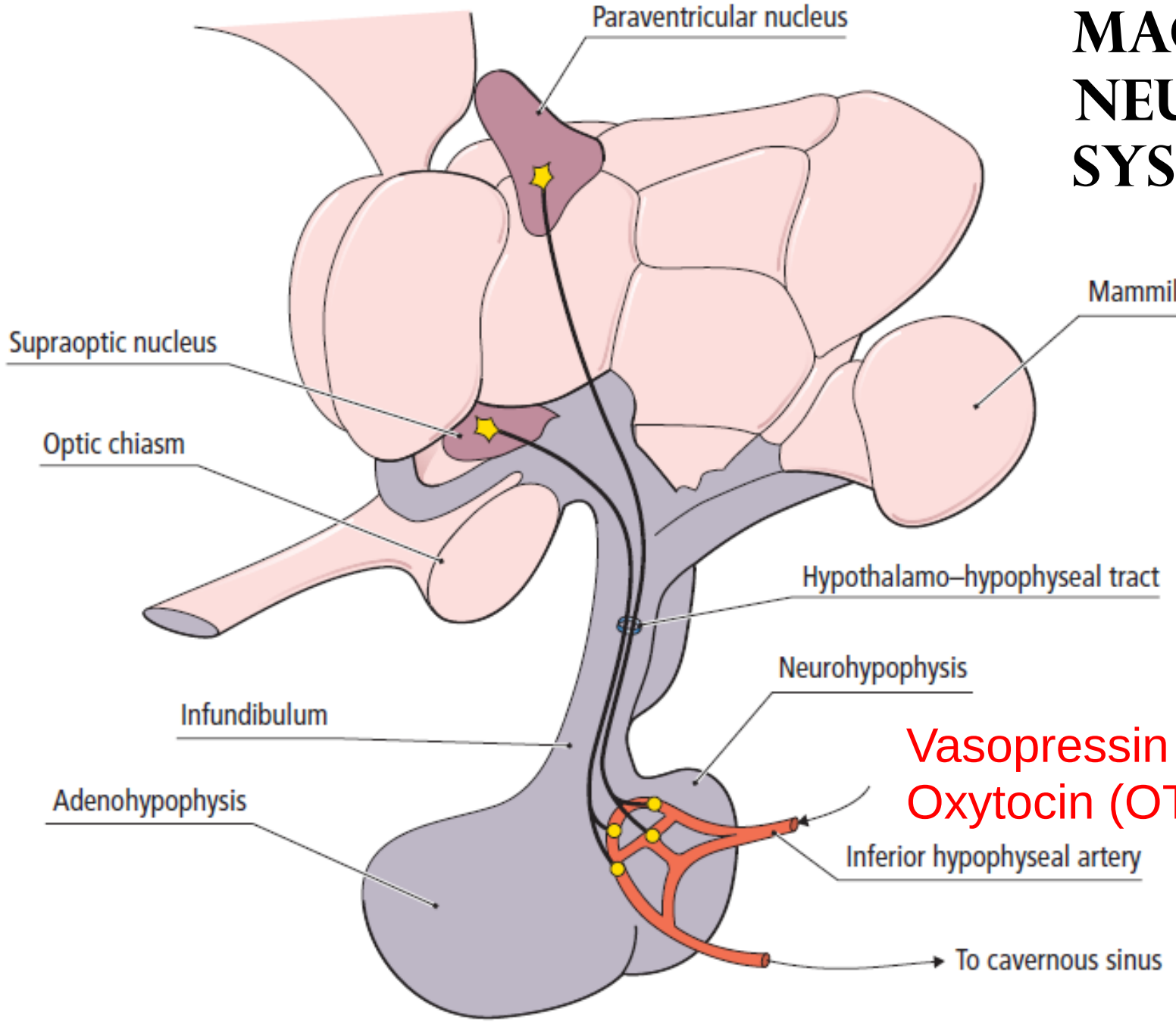

(a)
III Ventricle
Paraventricular nucleus
Supraoptic nucleus
LAT HYP
AHA-POA
Optic chiasm
Suprachiasmatic nuclei
(b)
III Ventricle
Fornix
LAT HYP
Optic tract
VMN
VMN
Median eminence region
Arcuate nucleus
Infundibulum


(c)
III Ventricle
Mammillothalamic tract
Posterior hypothalamic area
LAT HYP
Cerebral peduncle
Mammillary nuclear complex


(a)
IIIrd Ventricle
GnRH Immunofluorescence in nerve terminals of lateral median eminence

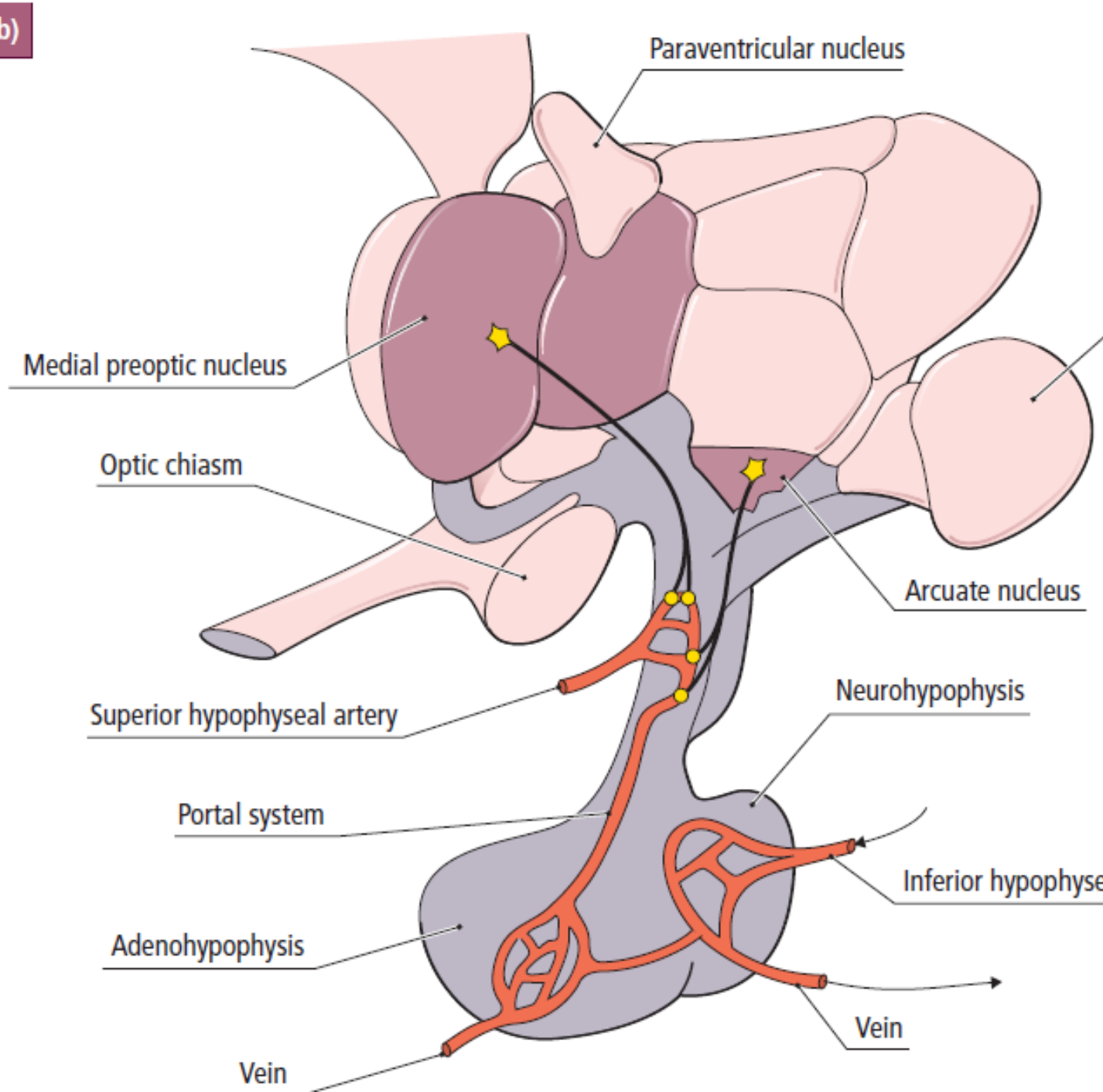

(b)
Dopamine neuron cell bodies in arcuate nucleus
IIIrd Ventricle
Catecholamine (tyrosine hydroxylase) immunofluorescence in external layer of median eminence

MAGNOCELLULAR NEUROSECRETORY SYSTEM



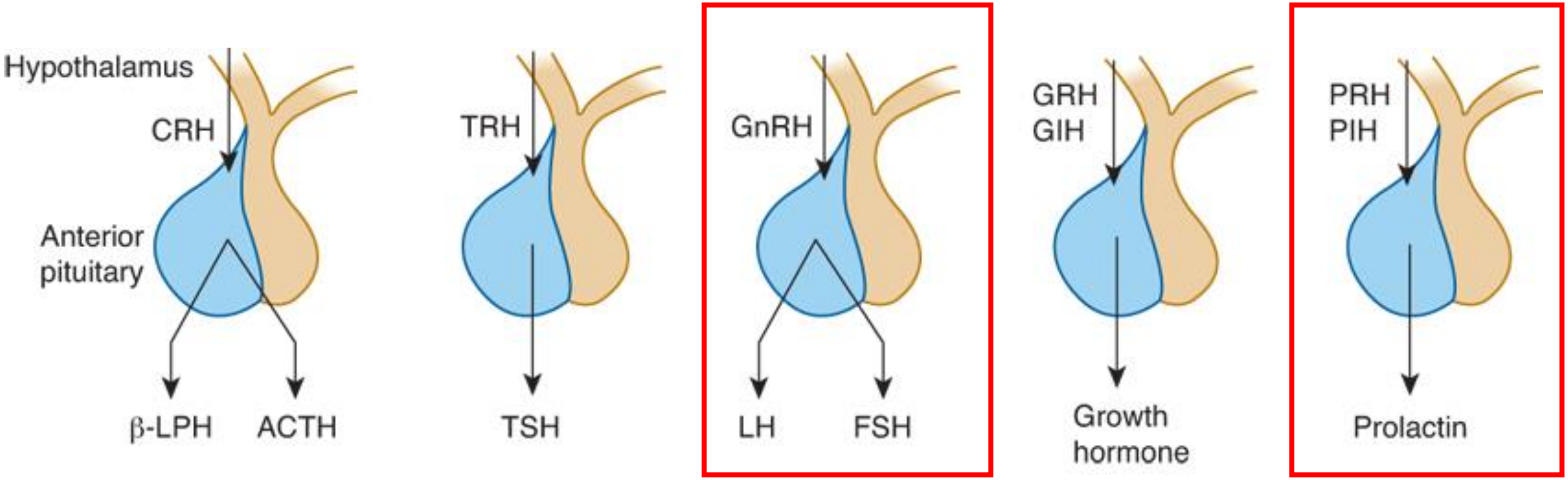
Vasopressin (antidiuretic hormone; ADH)
Oxytocin (OT)

PARVOCELLULAR NEUROSECRETORY SYSTEM



CRH, corticotropin-releasing hormone;
TRH, thyrotropin-releasing hormone;
GnRH, gonadotropin-releasing hormone;
GRH, growth hormone-releasing hormone;
GIH, growth hormone-inhibiting hormone;
PRH, prolactin-releasing hormone;
PIH, prolactin-inhibiting hormone (DOPAMINE)

Protein and Peptide Hormones



Effects of hypophyseotropic hormones on the secretion of anterior pituitary hormones.

CRH, corticotropin-releasing hormone;

TRH, thyrotropin-releasing hormone;

GnRH, gonadotropin-releasing hormone;

GRH, growth hormone-releasing hormone; GIH, growth hormone-inhibiting hormone;

PRH, prolactin-releasing hormone; PIH, prolactin-inhibiting hormone.

Anterior pituitary hormones.
ACTH, adrenocorticotropic hormone;
TSH, thyroid-stimulating hormone;
FSH, follicle-stimulating hormone;
LH, luteinizing hormone;
(In women, FSH and LH act in sequence on the ovary to produce growth of the ovarian follicle, ovulation, and formation and maintenance of the corpus luteum.
In men, FSH and LH control the functions of the testes)

Prolactin;
GH, growth hormone;

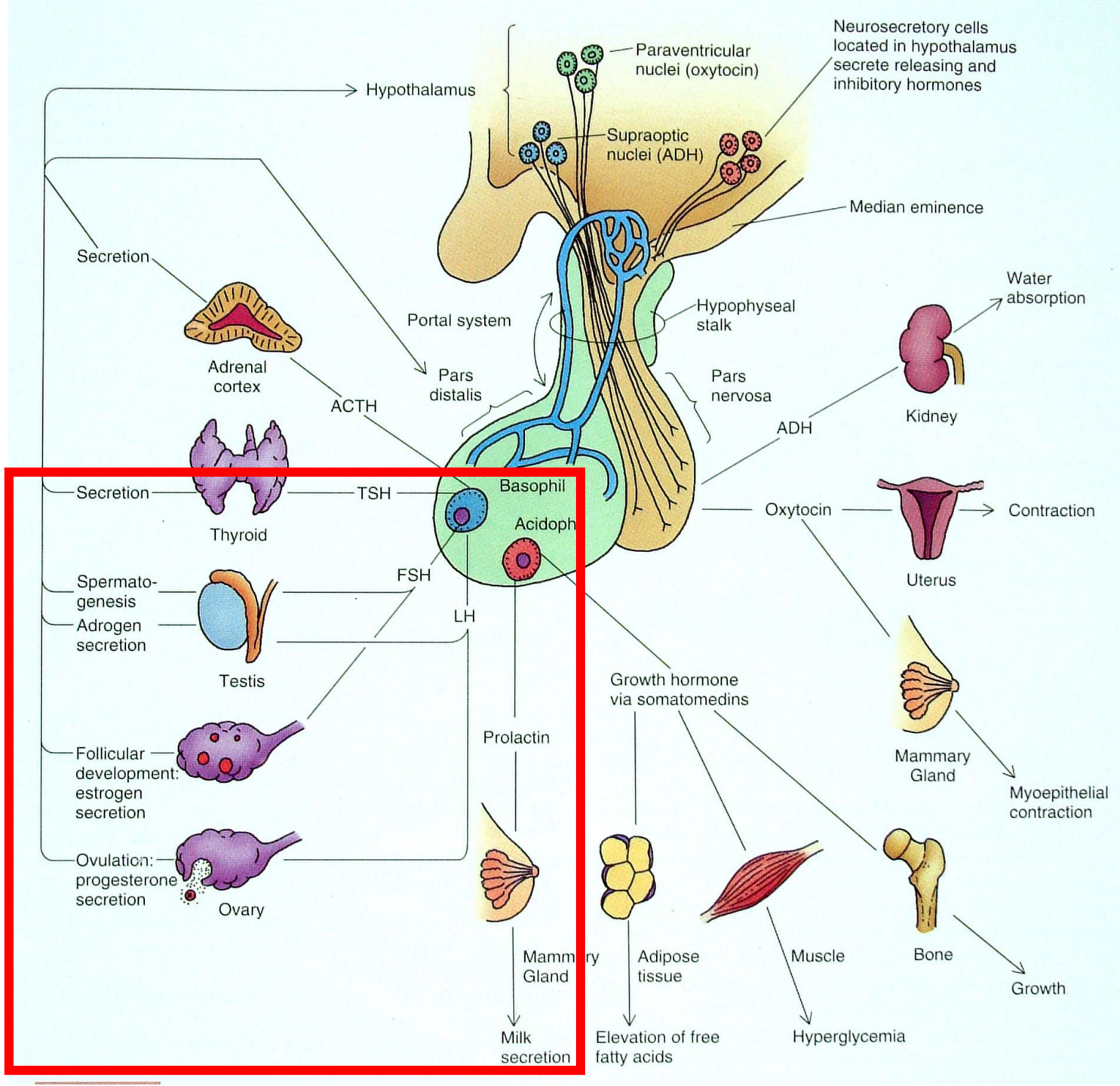


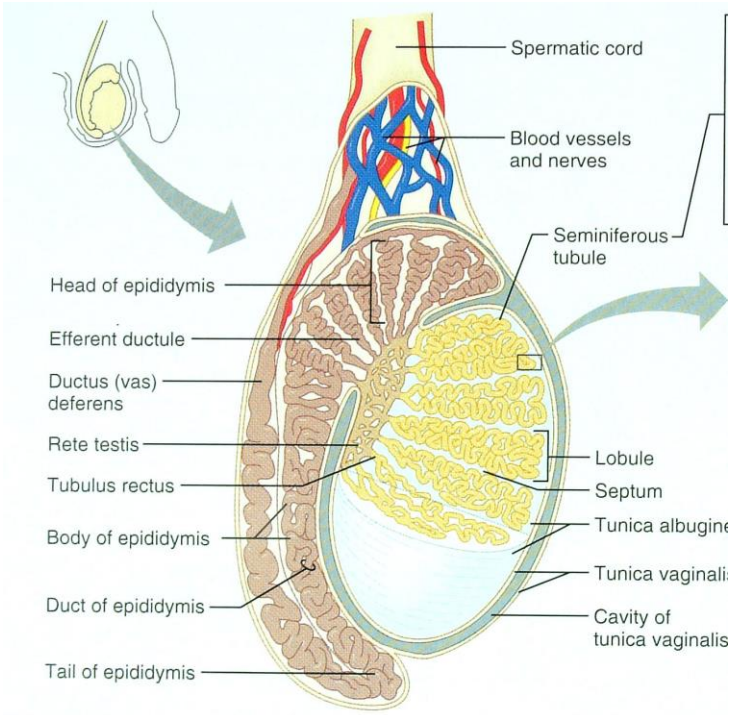
Table 1.4 Properties of human gonadotrophins

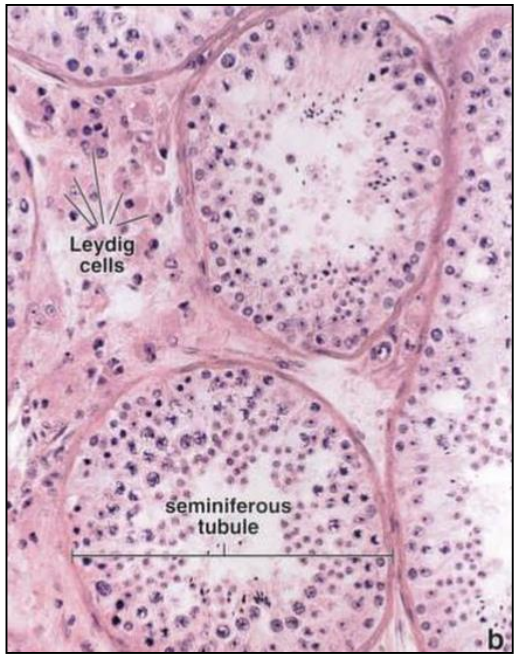
	Luteinizing hormone (LH) (also called interstitial cell-stimulating hormone [ICSH]) Molecular mass c. 28 kDa	**Follicle-stimulating hormone (FSH) Molecular mass c. 28 kDa**	**Chorionic gonadotrophin (hCG) Molecular mass c. 37 kDa**
Secreted from	Anterior pituitary gonadotrophs	Anterior pituitary gonadotrophs	Placental trophoblast
Main actions	Leydig cells (see Chapter 7) Thecal cells : antral follicles (see Chapter 8) Granulosa cells: preovulatory follicles (see Chapter 8) Luteal cells: corpus luteum (see Chapter 8)	Sertoli cells (see Chapters 6 and 7) Granulosa cells: follicles (see Chapter 8)	Luteal cells (see Chapters 12 and 13)
Composition	α-chain* (116 amino acids and 2 *N*-linked[1] carbohydrate chains) β-chain† (121 amino acids and one *N*-linked carbohydrate chain)	α-chain* as for LH β-chain† of 111 amino acids and 2 *N*-linked[1] carbohydrate chains	α-chain* as for LH β-chain† of 145 amino acids (a 29 carboxy addition to LHβ) with 2 *N*-linked[1] + *O*-linked[1] carbohydrate chains
Receptor	85–92-kDa glycoprotein; G-protein coupled; adenyl cyclase linked	75-kDa (675 aa) receptor that dimerizes on FSH binding; G-protein coupled; adenyl cyclase linked	As for LH

*The common or backbone subunit chain – encoded in a single gene on chromosome 6q12–q21.

†The subunit chain conferring specificity. FSHβ single gene on chromosome 11p13, having two splice variants (4262bp). LH/hCGβ gene cluster on chromosome 19q13.32 (LH – 1111 bp; CG – 1467 bp). Four CG genes are expressed, three with low activity. There is 80% homology between the common parts of CG and LH β-chains, but only 36% homology between LH and FSH β-chains.

[1]*O*-linked carbohydrate chains are attached to a serine or threonine residue via *N*-acetylgalactosamine; *N*-linked chains to asparagines via *N*-acetylglucosamine.



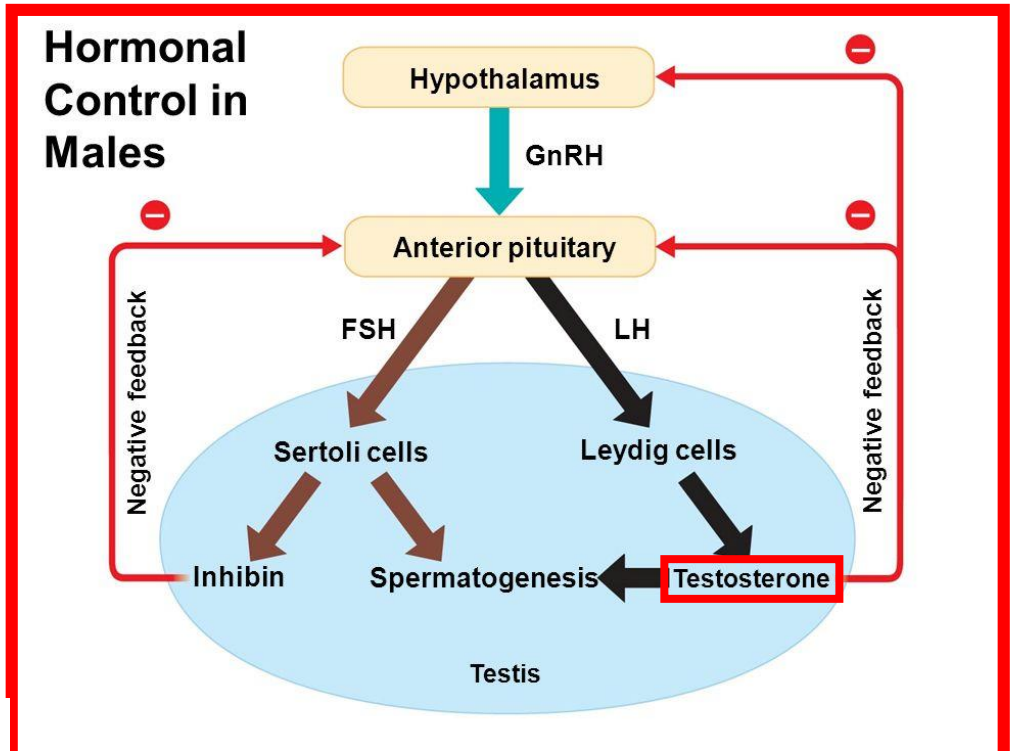


Leydig cells

↓

Testosterone

Human Anatomy
Marieb & Mallatt
3rd Edition, 2001



Pawlina, Histology A TEXT AND ATLAS, seven edition

Steroid Hormones

Acetate

↓

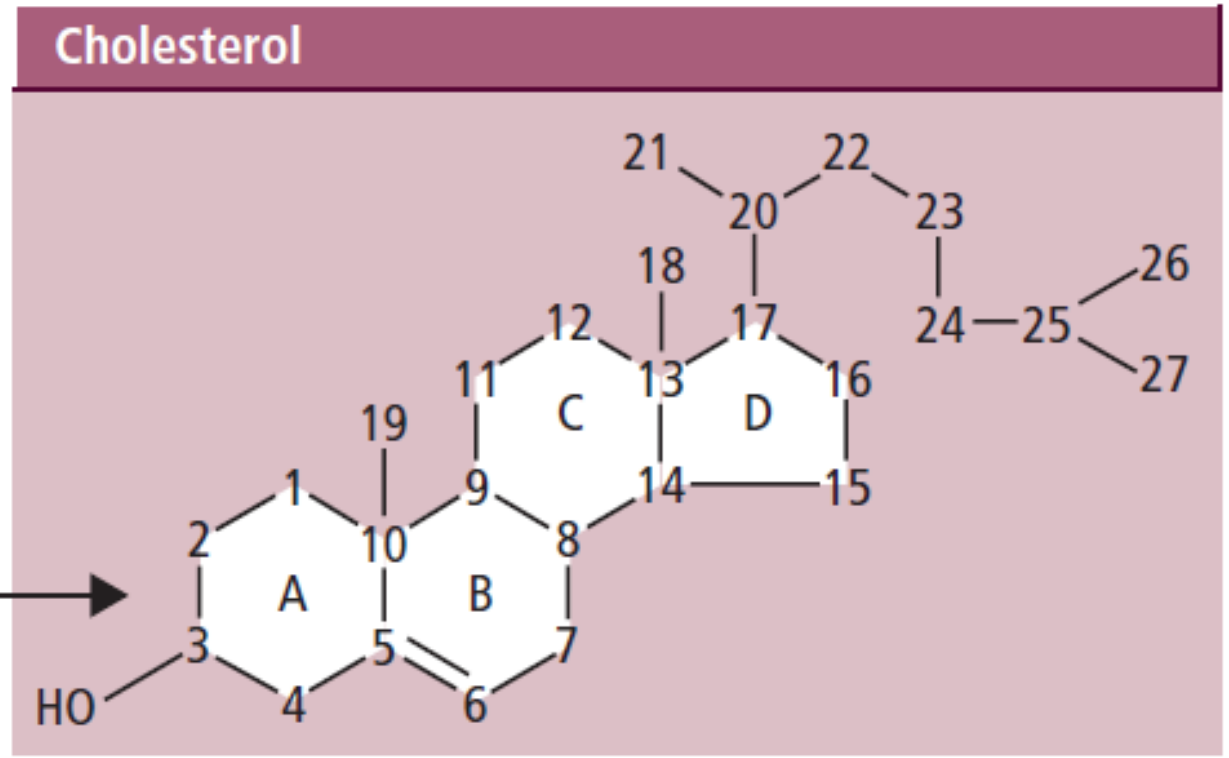
Mevalonate

↓

Squalene

↓

Lanosterol



.14 Basic structure of the cholesterol molecu

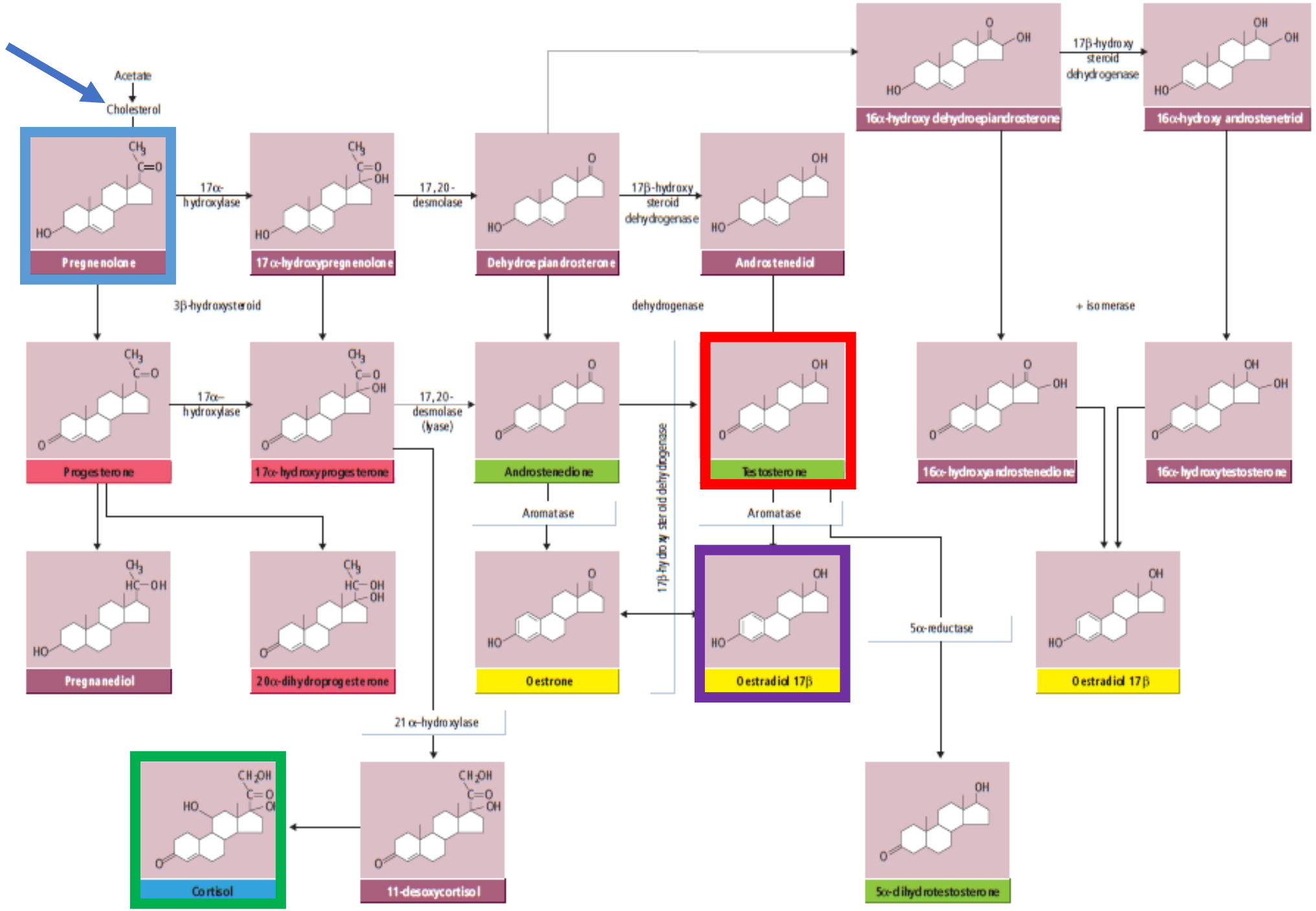

Acetate
Cholesterol
Pregnenolone
17α-hydroxylase
17 α-hydroxypregnenolone
17,20-desmolase
Dehydroepiandrosterone
17β-hydroxy steroid dehydrogenase
Androstenediol
16α-hydroxy dehydroepiandrosterone
17β-hydroxy steroid dehydrogenase
16α-hydroxy androstenetriol
3β-hydroxysteroid dehydrogenase
+ isomerase
Progesterone
17α-hydroxylase
17α-hydroxyprogesterone
17,20-desmolase (lyase)
Androstenedione
Testosterone
16α-hydroxyandrostenedione
16α-hydroxytestosterone
Aromatase
Aromatase
17β-hydroxy steroid dehydrogenase
Pregnanediol
20α-dihydroprogesterone
Oestrone
Oestradiol 17β
Oestradiol 17β
5α-reductase
21 α-hydroxylase
Cortisol
11-desoxycortisol
5α-dihydrotestosterone

Table 1.1 Principal properties of natural progestagens and their receptors*

Progestagens	Relative potency (%)	Key properties	Receptors
Progesterone (P4)	100	1. Prepare uterus to receive conceptus 2. Maintain uterus during pregnancy 3. Stimulate growth of mammary glands, but suppress secretion of milk 4. Mild effect on sodium loss via distal convoluted tubule of kidney 5. General mild catabolic effect 6. Regulate secretion of gonadotrophins	Two isoforms PR-A and -B, sharing 780 identical amino acids, but with PR-B having an additional 164 amino acids. Each receptor, on binding P4, transcriptionally activates different genes by binding to sequences in their promoters
17α-Hydroxyprogesterone (17α-OHP)	40–70		
20α-Hydroxyprogesterone (20α-dihydroprogesterone or 20α-OHP)	5		

*In Tables 1.1–1.3 the relative potencies are only approximate since they vary with species and with the assay used. This variation is due partly to differences in the relative affinity of receptors in different tissues, partly to differences in local enzymic conversions of steroids within tissues and partly to differences in systemic metabolism: see text for discussion of these factors.
Common abbreviations or alternative names encountered in the literature are also recorded in Tables 1.1–1.3.

Table 1.2 Principal properties of natural androgens*

Androgens	Relative potency (%)	Key properties	Receptors
5α-dihydrotestosterone (DHT)	100	1. Induce and maintain differentiation of male somatic tissues 2. Induce secondary sex characters of males (deep voice, body hair, penile growth) and body hair of females 3. Induce and maintain some secondary sex characters of males (accessory sex organs) 4. Support spermatogenesis 5. Influence sexual and aggressive behaviour in males and females 6. Promote protein anabolism, somatic growth and ossification 7. Regulate secretion of gonadotrophins (testosterone) 8. Anticorticosteroid effects (DHEA)	A single androgen receptor isoform, AR, of 918 amino acids. However, the gene is highly polymorphic and shows variation in the number of CAG codon repeats in exon 1, the number of which is inversely correlated with both levels of transcriptional activity and receptor expression. Thus, isoforms with shorter repeats are more sensitive to ambient androgen levels
Testosterone (T)	50		
Androstenedione (A4)	8		
Dehydroepiandrosterone (DHEA)	4		

Table 1.3 Principal properties of natural oestrogens*

Oestrogens	Relative potency (%)	Key properties	Receptors
Oestradiol 17β (estradiol or E_2) Oestriol (estriol or E_3) Oestrone (estrone or E_1)	100 10 1	1. Stimulate secondary sex characters of female. Prepare uterus for spermatozoal transport 2. Increase vascular permeability and tissue oedema 3. Stimulate growth and activity of mammary gland and endometrium 4. Prepare endometrium for progestagen action 5. Mildly anabolic; stimulate calcification 6. Active during pregnancy 7. Regulate secretion of gonadotrophins 8. Associated with sexual behaviour in some species	Two receptors exist, ERa (c.595 amino acids) and ERb, which has several isoforms arising from splice variants giving a size range of c.480–530 amino acids

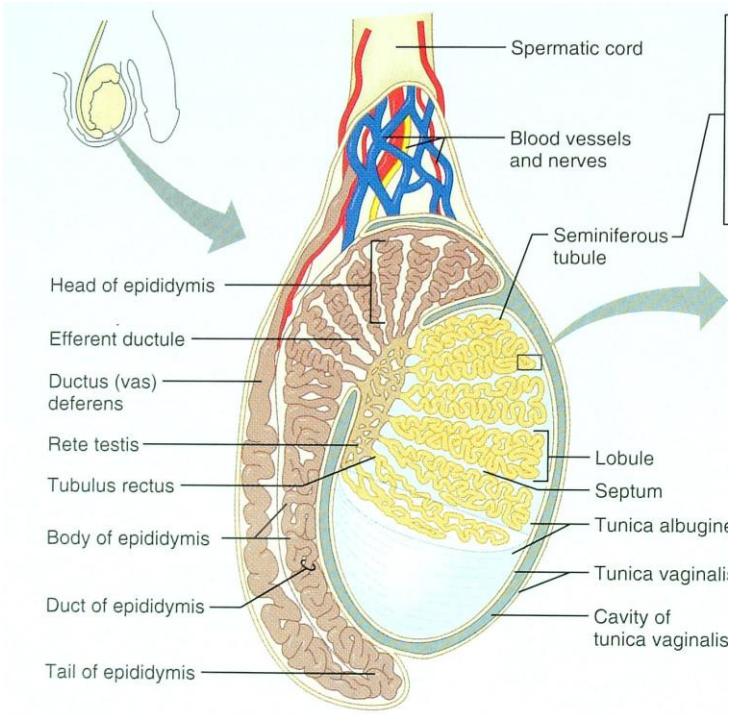
Reproductive messengers

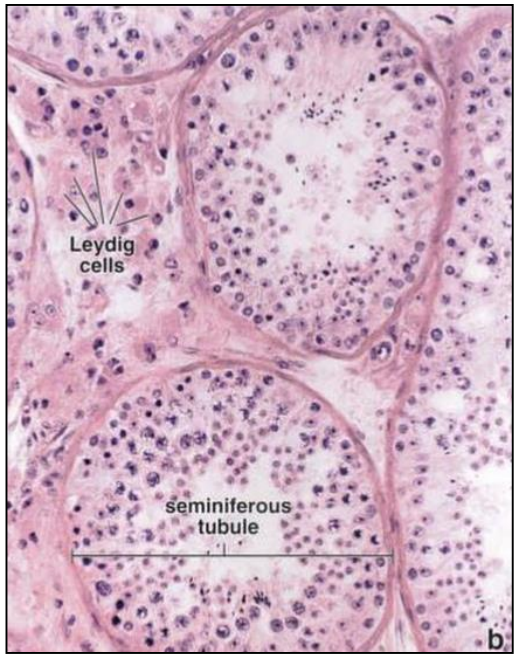
Sex steroid receptors

WHETHER OR NOT A PARTICULAR STEROID AFFECTS A TISSUE, AND HOW IT AFFECTS IT, DEPENDS MAINLY ON WHETHER THAT TISSUE EXPRESSES A **STEROID RECEPTOR**.

STEROIDS, BEING LIPID SOLUBLE, CAN PASS FREELY *into* A TARGET CELL NUCLEUS TO COMBINE WITH AN **INTRANUCLEOPLASMIC RECEPTOR**, THEREBY ACTIVATING IT.

THIS STEROID–RECEPTOR COMPLEX, BUT NOT THE STEROID OR RECEPTOR ALONE, CAN THEN BIND TO SPECIFIC DNA SEQUENCES IN THE CHROMATIN: THE SO-CALLED ACCEPTOR SITES OR **STEROID RESPONSE ELEMENTS (SRES)** SPECIFIC FOR



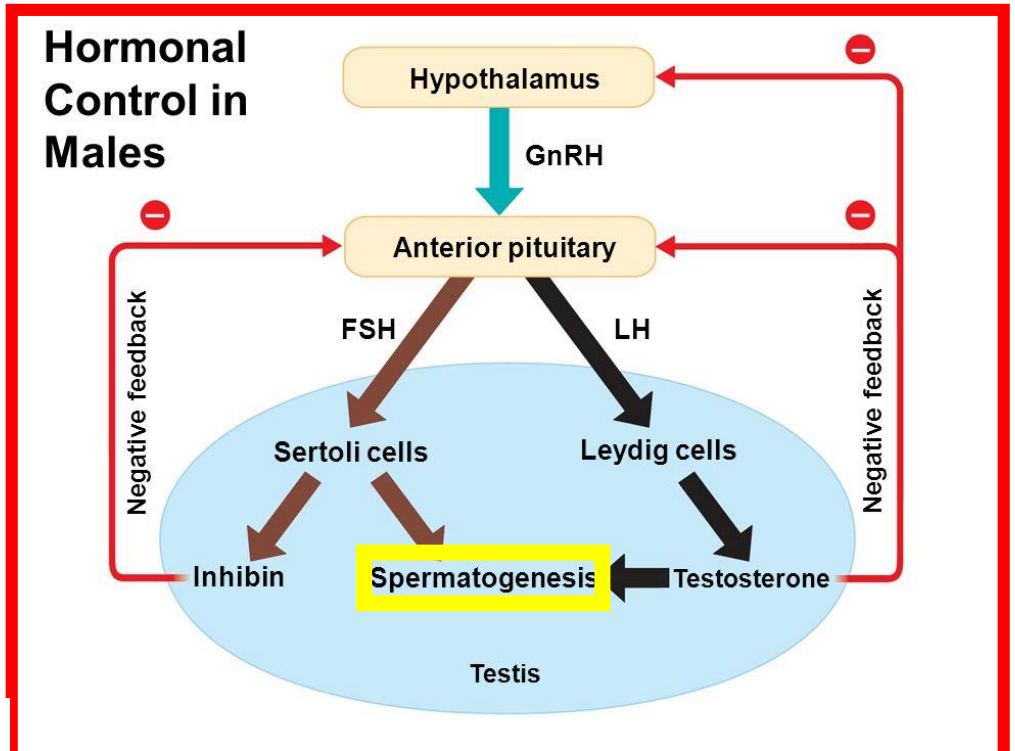


Leydig cells

↓

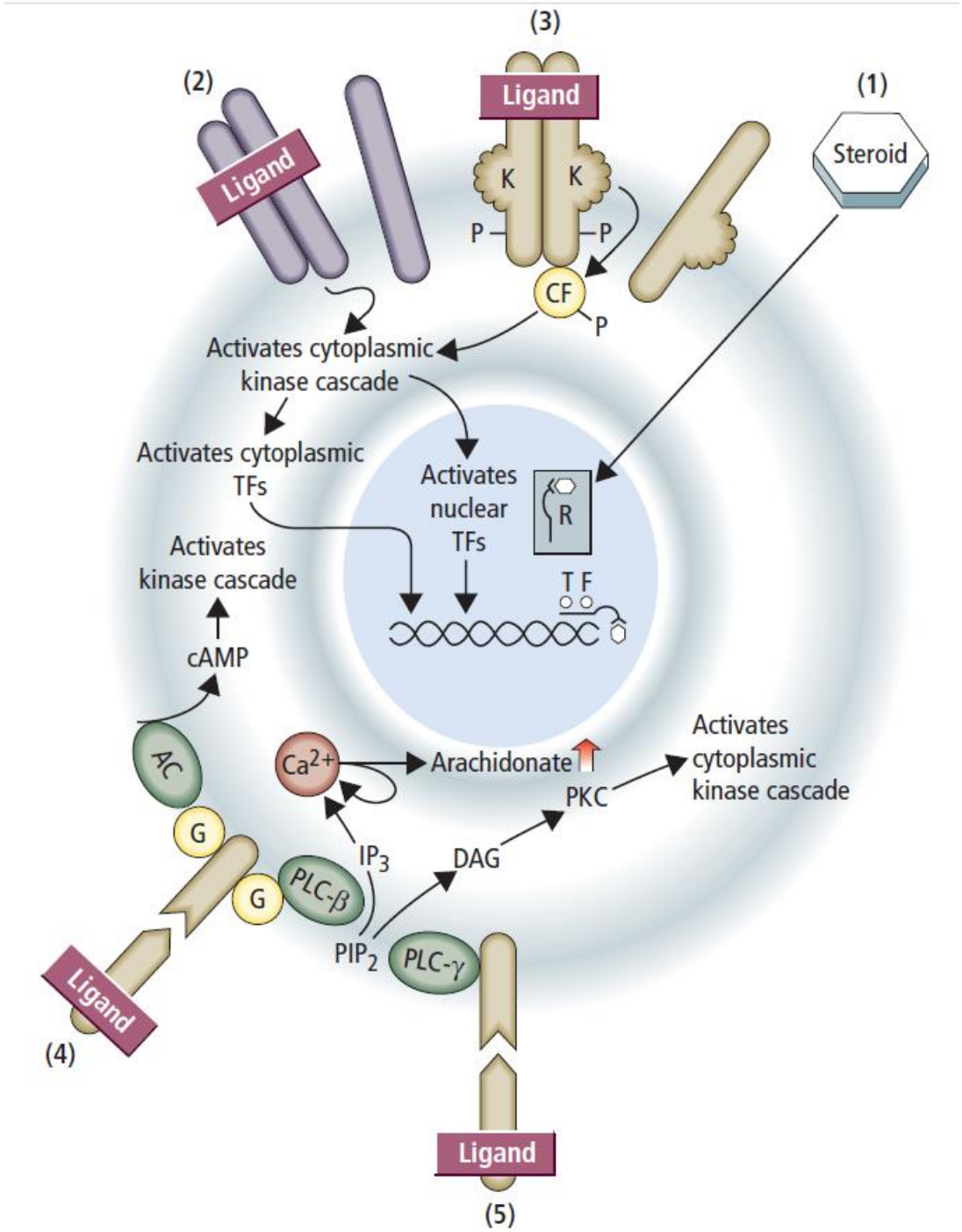
Testosterone

Human Anatomy
Marieb & Mallatt
3rd Edition, 2001



Pawlina, Histology A TEXT AND ATLAS, seven edition

THE **MEASUREMENT OF VARIATION IN HORMONE LEVELS ALONE WILL NOT PROVIDE AN ADEQUATE BASIS FOR UNDERSTANDING REPRODUCTIVE FUNCTION. THE RECEPTOR PROFILE MUST ALSO BE KNOWN.**



Signaling Pathways

Somatomammotrophic polypeptides, WHICH EXERT PERVASIVE EFFECTS ON TISSUE GROWTH AND FUNCTION, INCLUDING EFFECTS ON THE MAMMARY GLAND.

THE THREE MAIN MEMBERS ALL EVOLVED FROM A SINGLE ANCESTORIAL GENE THROUGH DUPLICATION AND MODIFICATION, AND SO ARE STRUCTURALLY AND FUNCTIONALLY RELATED:
prolactin (**PRL**; BOX 1.3),
placental lactogen (**PL**; ALSO CALLED **placental somatomammotrophin**)
AND
growth hormone (**GH**; ALSO CALLED **somatotrophin**).

EACH CONSISTS OF A SINGLE POLYPEPTIDE CHAIN.
PRL AND PL ARE PARTICULARLY CONCERNED WITH LACTATION,

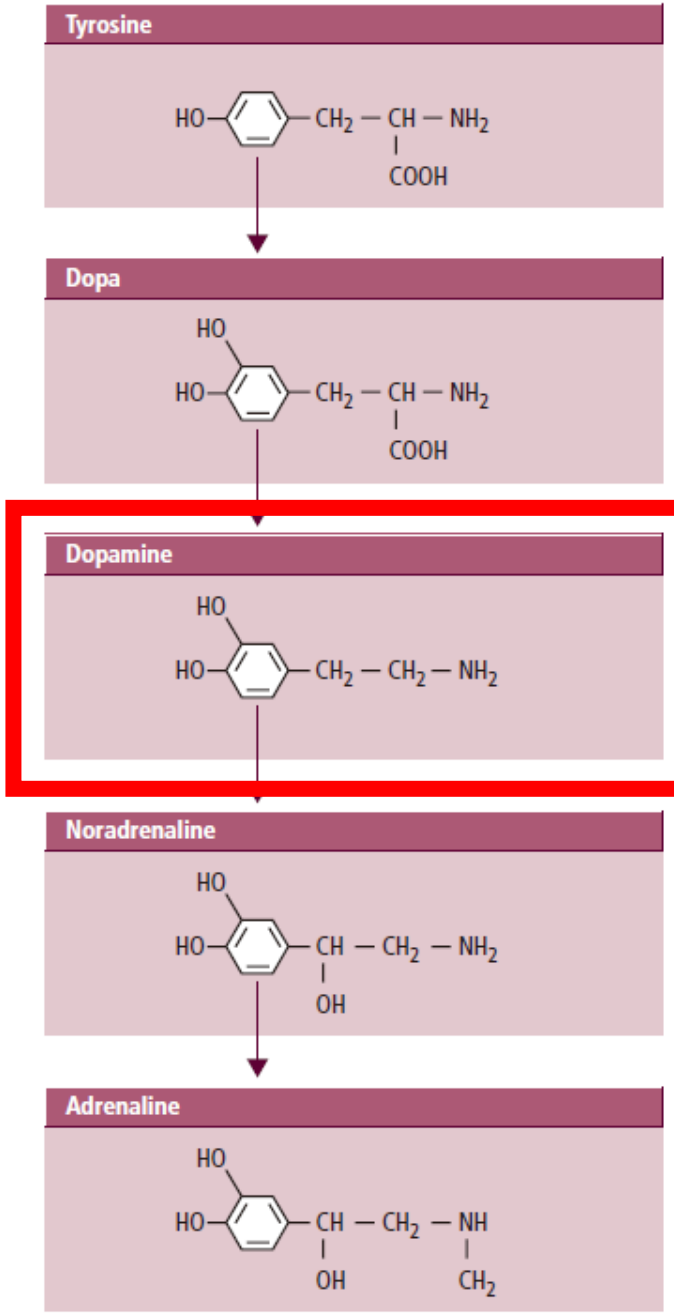
Table 1.5 Properties of the human somatomammotrophic polypeptides+

	Prolactin (PRL)* Molecular mass 23kDa (isoforms 16, 25, 50–60 and 100)	Placental lactogen** (PL; also called chorionic somatomammotrophin [CSA], B and V for three variant forms) Molecular mass 22 kDa	Growth hormone*** (GH-N; also called chorionic somatotrophin) GH-V: a second GH placental gene variant Molecular mass 22 kDa
Secreted by	Anterior pituitary lactotrophs and (in humans) placental decidua + many other tissues	Cytotrophoblast to week 6, then syncytiotrophoblast + invasive mononuclear trophoblast. (In farm animals, binucleate cells)	GH-N: pituitary somatotrophs GH-V: syncytial trophoblast
Main actions	Leydig cells; seminal vesicle and prostate; ovarian follicles; corpus luteum; mammary glands; amnion	Maternal intermediary metabolism; mammary gland; fetal growth	Postnatal growth; general follicle support; puberty; breast development
Composition	Polypeptide chain of 199 amino acids (multiple isoforms)*	Non-glycosylated polypeptide chain of 191 amino acids (25% homology to PRL, 85% to GH)**	191 amino acids (GH-V single glycosylation site)***
Receptor	Binds PRL receptor: long and short forms which are modified to at least seven isoforms	Binds PRL-R (same affinity) and GH-R (affinity 1/2000 < GH)	Binds GH-R and PRL-R (GH-V binds PRL-R > GH-N and GH-R < GH-N)

+These three are members of a large family that in humans are evolved from a primary GH gene, and include prolactin-like proteins (PLPs), PRL-related proteins (PRPs), proliferins and proliferin-related proteins, many of which are made in the placenta.
*A single 10-kb gene on chromosome 6 with five exons + an extra upstream exon 1a only expressed in decidual tissue.
**Three genes on chromosome 17 encoding CSA and B, pus a variant form CS-V.
***Two genes on chromosome 17 in PL cluster encoding GH, GH-V.

Biosynthetic pathway (from top downwards) and molecular structures of the catecholamines: **dopamine**, noradrenaline and adrenaline.

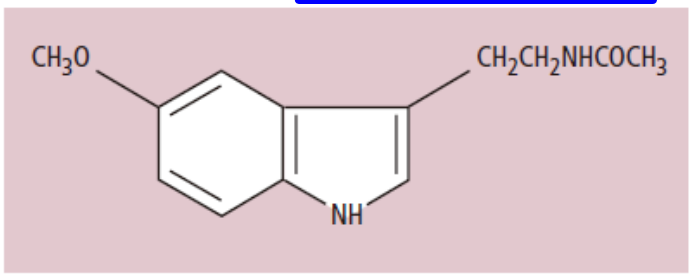
(a)

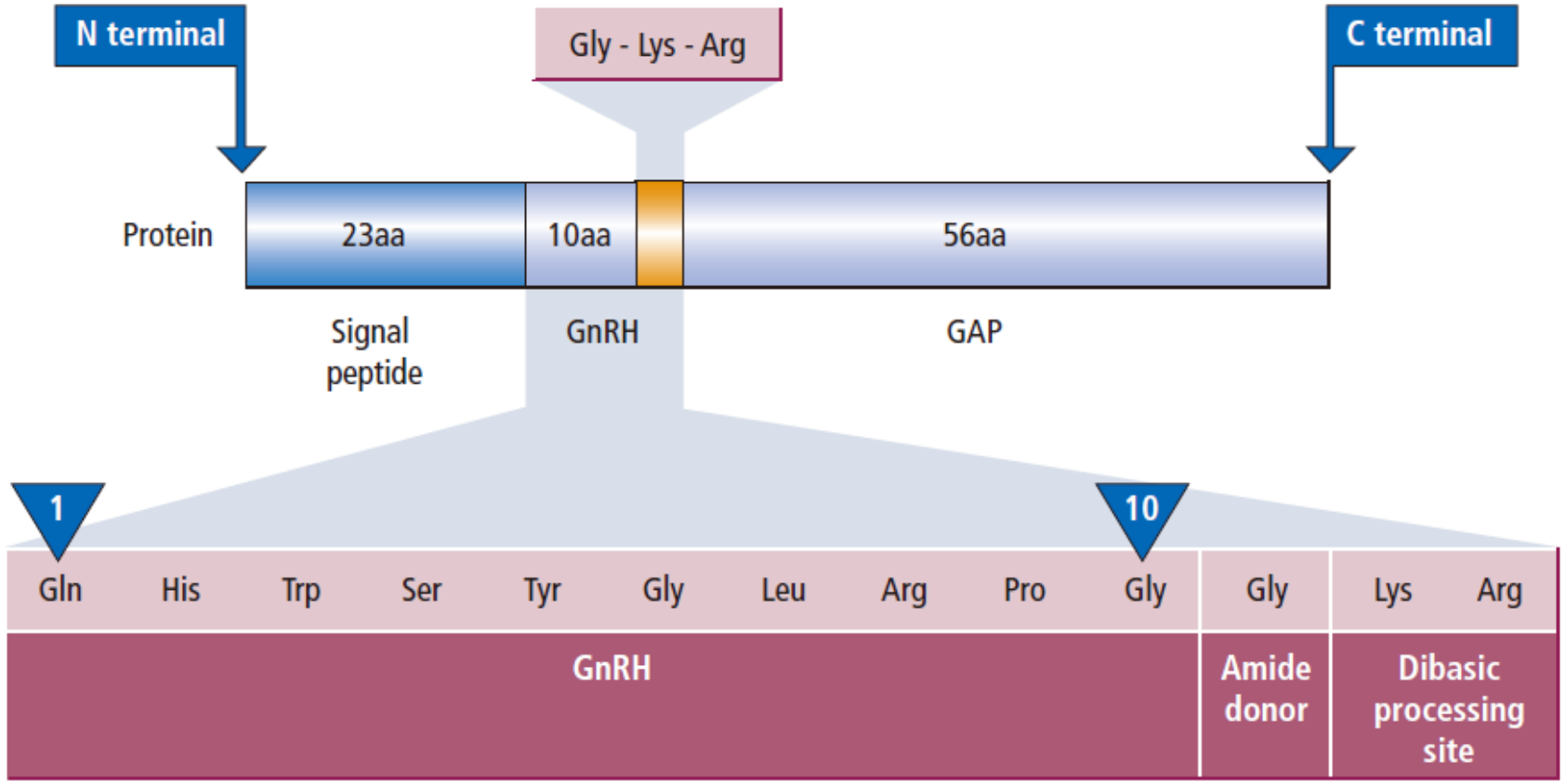


Prolactin Inhibitory Hormone

(b)

Melatonin





GnRH is a decapeptide derived by cleavage from a larger precursor called prepro-GnRH. The upper blue bar shows the structure of the human cDNA for prepro-GnRH (molecular weight 10 000), which comprises the decapeptide GnRH preceded by a signal sequence of 23 amino acids and followed by a Gly – Lys – Arg sequence necessary for enzymatic processing and C-terminal amidation of GnRH

Oxytocin, like GnRH, is also derived from a larger precursor (a) consisting of (central yellow bar): a leader sequence (S); the oxytocin nonapeptide sequence (OT); a Gly – Lys – Arg linker sequence, serving the same function as described for GnRH in the legend to Figure 1.18, and a neurophysin sequence.

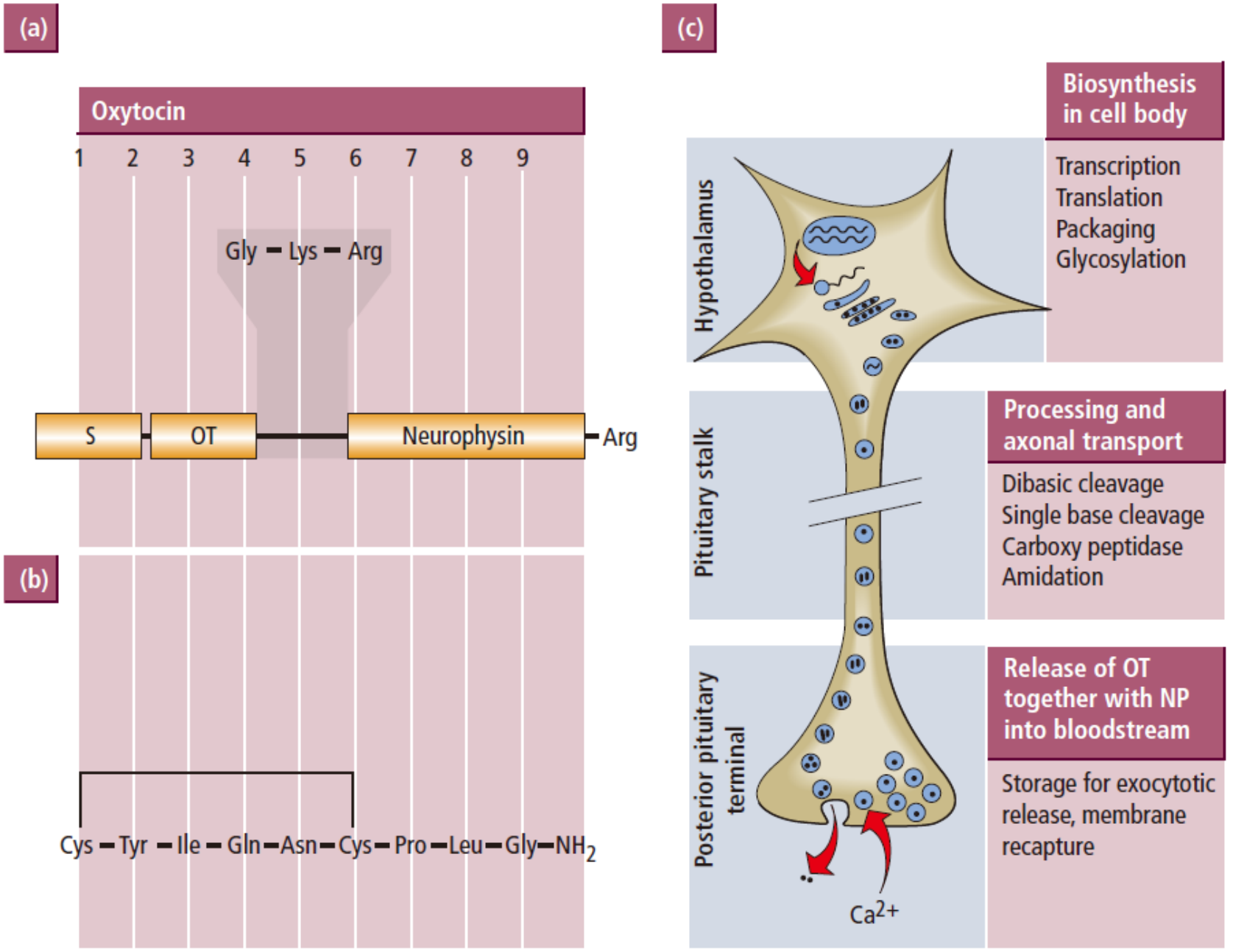


Table 1.6 Half-lives of some hormones in the blood

Hormone	Half-life
Steroids	2–3 min
Prostaglandins	3–10 min
Gonadotrophins:	
LH	30 min
FSH	3–4 h
CG	c. 24 h*
Prolactin and placental lactogen	10–20 min and 24 h (biphasic)

*Stabilized by the *O*-linked carbohydrate chains on tail of β-chain.

Table 1.7 Steroid-binding proteins in human plasma

Binding protein	Percentage of non-conjugated steroids bound*			
	Progestagens	Androgens	Oestrogens†	Cortisol
Albumin	48	32	63	20
Cortisol-binding globulin§	50	1	–	70
Sex steroid-binding globulin	–	66	36	–
Free steroid	2	1	1	10

*Steroids conjugated as sulphates or glucosiduronates bind weakly to albumin only.
†Oestrone and oestriol bind mainly to albumin.
§Also called transcortin.
Note: Albumin is a low-affinity/high-capacity binding protein whilst the globulins are high-affinity/low-capacity binding proteins. There are sex differences, females in general binding proportionately more androgens/oestrogens to sex steroid-binding globulin than to albumin.

Endocrine

Exocrine

Paracrine

Autocrine

Juxtacrine

Key learning points

- Mammals reproduce sexually through the union of a haploid egg with a haploid spermatozoon.
- Sexual selection operates in mammals and is culturally influenced.
- The mammalian female reproductive tract has a dual role.
- Fertilization is internal and involves spermatozoal transport and fewer eggs being shed.
- Development is viviparous and involves smaller eggs and embryos.
- Early development is slower and involves attachment to the mother's uterus that leads ultimately to placental formation.
- Birth marks the beginning of the period of parental care of neonates through milk production: the unique feature of all mammals.
- Overall, mammals have a high-investment, low-volume reproductive strategy.
- The somatic reproductive life cycle involves growth, sexual maturation at puberty, a period of fecundity and then reproductive decline.
- Reproductive decline in women is more marked than in men, occurring earlier, being steeper and resulting in complete loss of fecundity at the menopause.
- The generative life cycle involves the setting aside within the embryo of a population of pluripotent germ cells that develop into the gametes in the ovary and testis.
- The epigenetic life cycle describes the corresponding changes in chromatin and DNA modification that underlie pluripotency.
- Parental imprinting describes the epigenetic marks that identify some genes as being derived from the mother and some from the father, and which also ensure that those genes are not expressed in somatic cells.
- The reproductive body centres on anatomical and functional differences between testes and ovaries and their associated reproductive tracts.
- The gonads interact with the pituitary and the brain, especially the hypothalamus.
- The hypothalamus and pituitary are connected by both nervous and vascular routes, involving release of oxytocin,

SEE YOU AROUND!