Lecture 5
Neuroendocrinology

PSYC 304

Announcements

Midterm 1

- Next week Tuesday!

Reading club 1A/1B

- Next Class!

Review

The Synapse & Neuroanatomy

The brain continued

The brain

The cortex has four lobes:

- **Frontal**—movement and high-level cognition
- **Parietal**—spatial cognition, sensory processing
- **Occipital**—visual processing
- **Temporal**—auditory processing, sense of smell, aspects of learning

Activity

On the next 2 slides there are images from different angels of the human brain. From your memory please label the following aspects of the brain:

Frontal lobe

Temporal lobe

Parietal lobe

Occipital lobe

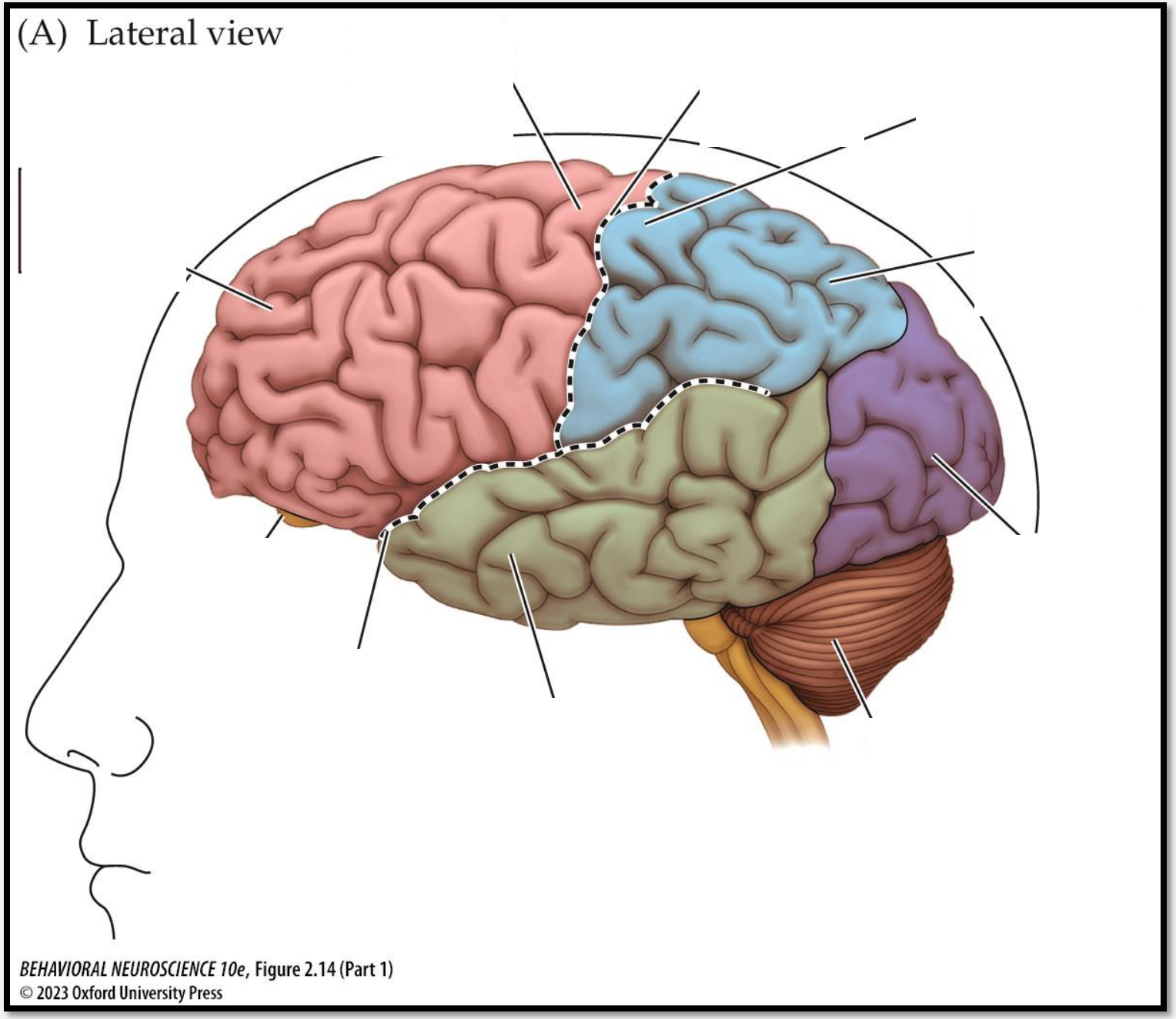
Cerebellum

Spinal cord

Brain stem

Central Sulcus

Lateral fissure



Activity

From your memory please label the following aspects of the brain:

Frontal lobe

Temporal lobe

Parietal lobe

Occipital lobe

Cingulate cortex (limbic lobe)

Cerebellum

Spinal cord

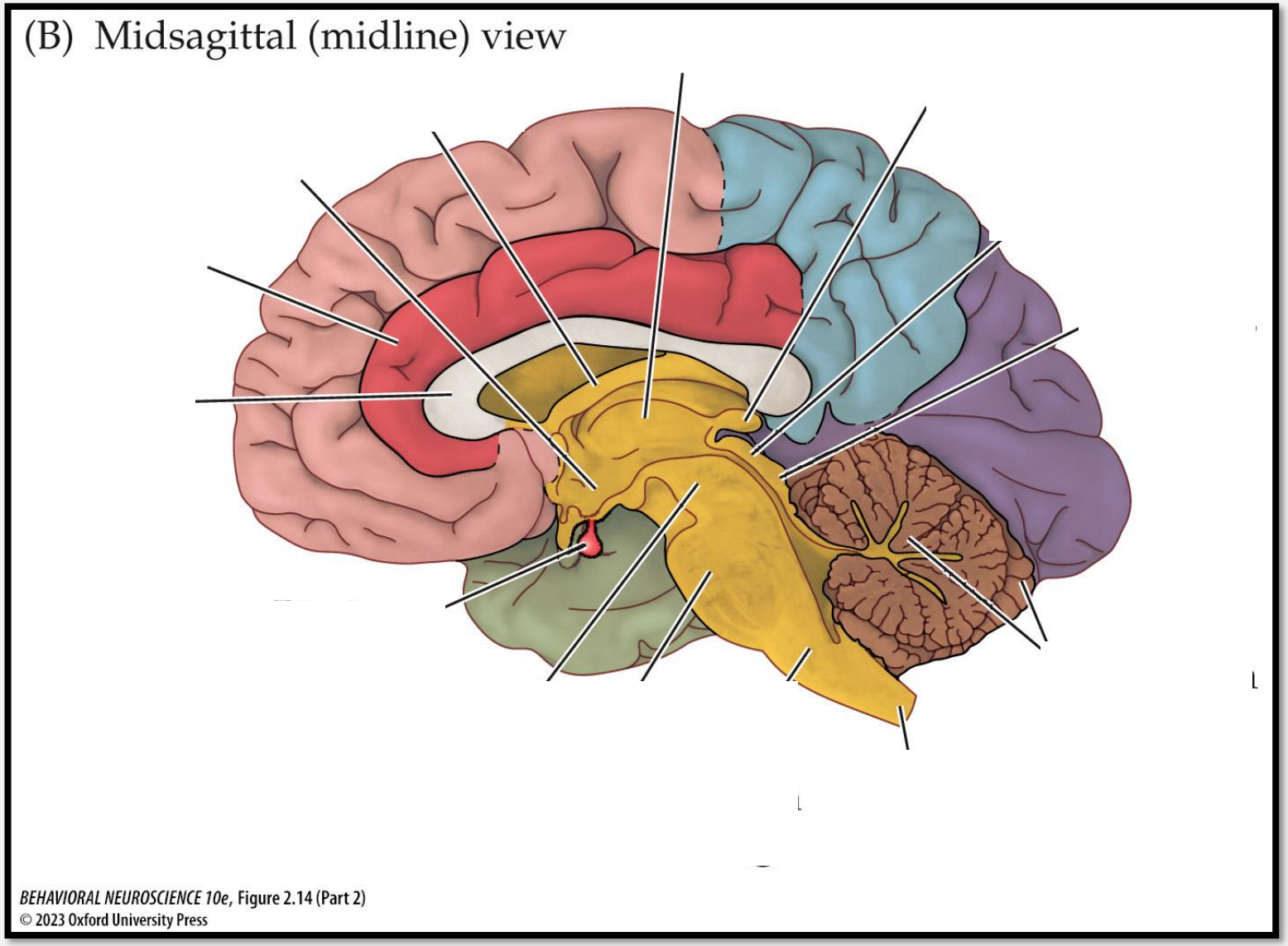
Brain stem – midbrain, pons, medulla

Central Sulcus

Thalamus

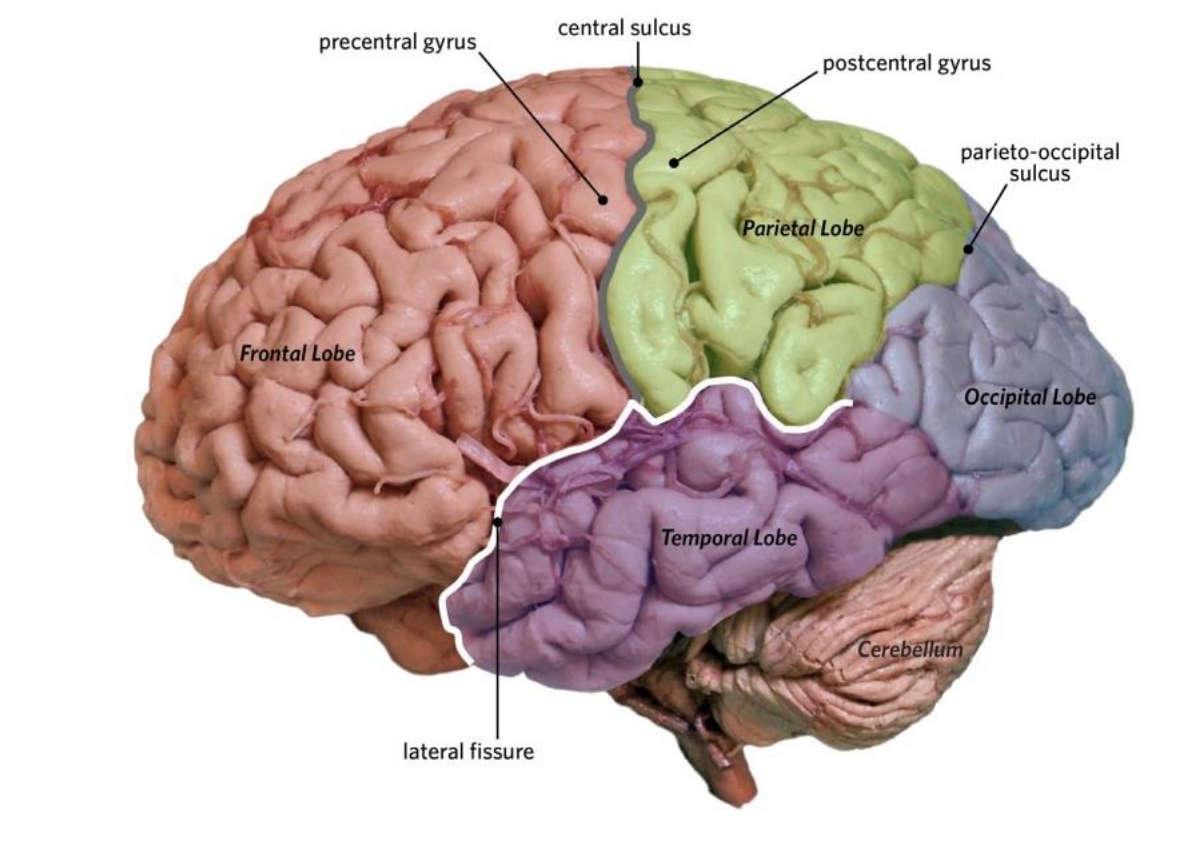
Hypothalamus

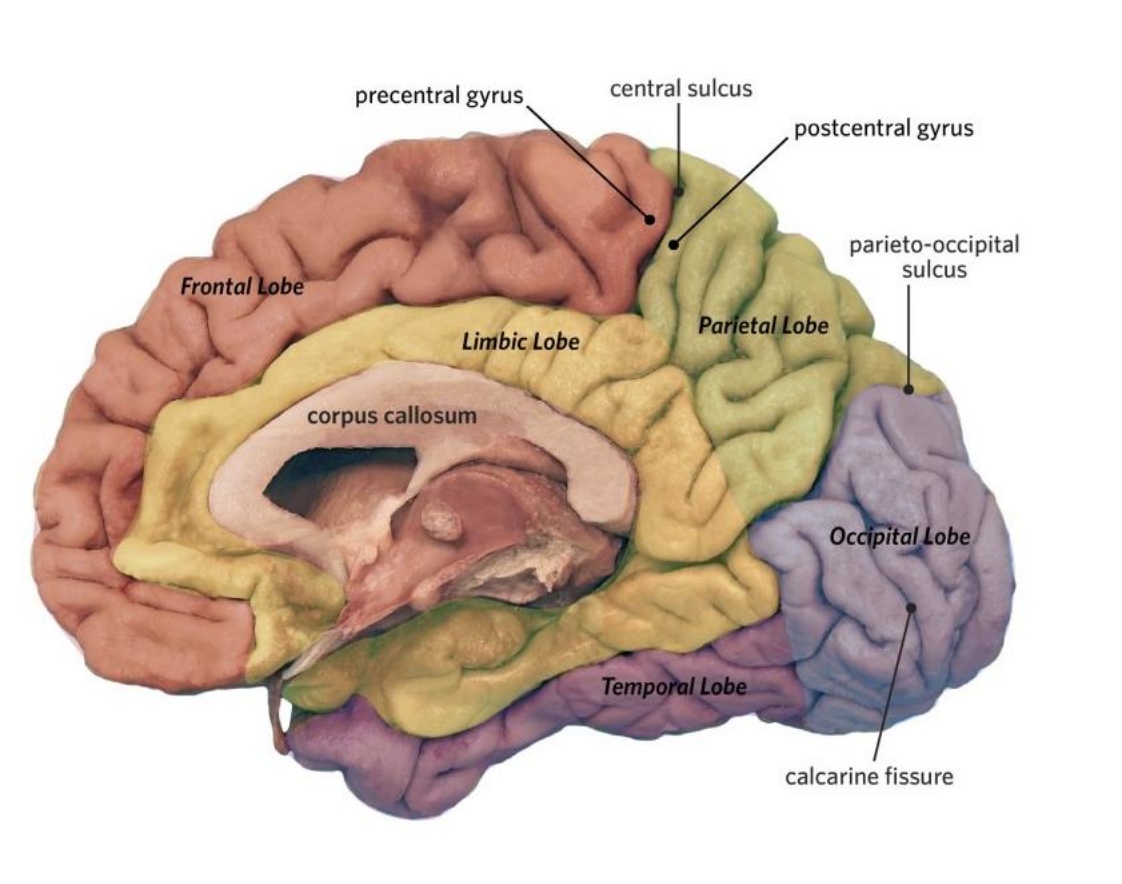
Corpus callosum



BEHAVIORAL NEUROSCIENCE 10e, Figure 2.14 (Part 2)

Answer key


precentral gyrus
central sulcus
postcentral gyrus
parieto-occipital sulcus
Parietal Lobe
Frontal Lobe
Occipital Lobe
Temporal Lobe
Cerebellum
lateral fissure


precentral gyrus
central sulcus
postcentral gyrus
parieto-occipital sulcus
Frontal Lobe
Limbic Lobe
Parietal Lobe
corpus callosum
Occipital Lobe
Temporal Lobe
calcarine fissure

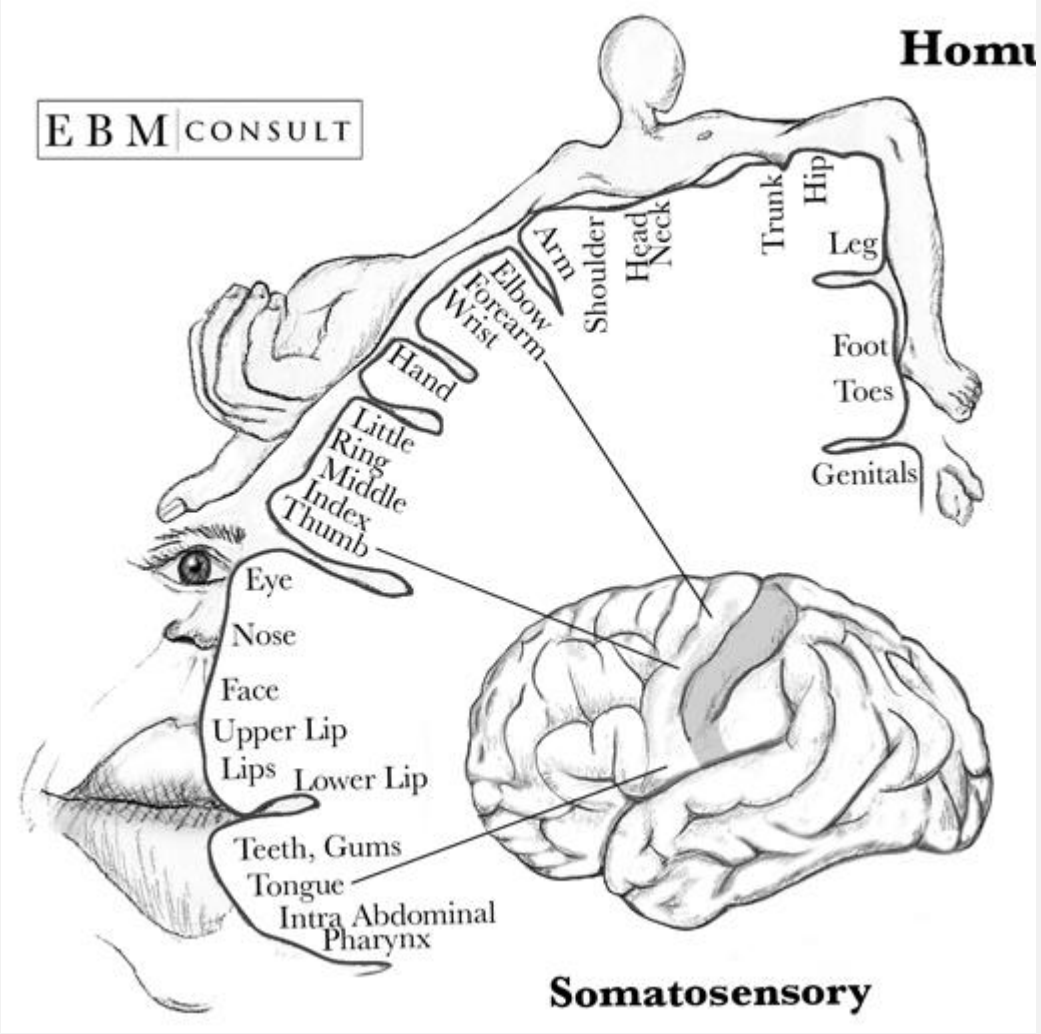
Follow the language

The postcentral gyrus

- is a strip of cortex behind the central cortex that is important for touch.

Sensory Homunculus

- The human body maps onto the somatosensory cortex (part of the parietal lobe)



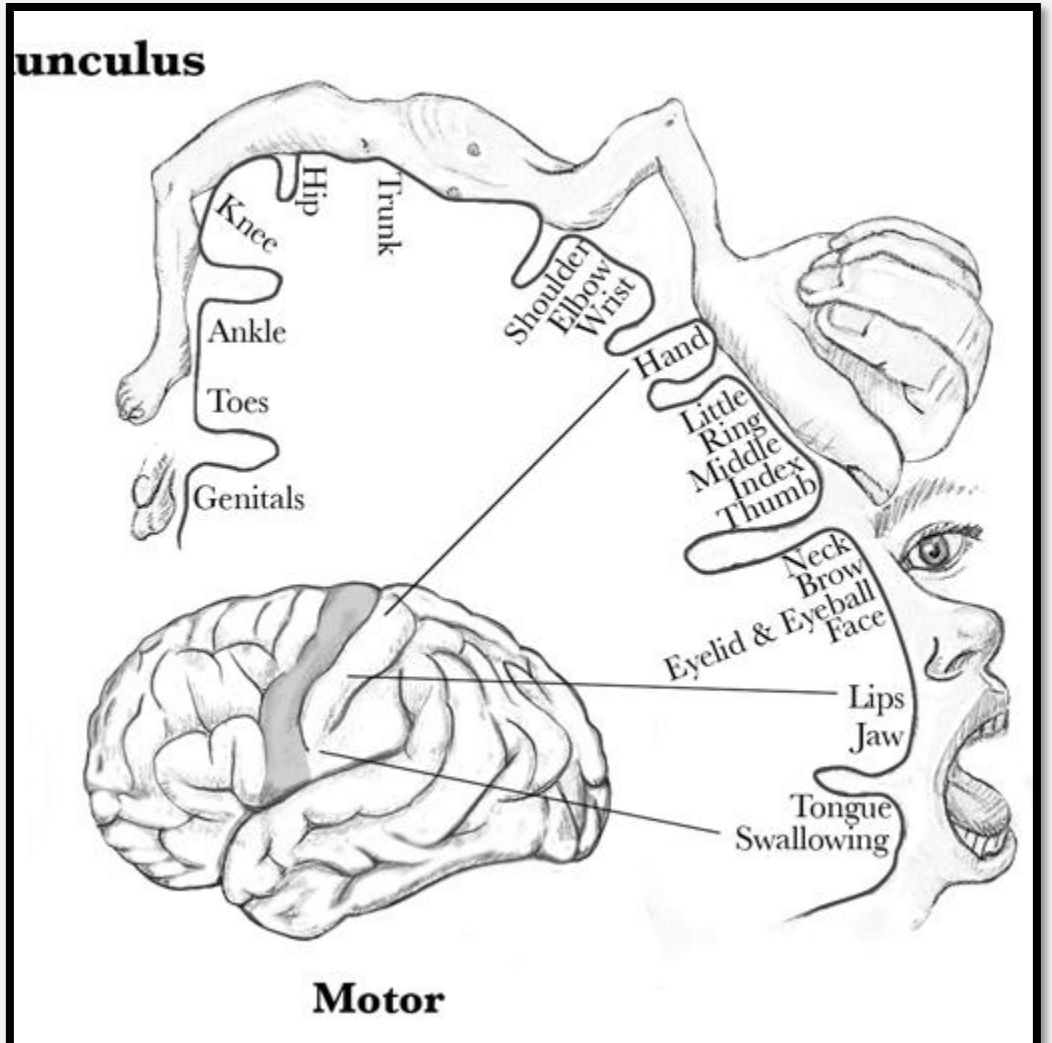
Follow the language

The precentral gyrus

- In the frontal lobe, important for motor control .

Motor Homunculus

- Motor control is somatotopically mapped along the precentral gyrus

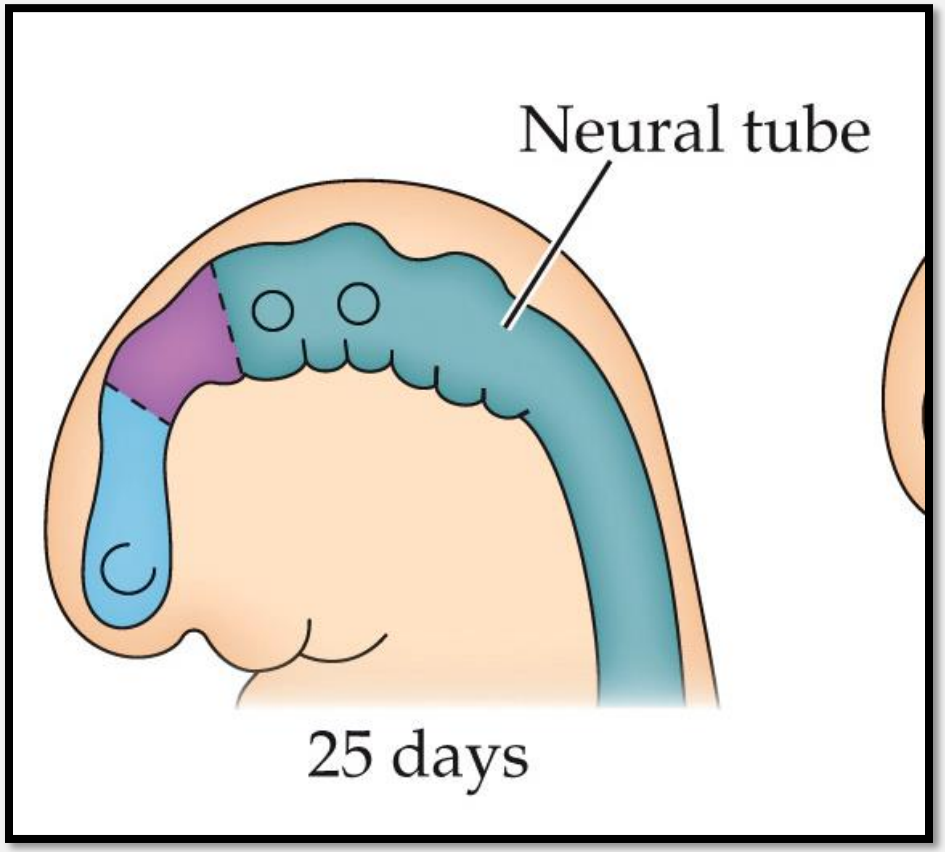


Brain development – 25 Days

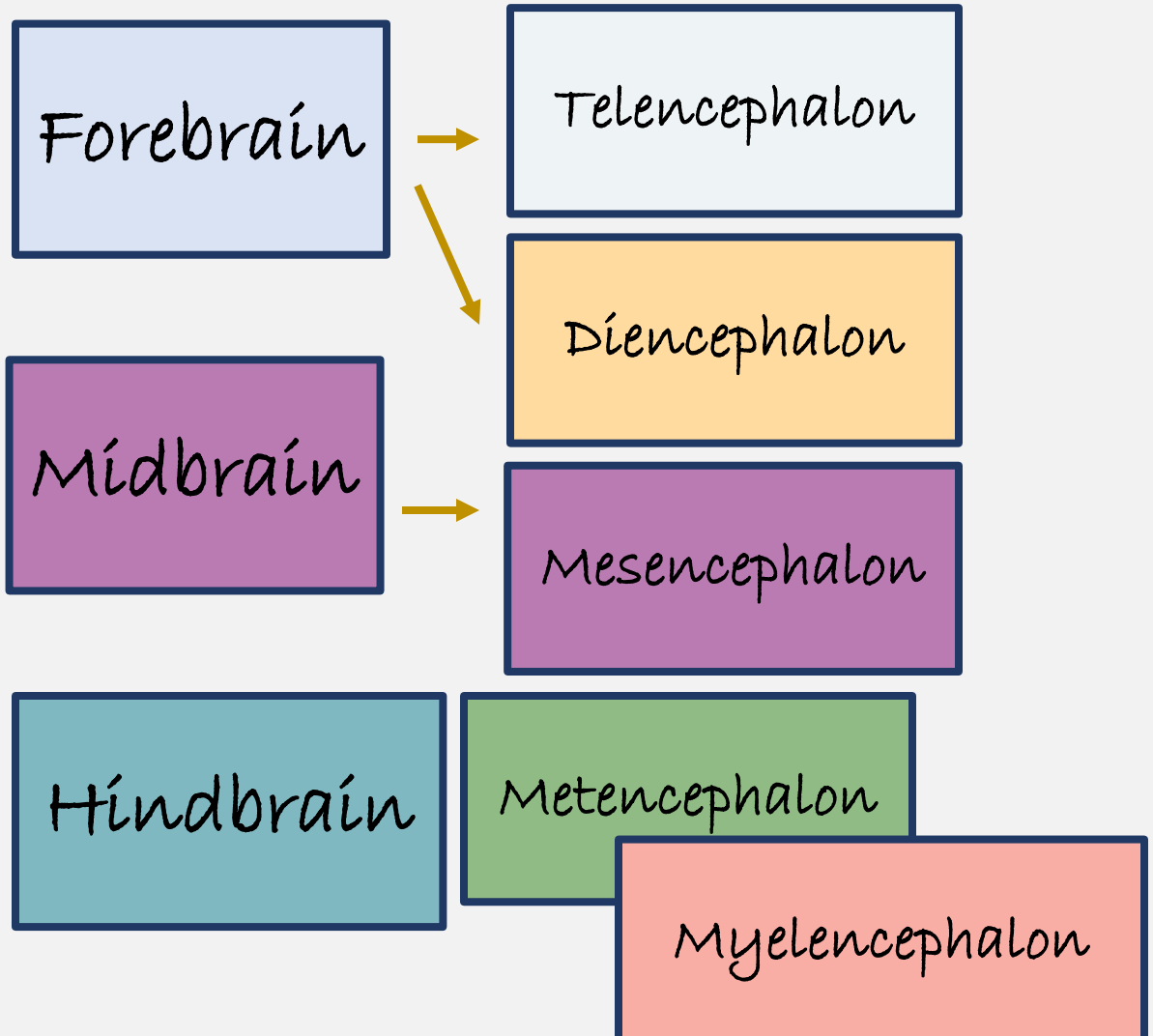
Forebrain

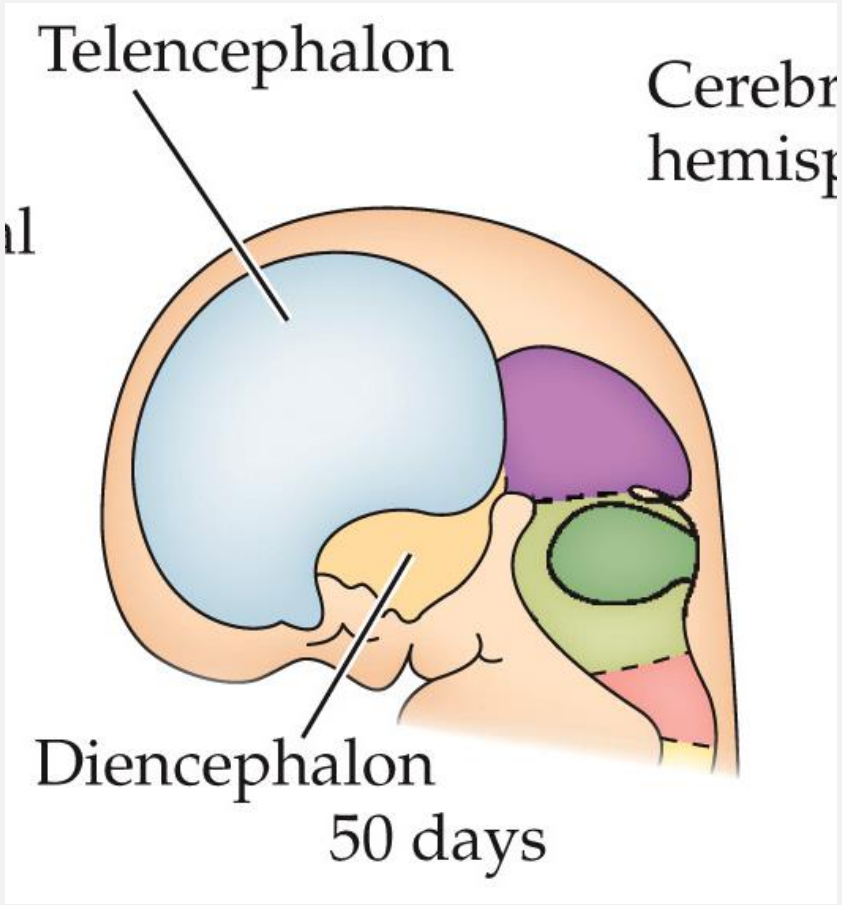
Midbrain

Hindbrain



Brain development – 50 Days





Myel – marrow, spinal cord

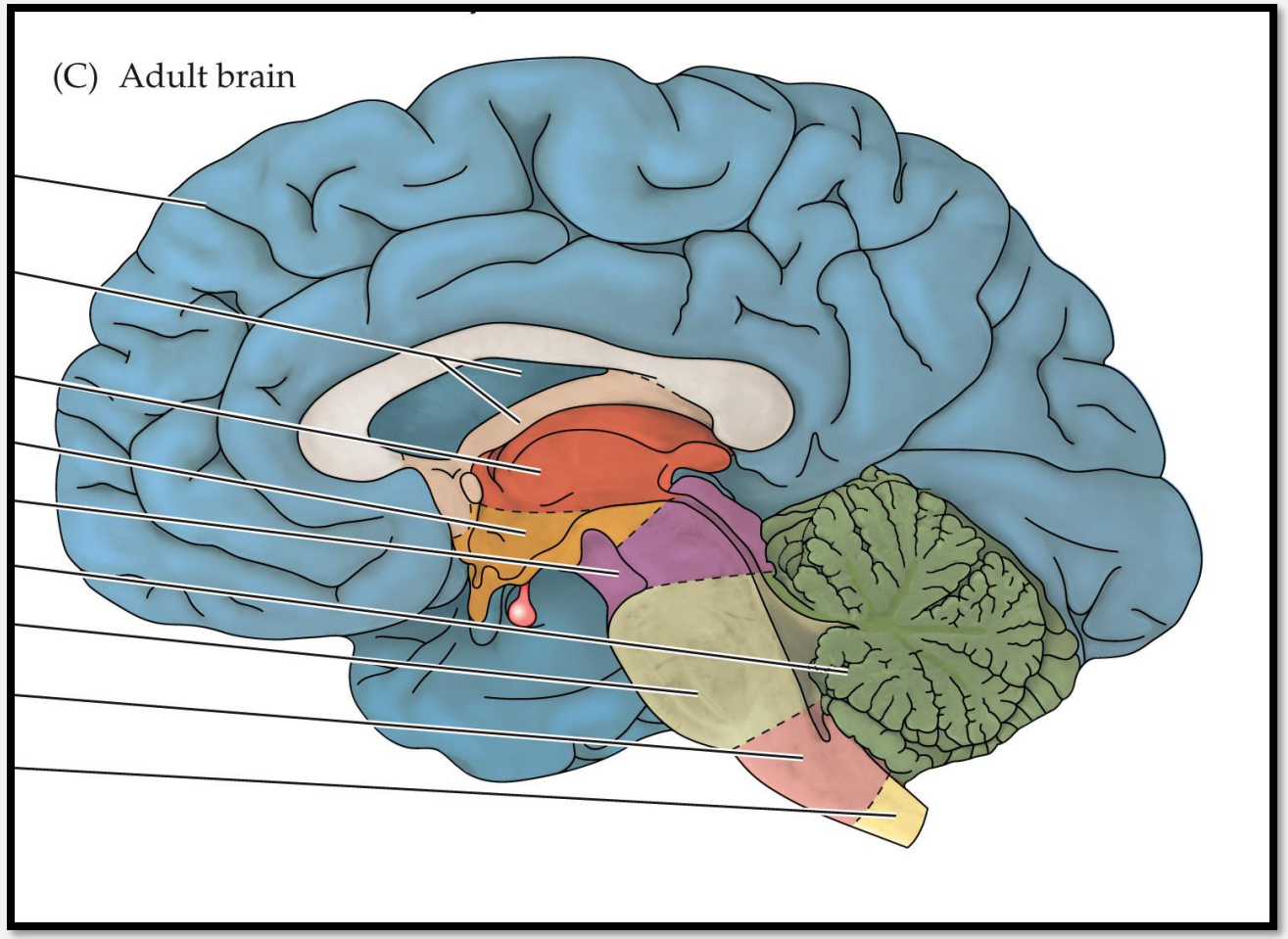
The Hindbrain

Myelencephalon

Medulla – regulates breathing and heartrate

All neurons passing from the brain to the spinal cord pass through the medulla

Medulla (Brainstem)



Met – beside/after

The Hindbrain

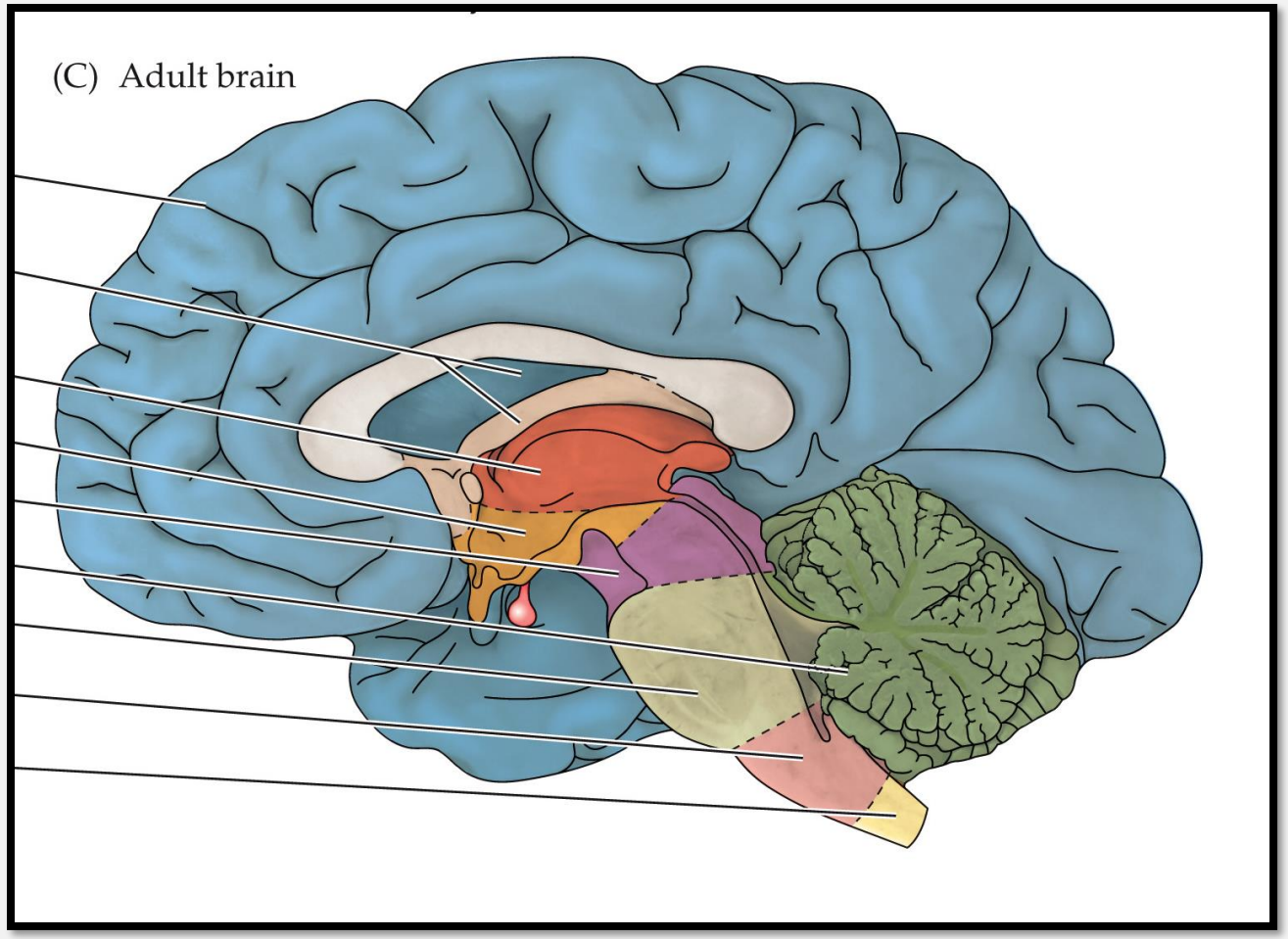
Metencephalon

Pons (brainstem)

Cerebellum

Pons – "bridge" connects medulla to midbrain

Cerebellum – Balance, coordination



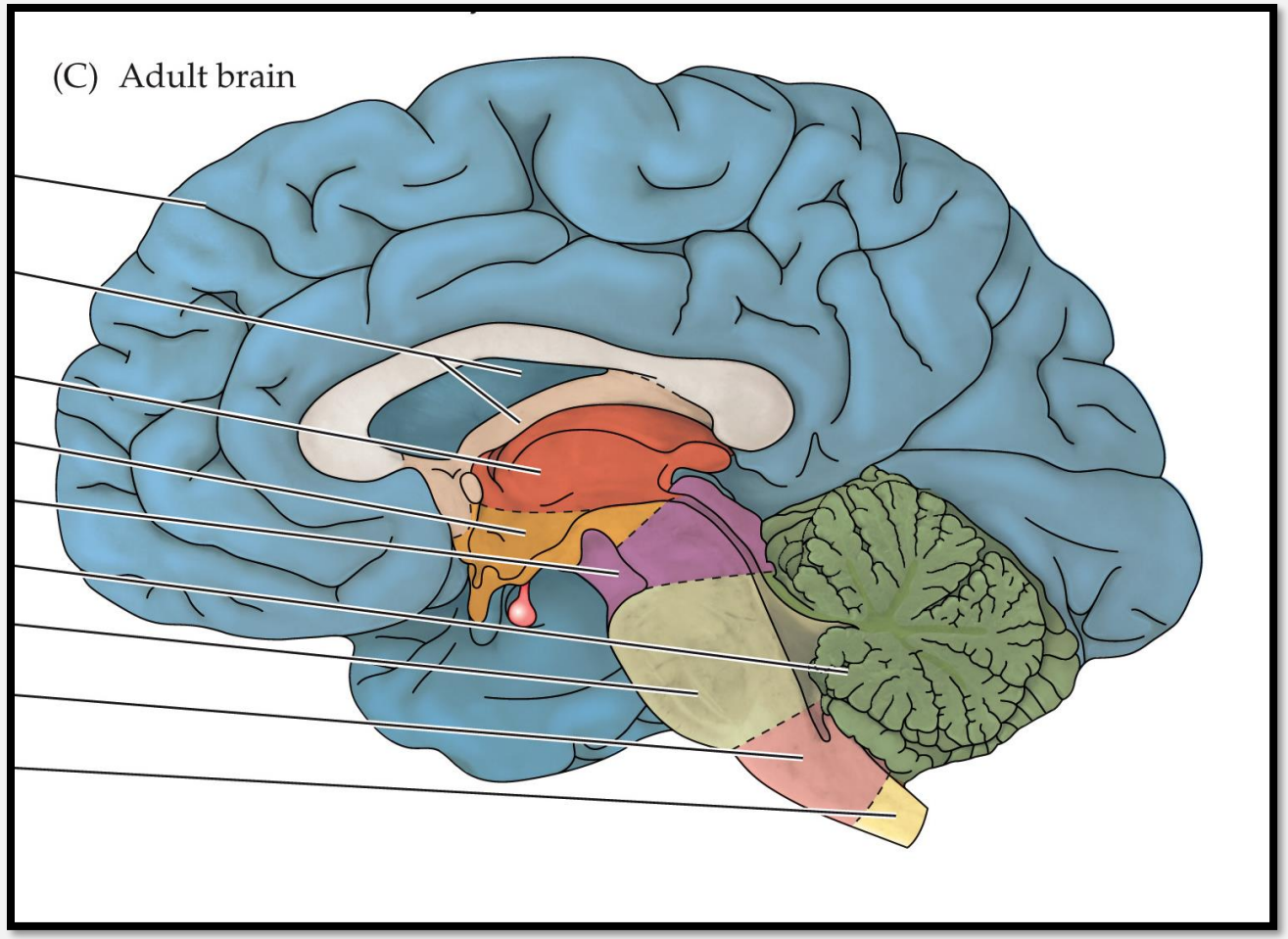
Mes - middle

The Midbrain

Mesencephalon

Midbrain (Brainstem)

Midbrain – Tectum: sensory and motor functions
Reticular formation
Sleep, arousal, temperature control, motor control



Di – two

Forebrain structures

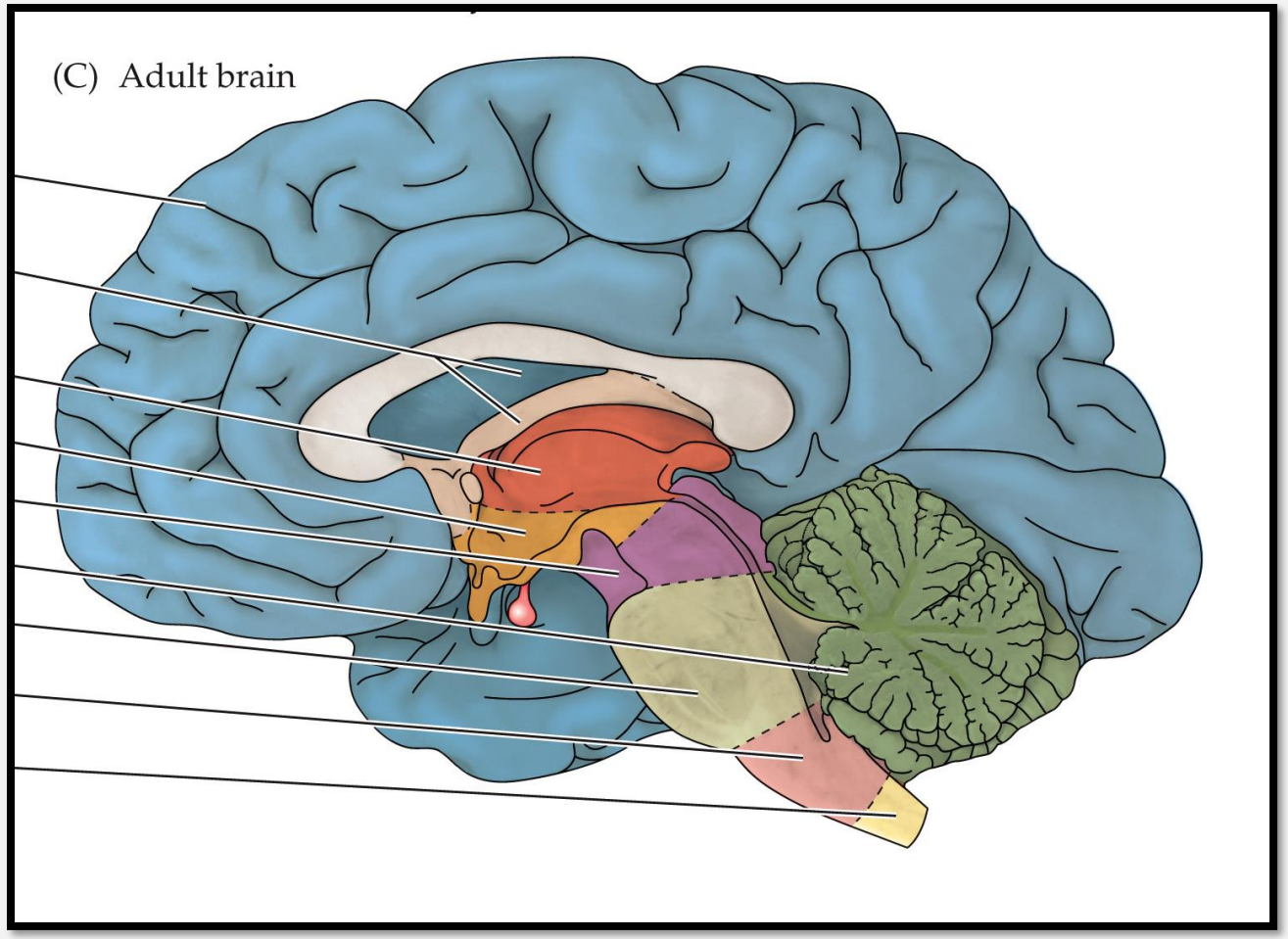
Diencephalon

Thalamus – relay station for all incoming sensory information

Thalamus

Hypothalamus

Hypothalamus – "below" the thalamus, contains nuclei with many vital functions (hunger, thirst, temperature regulation, sex, and more); also controls the pituitary



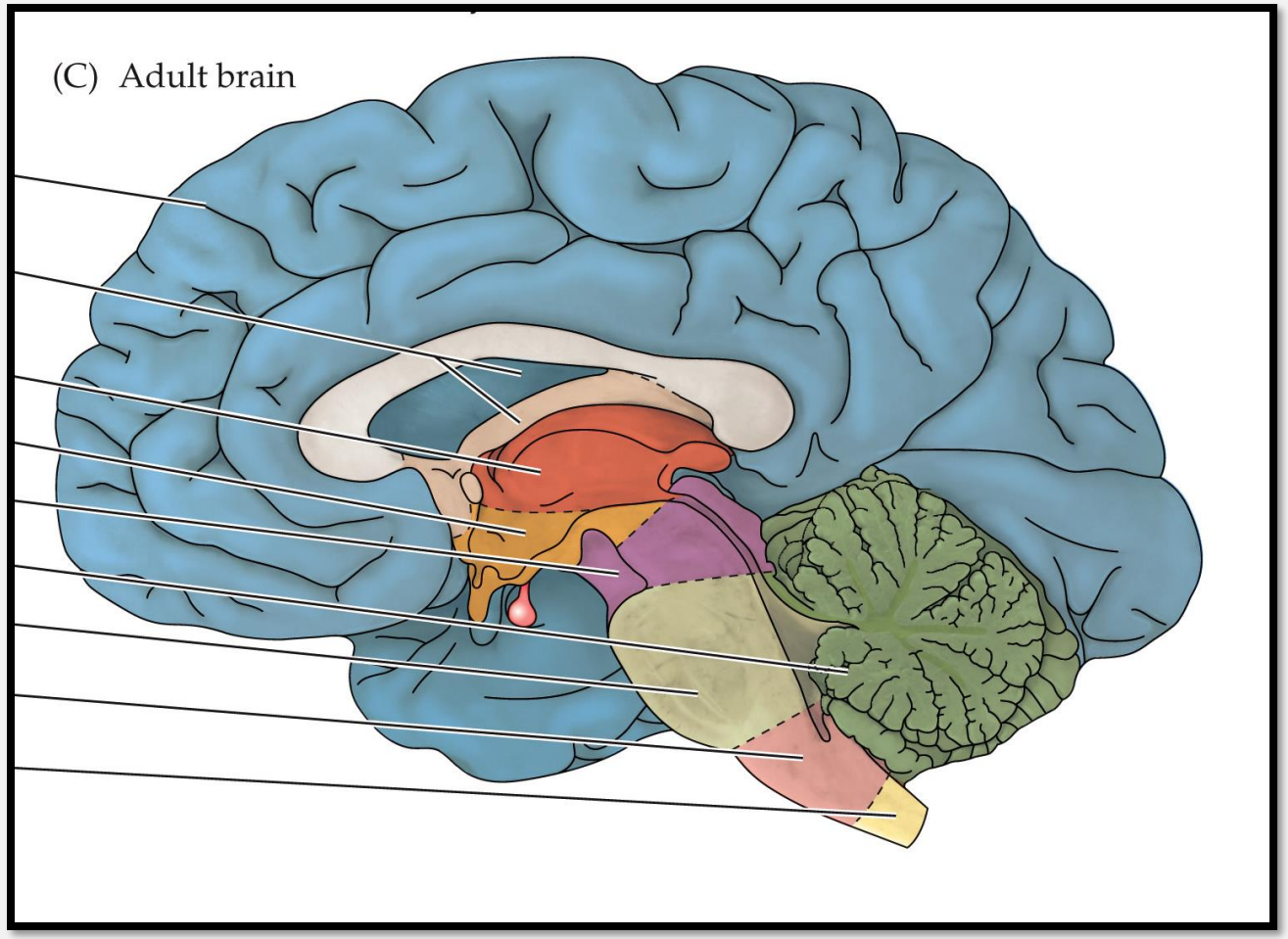
Tel – far off
distant

Forebrain structures

Telencephalon

Cerebral cortex

Higher cortical functioning



Brain imaging techniques

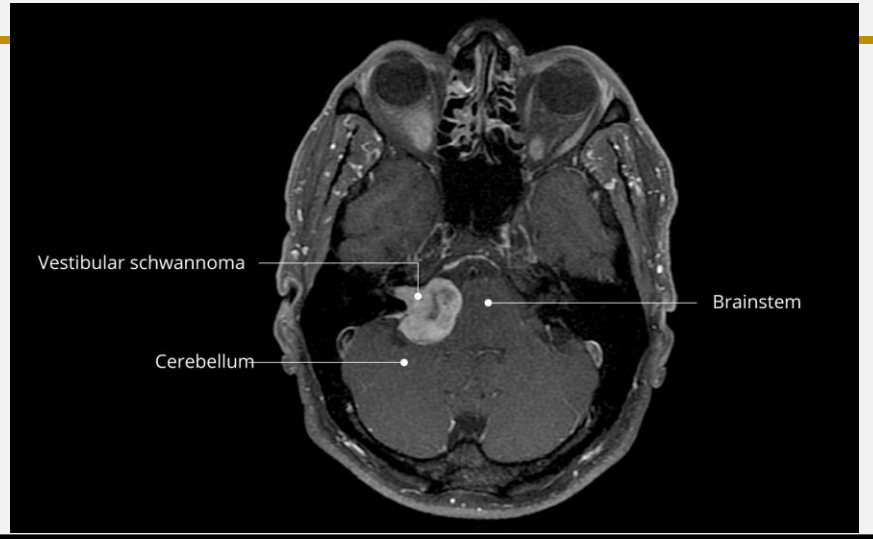
Brain-Imaging Techniques

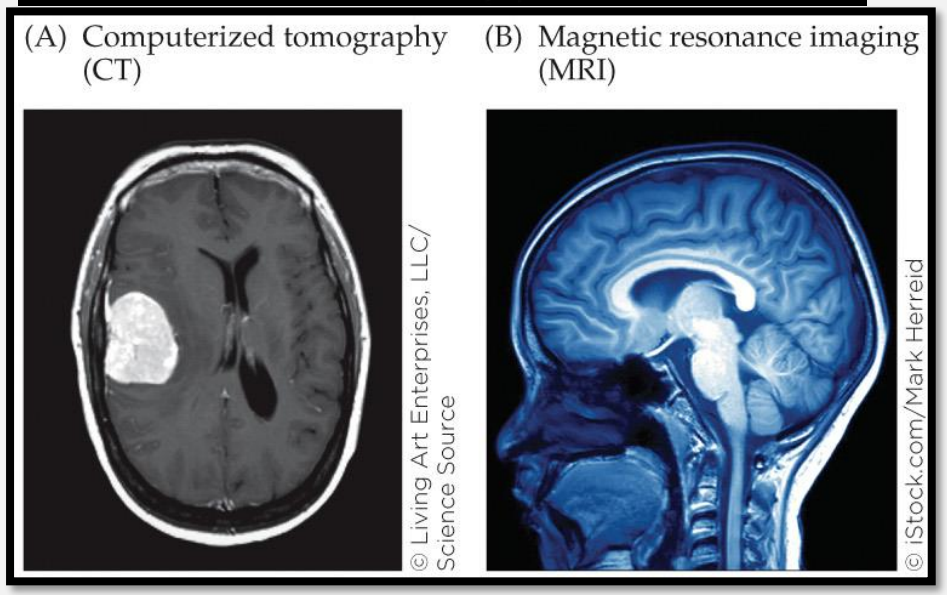
Computerized axial tomography

- (**CAT or CT**)—a measure of X-ray absorption with ionizing radiation at several positions around the head; maps tissue density
- Great for imaging bones, detecting tumors, bleeds (best for solid structures)

Magnetic resonance imaging (MRI)

- produces high-resolution images using radio frequency energy.
- Better for detailed images of softer tissue

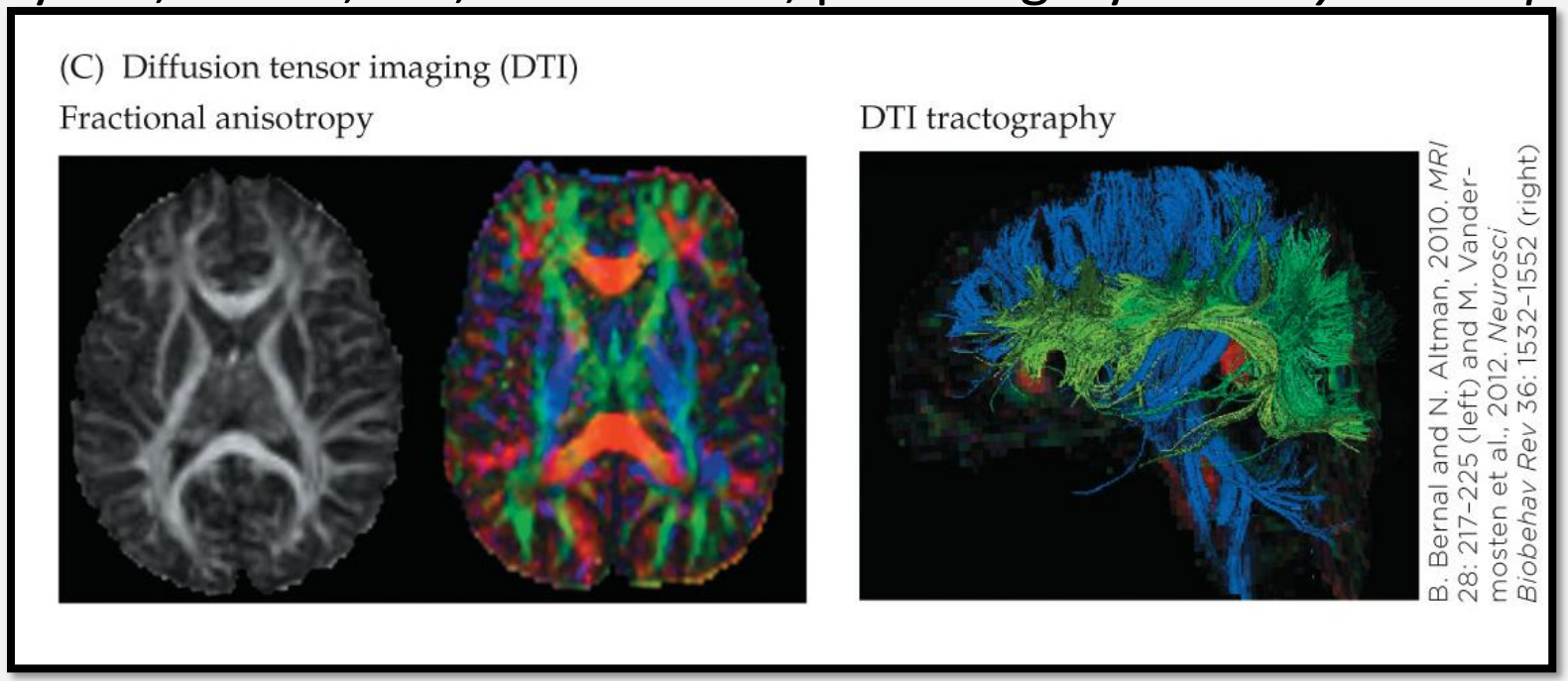




Brain imaging techniques

Diffusion tensor imaging (DTI)

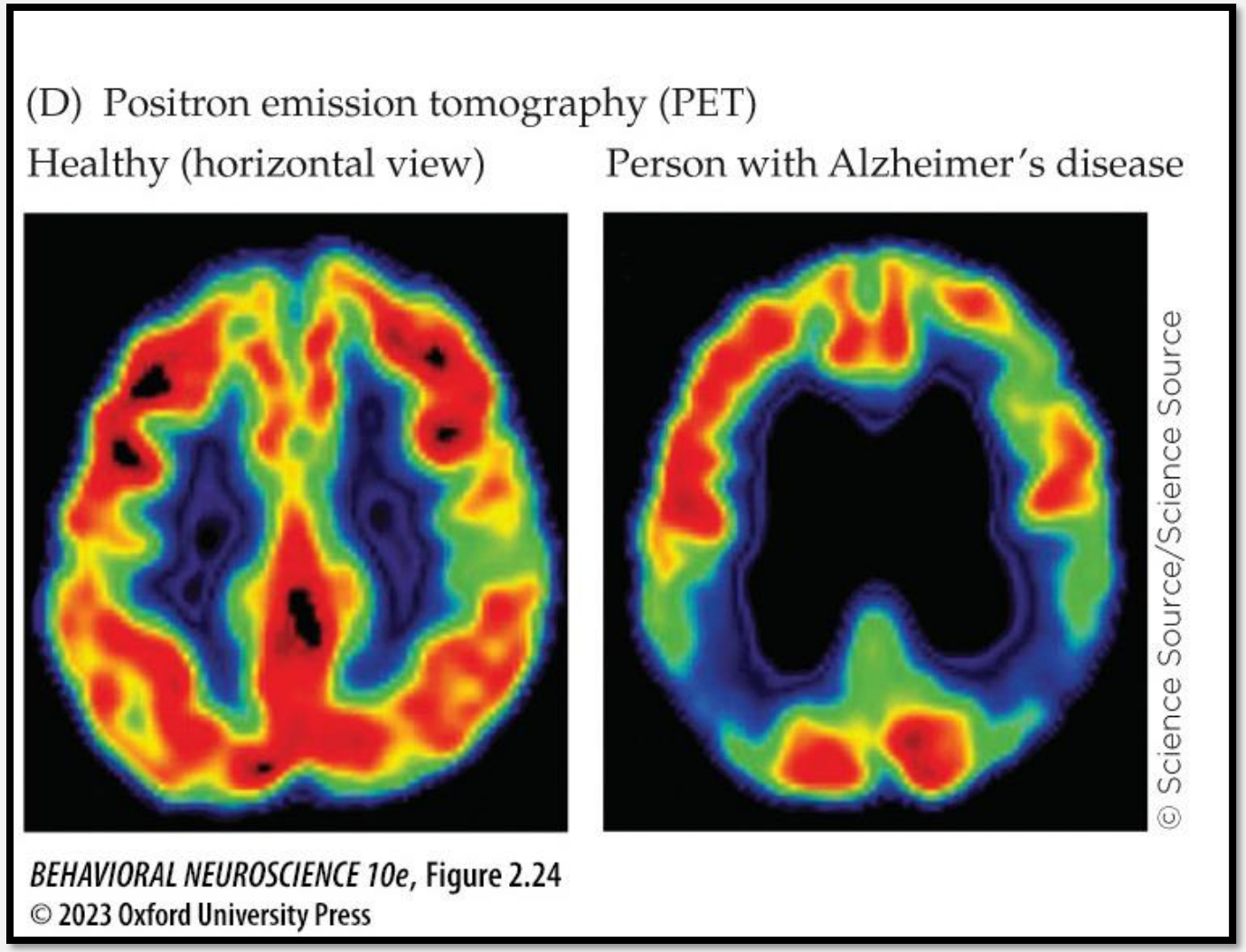
- uses MRI technology to study white matter tracts; based on **fractional anisotropy** (**FA**) – fancy way of saying water diffusing in along the length of white matter tracts.
- Study MS, stroke, *TBI*, Alzheimer's, plan surgery & *study development*



Brain Imaging Techniques

Positron emission tomography (PET)

- produces images of brain activity: identifies brain regions that contribute to specific functions.
- Involves a radioactive tracer (form of glucose).
- Metabolically active tissue will use more glucose
- Tracer emits gamma waves as it breaks down
- Detects cancer, observe heart damage, study brain function

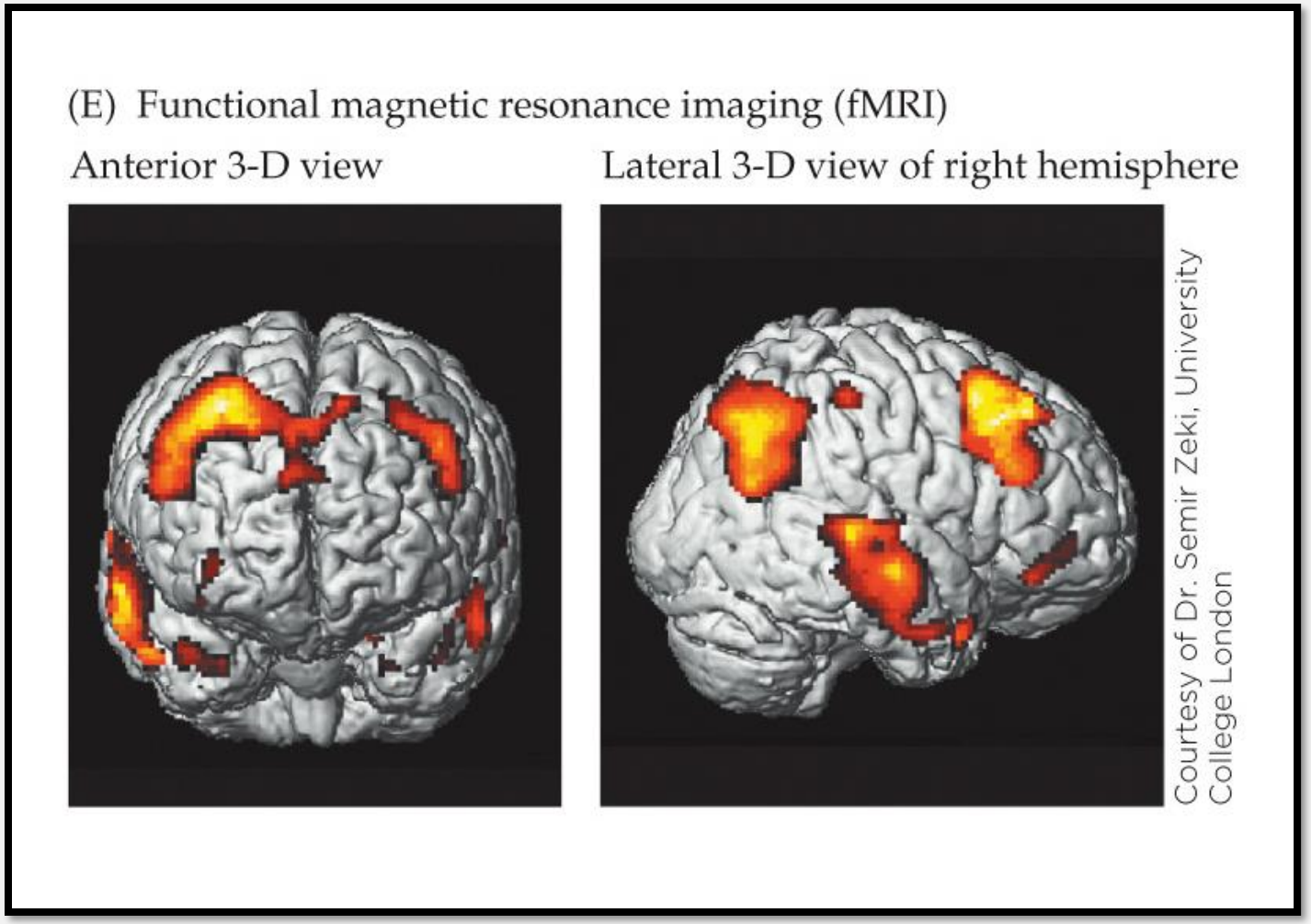


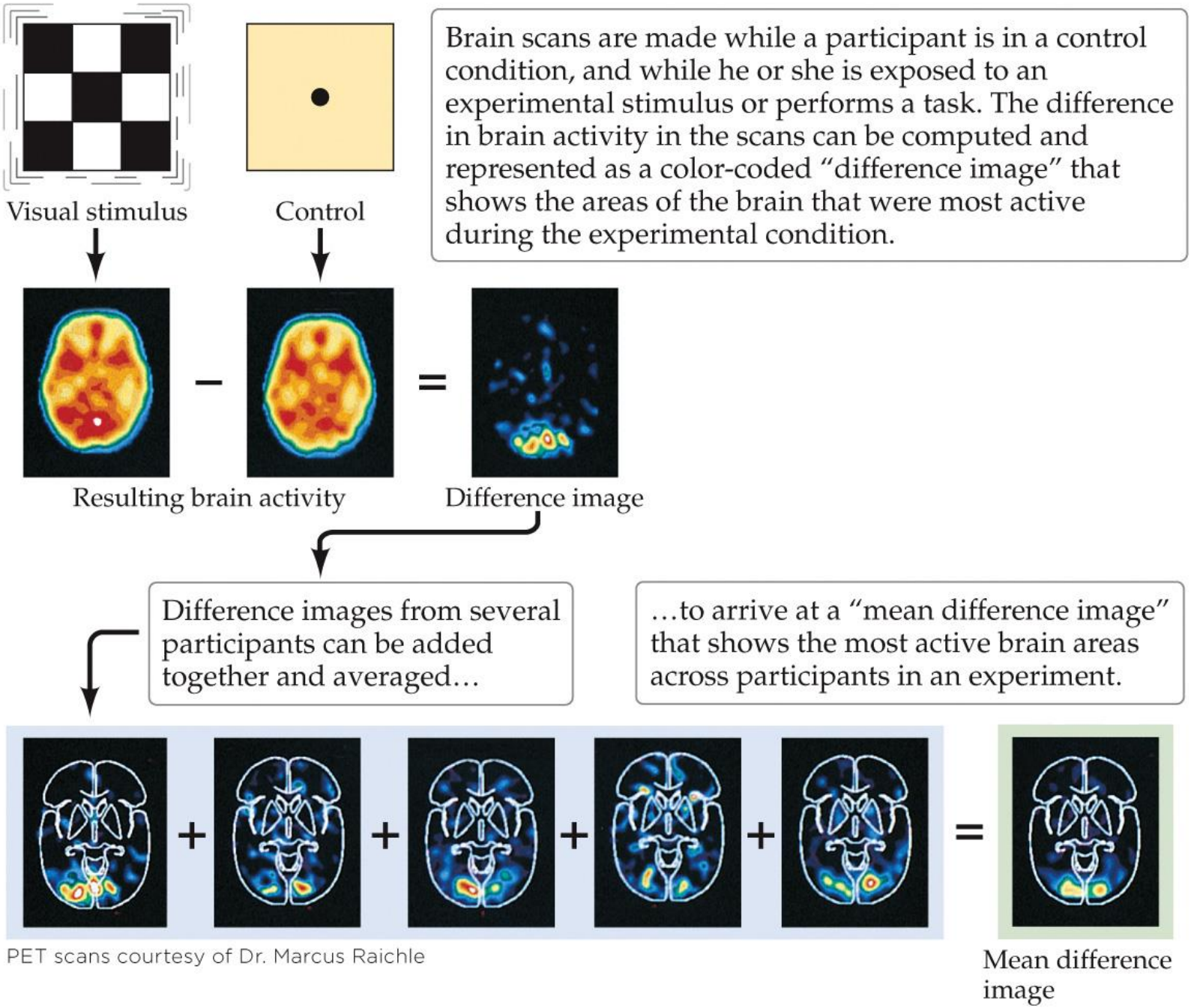
BEHAVIORAL NEUROSCIENCE 10e, Figure 2.24

Brain Imaging Techniques

Functional MRI (fMRI)

- detects small changes in brain metabolism, such as oxygen use, in active brain areas.
- fMRI can show how networks of brain structures collaborate.

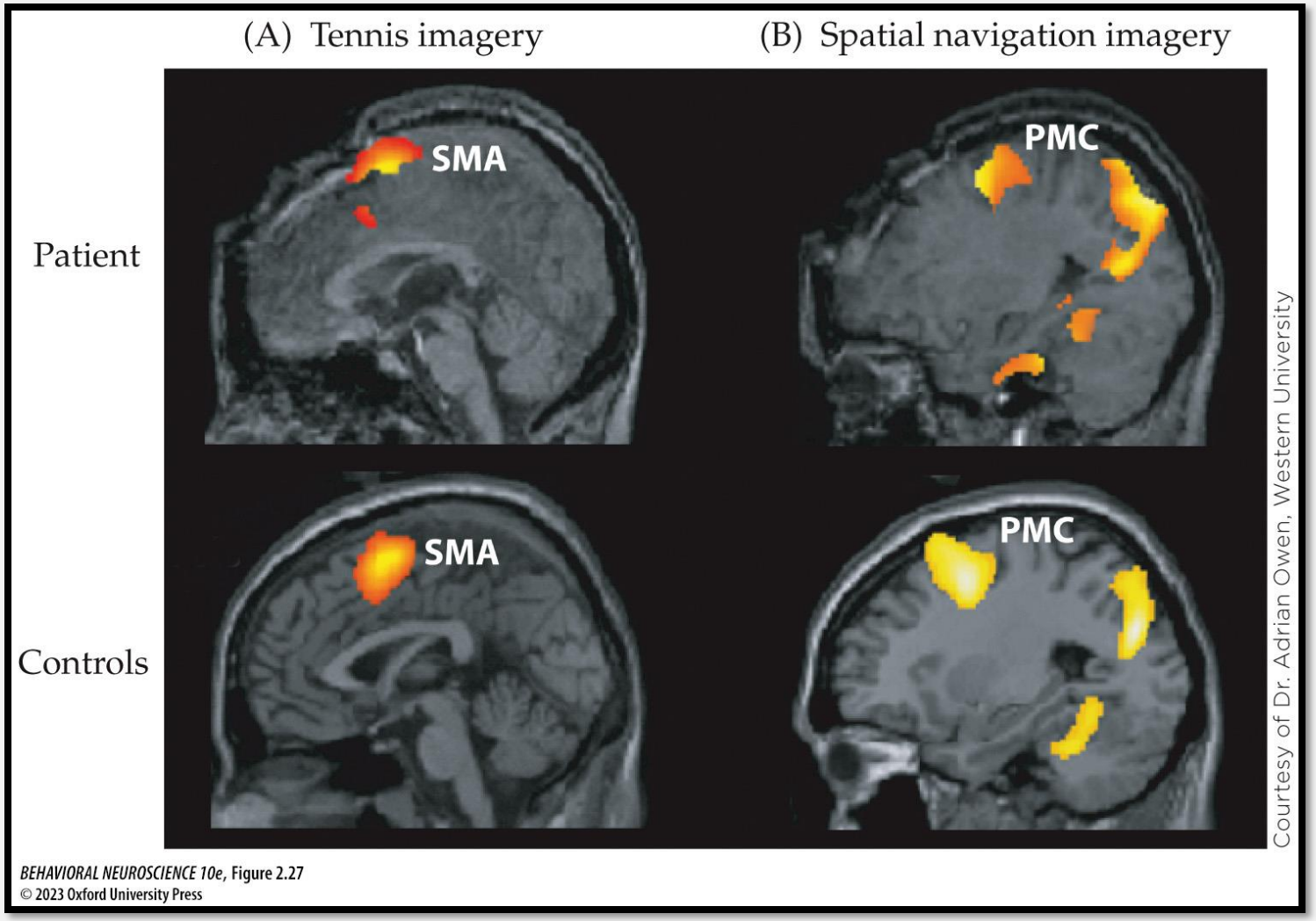




BEHAVIORAL NEUROSCIENCE 10e, Box 2.3

Brain Imaging Techniques

- Imaging can overcome the limitations of other methods of assessment and complement traditional studies of brain **lesions** (regions of damage).
- One question that can be addressed is the state of consciousness of people in comas.
- **Study:** Prompted brain activity in an individual in a Coma



Cutting edge research

Social neuroscience

- aims to understand brain activity as it relates to our interactions with others.

Dyadic functional MRI (dfMRI)

- employs an MRI scanner that is fitted with specially designed dual head coils (encircling the head to produce brain images).

Cutting edge research

- As a pair of friends blinked and gazed at each other's faces, enhanced BOLD signal was observed in the region of the temporoparietal junction (TPJ, a region previously implicated in social cognition), the fusiform face area, and the frontal cortex.

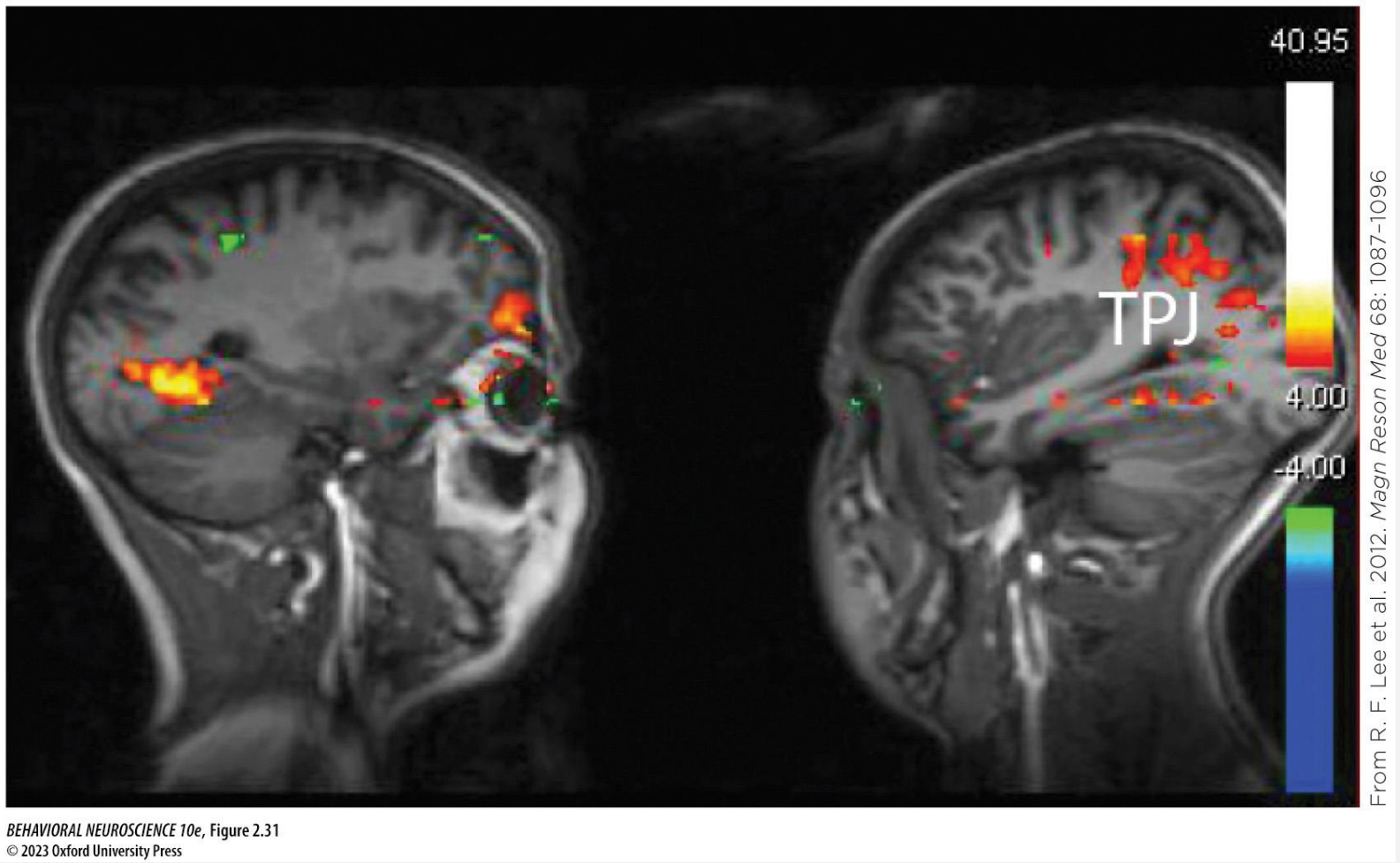
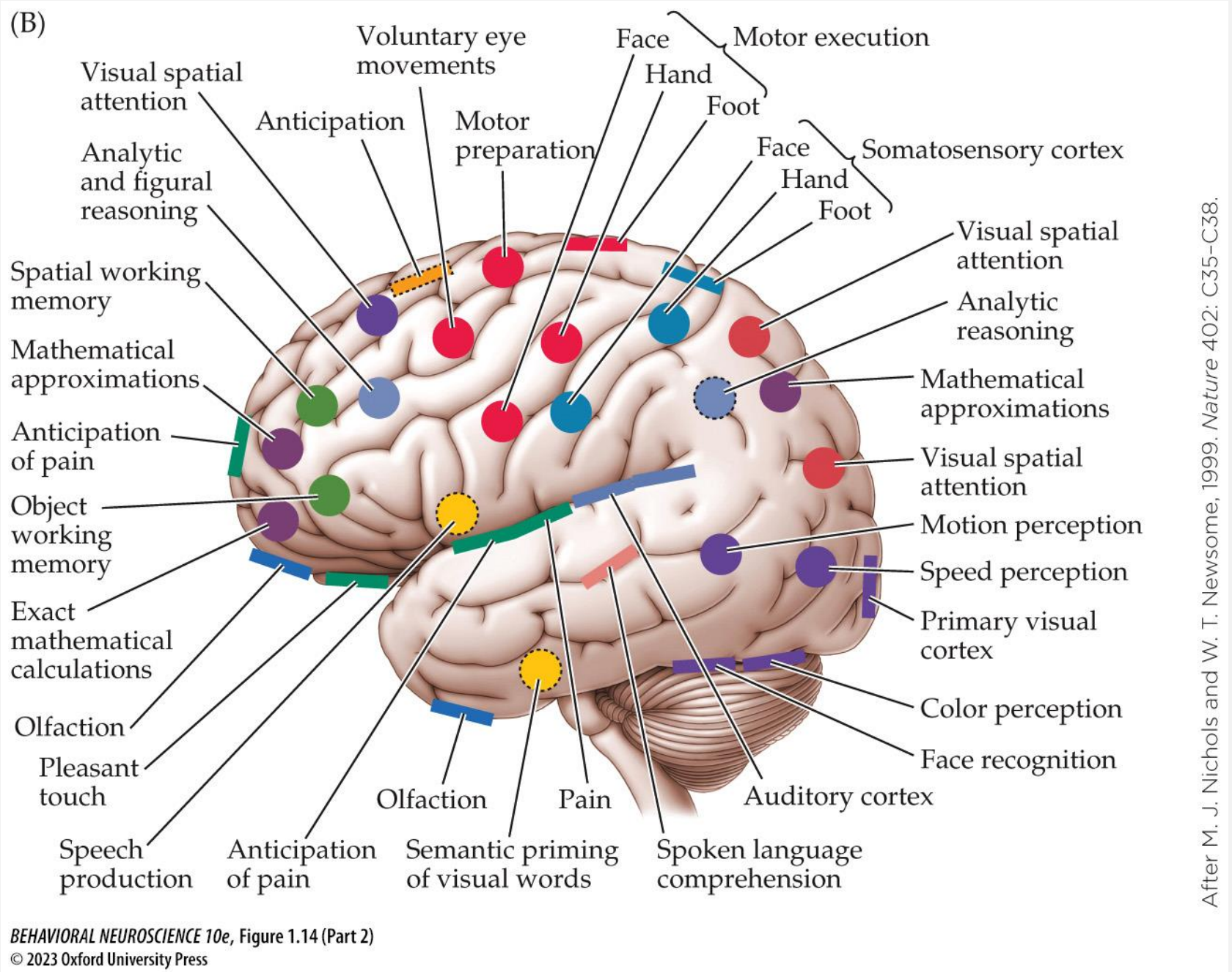


FIGURE 1.14 Old and New Phrenology (Part 2)



BEHAVIORAL NEUROSCIENCE 10e, Figure 1.14 (Part 2)

Endocrinology

Learning objectives

By the end of class, you should be able to:

1. Contrast the different chemical signaling systems within the body and between individuals.
2. Classify the major classes of hormones and describe how they affect target cells.
3. Describe the structure and function of neuroendocrine cells.
4. Contrast the receptors and mechanisms of action of peptide and amine hormones versus steroid hormones.
5. Compare the genomic versus nongenomic actions of steroid hormones.
6. Understand how the brain regulates hormone production and secretion
7. Distinguish the mechanisms of hormone secretion in the posterior versus anterior pituitary gland.
8. Survey the many endocrine hormones regulated by the anterior pituitary and their effects.
9. List six anterior pituitary tropic hormones that affect endocrine glands.
10. Describe neurobehavioral functions of hormones secreted from the adrenal, thyroid, and pineal glands.
11. Describe the ways the brain regulates secretion of hormones from the gonads.
12. Understand how gonadal steroids activate mating behavior in male and female vertebrates.
13. Describe how hormones play a role in pair-bonding in monogamous species of voles.
14. Appreciate the reciprocal nature of hormonal effects on behavior—that behaviors affect hormone release too

A brief history

Ancient Greeks & the body's Humors

- Phelgm – *phlegmatic* (impassive)
- Black bile – *bilious* (irritable)
- Blood – *sanguine* (cheerful)
- Yellow bile (choler) – *choleric* (hot-tempered)

Aristotle

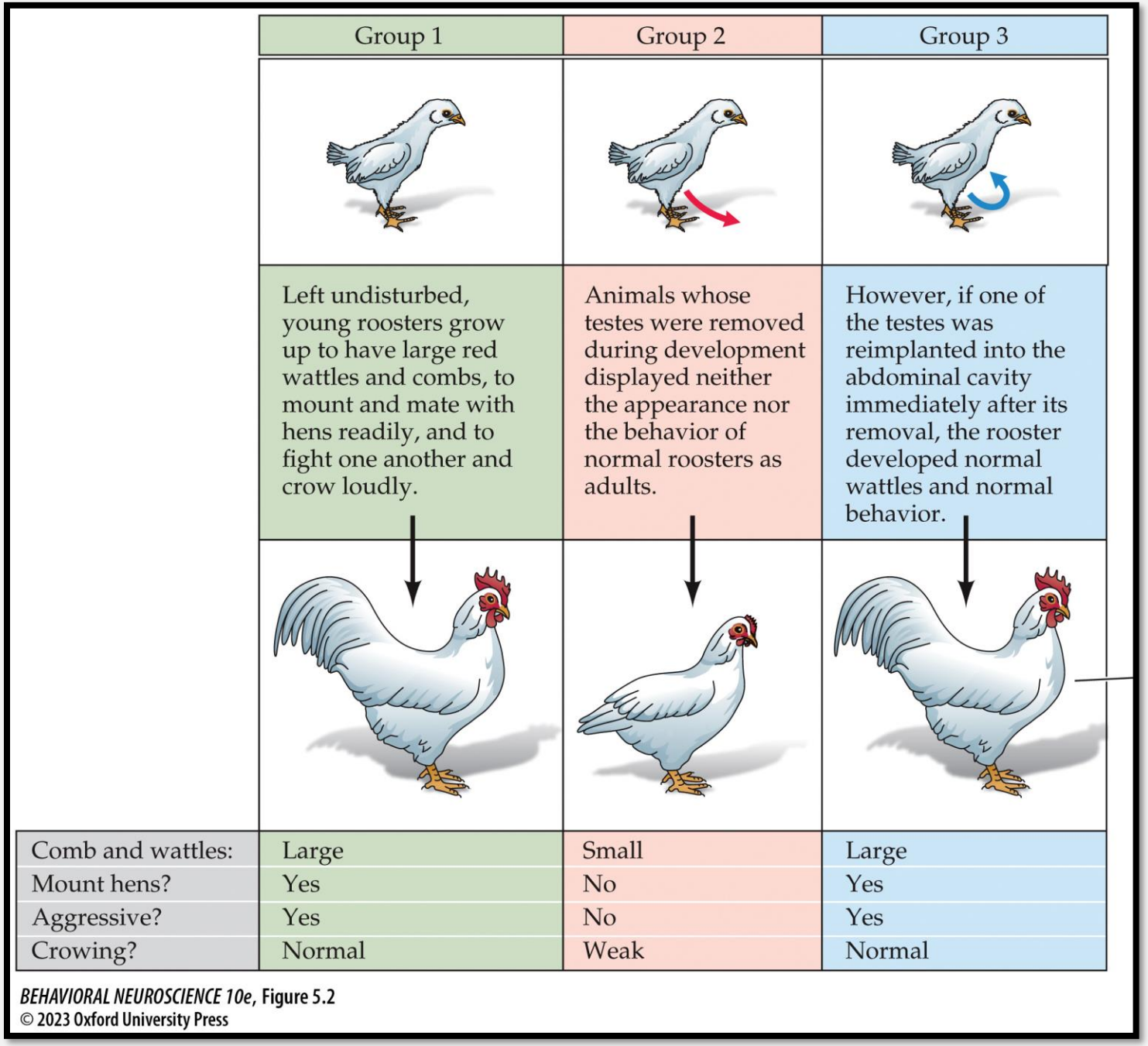
- Accurately described effects of castration in birds, and compared the effects to those observed in eunuchs (castrated men)

A brief history

Behavioural endocrinology

1849

- Arnold Adolf Berthold (after John Hunter)
- Observed behaviour and development of castrated, uncastrated and reimplanted roosters
- Results →



BEHAVIORAL NEUROSCIENCE 10e, Figure 5.2

Hormones

Hormones

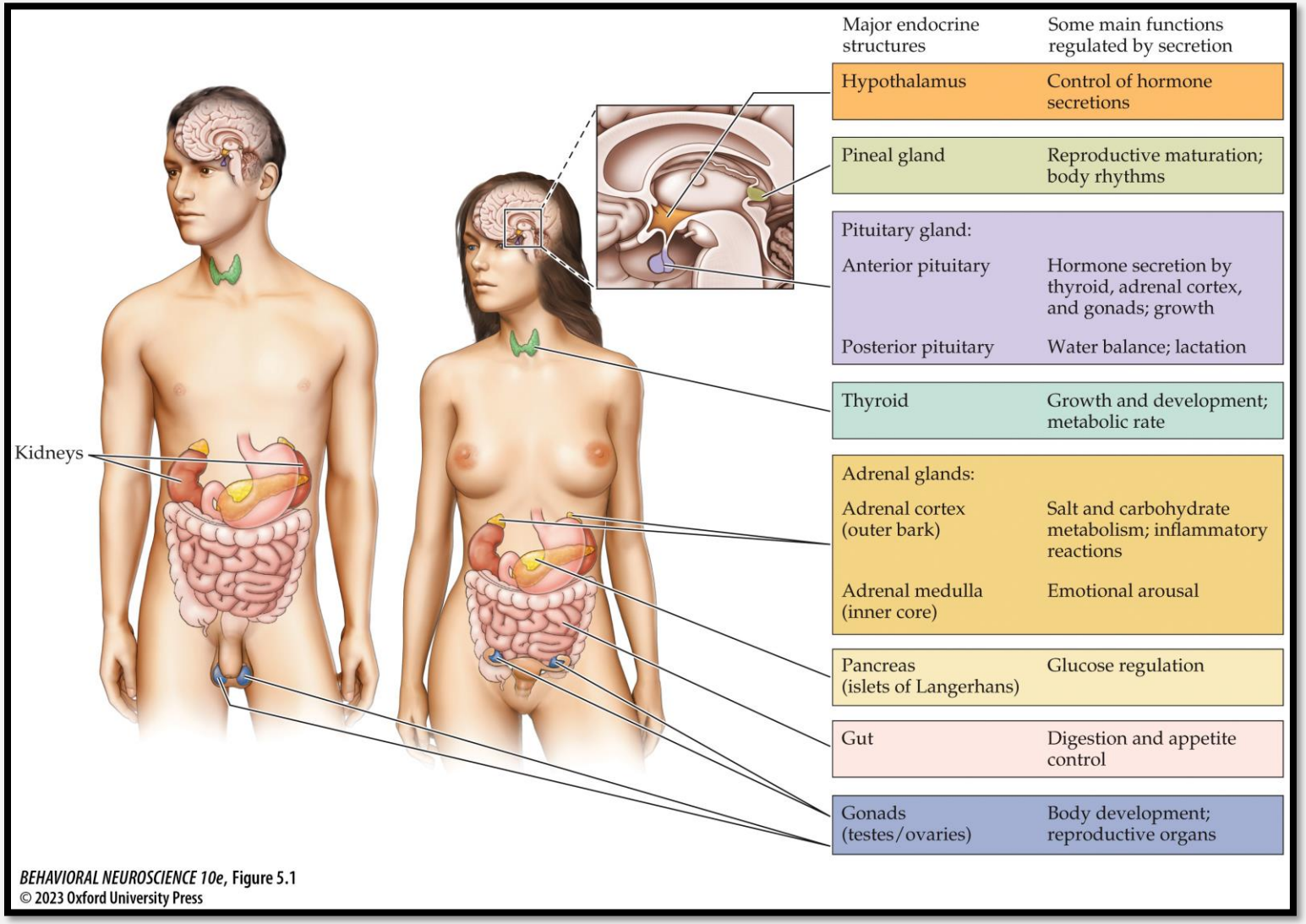
- chemicals secreted by cells in one part of the body that travel through the bloodstream to act on targets in other parts of the body.

Endocrine glands

- release hormones within the body.

Exocrine glands

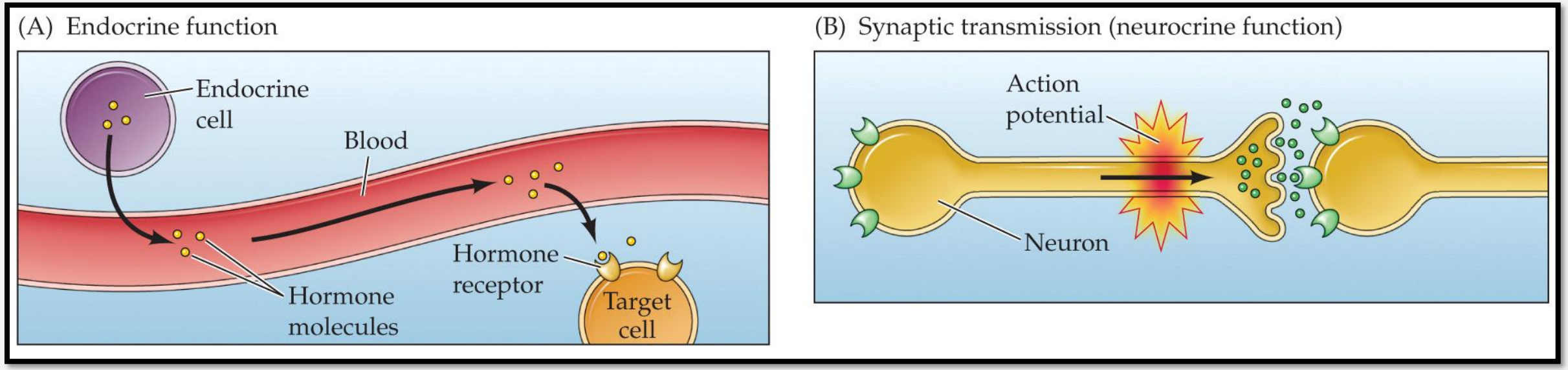
- use ducts to secrete fluids such as tears and sweat outside the body.



Chemical communication

Forms of chemical communication:

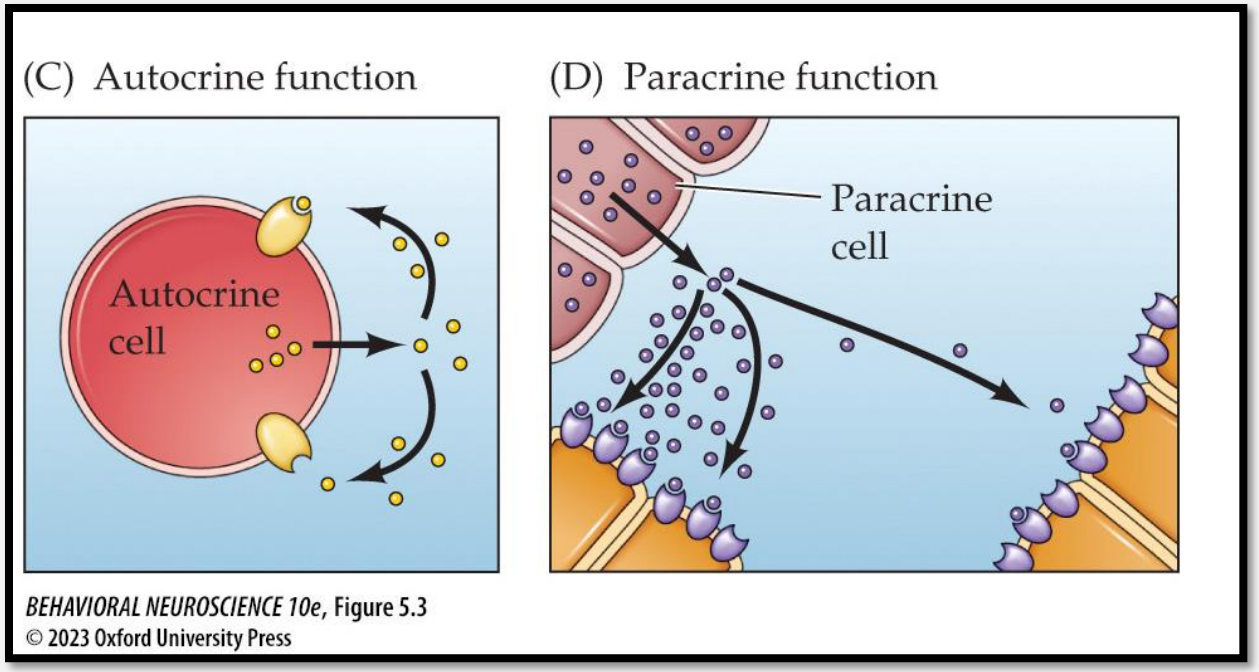
- **Endocrine**—a hormone is released into the bloodstream to act on target tissues
- Synaptic (**neurocrine**)—chemical release and diffusion across a synapse.



Chemical communication

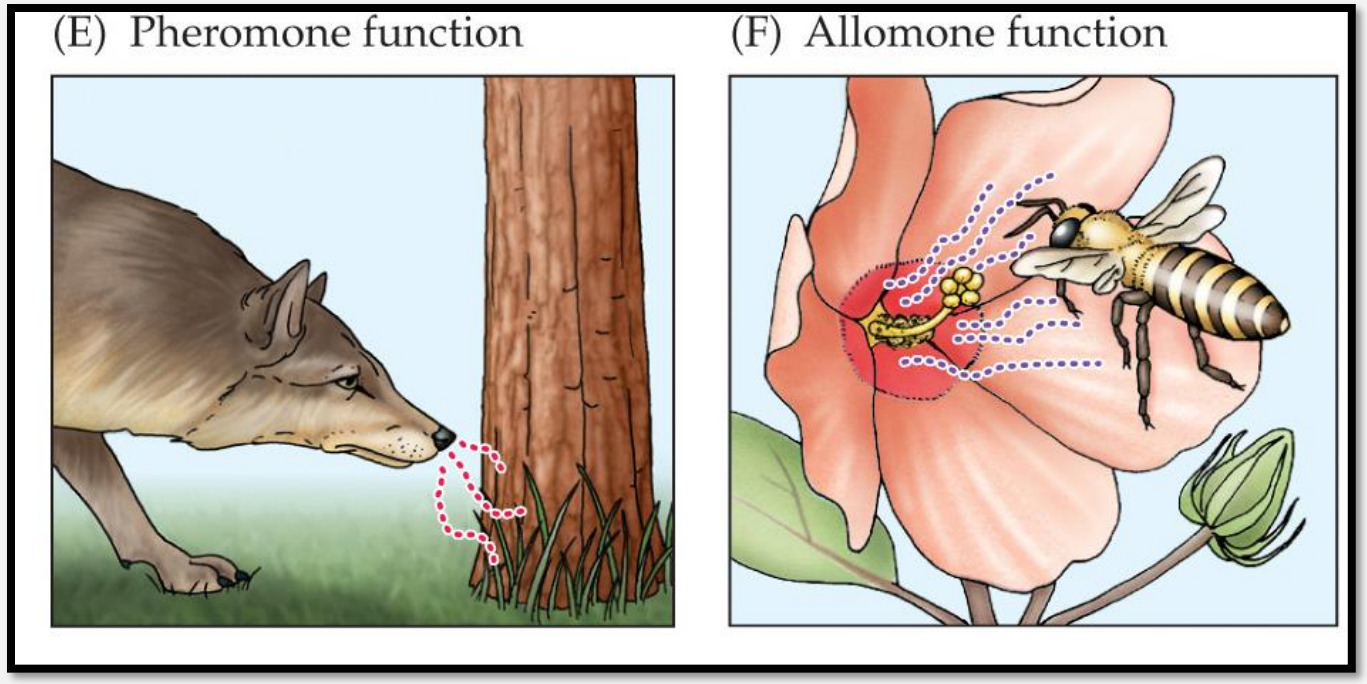
Forms of chemical communication:

- **Autocrine**—released chemical acts on the releasing cell
- **Paracrine**—the released chemical diffuses to nearby target cells



Chemical communication

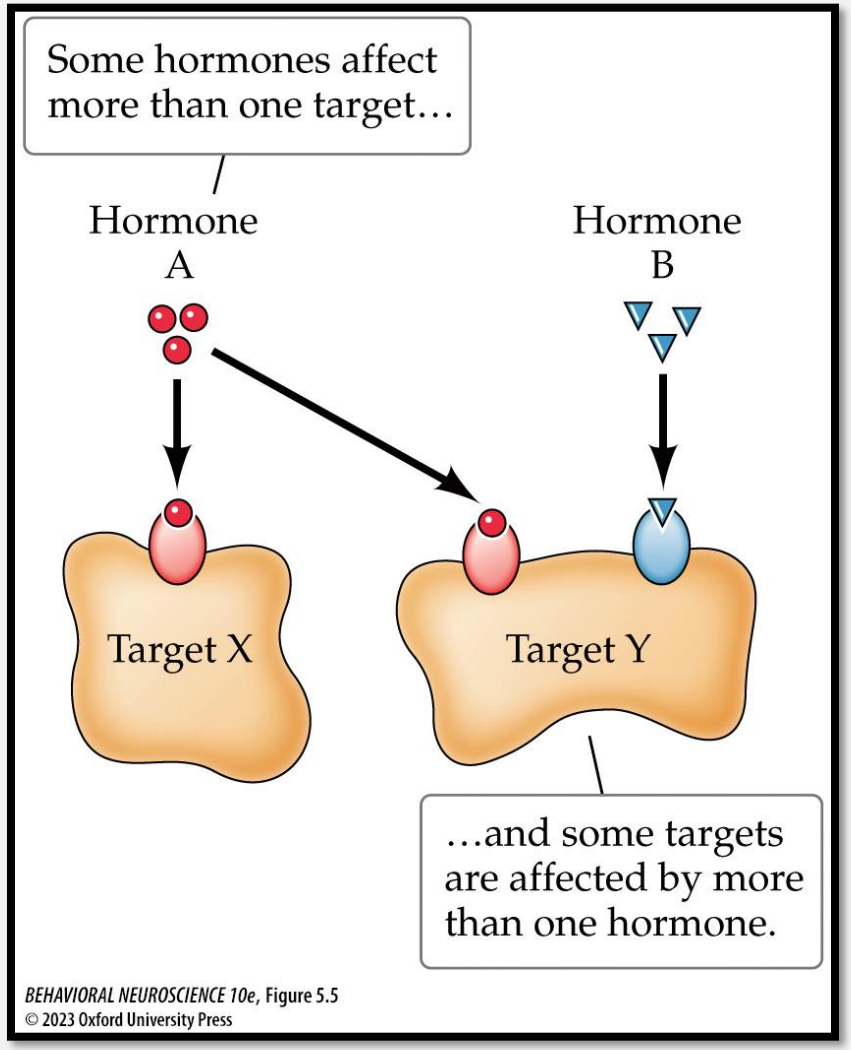
- **Pheromone**—hormones used to communicate between individuals of the same species; pheromones are released into the environment.
- **Allomone** communication—allomones are chemicals released by one species to affect the behavior of another species.



Hormone action

General principles of hormone action:

1. Hormones act in a gradual fashion.
2. Hormones act by changing the probability or intensity of a behavior.
3. The relationship between behavior and hormones is reciprocal.
4. A hormone may have multiple effects, and one behavior can be affected by several hormones.



Hormone action

General principles of hormone action:

5. Hormones often have a pulsatile secretion pattern—in bursts.
6. Some hormones are controlled by circadian clocks in the brain.
7. Hormones can interact with other hormones and change their effects.
8. Hormones can only affect cells with a receptor protein for that hormone.

Hormones

Neuroendocrine cells

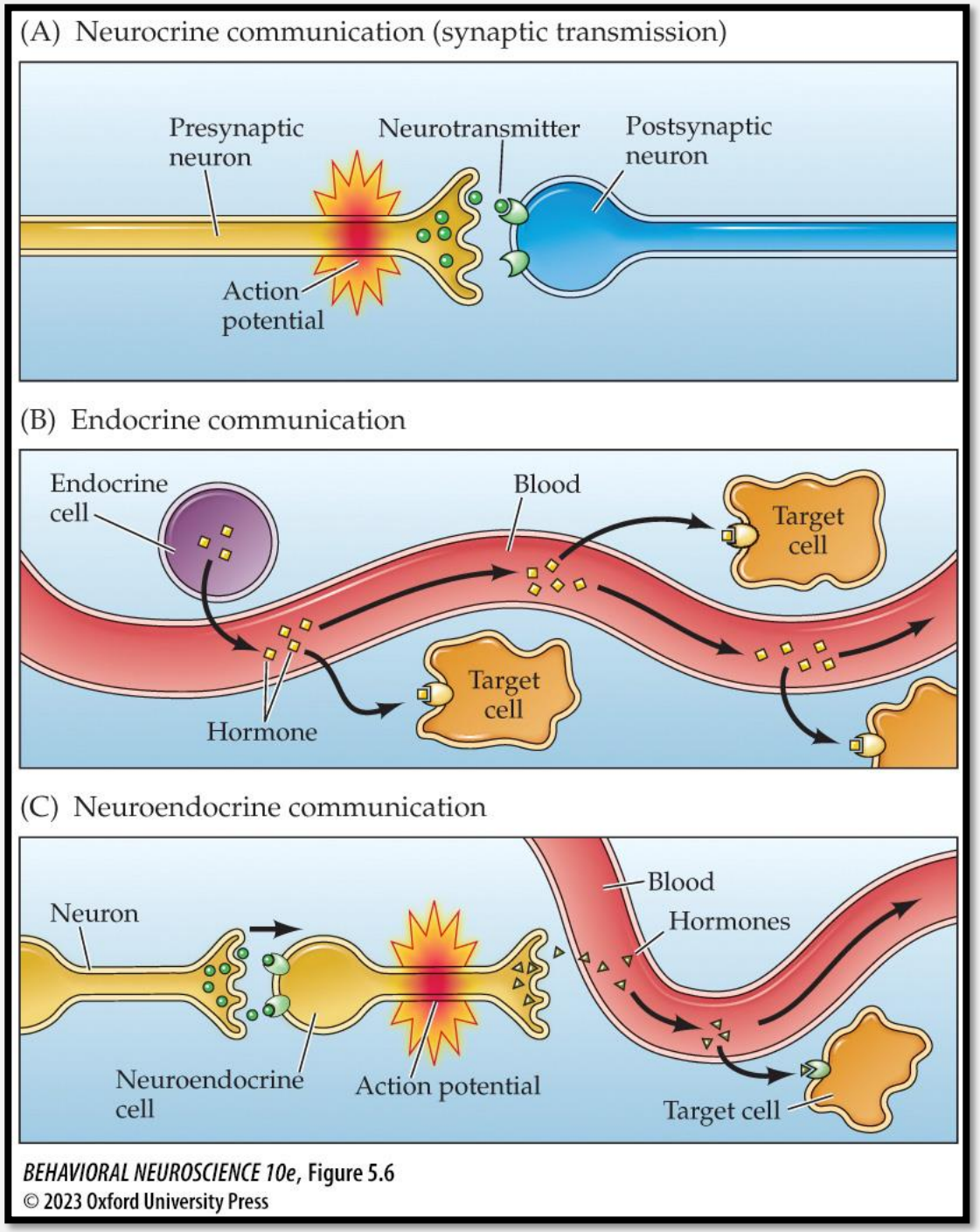
- are neurons that release hormones into the blood.

Neuropeptides

- (peptides used by neurons) can act as neuromodulators and alter sensitivity to transmitters.

Neuromodulators

- can modify the reactivity of cells to specific transmitters—they act more slowly than neurotransmitters and have longer lasting effects.

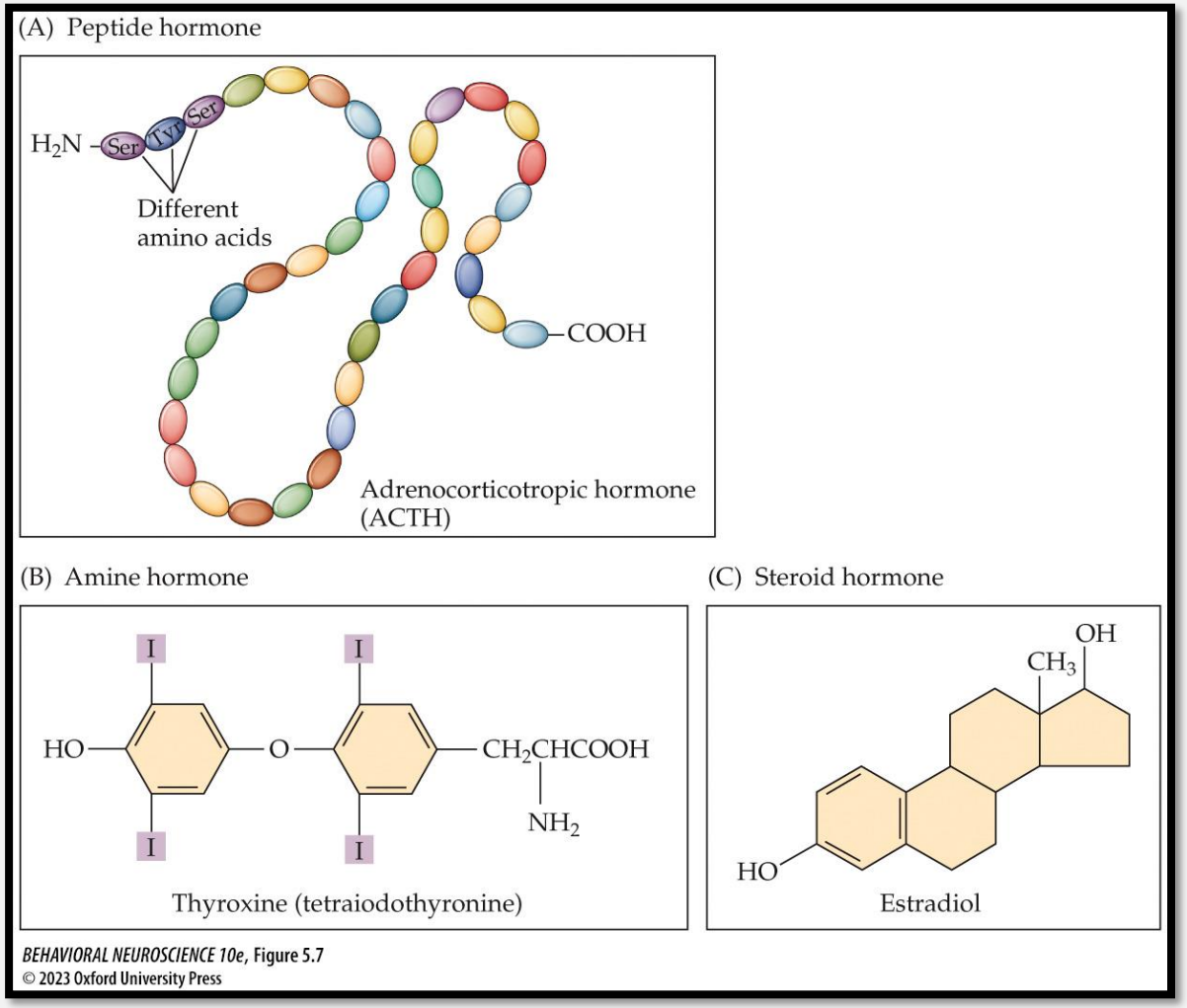


BEHAVIORAL NEUROSCIENCE 10e, Figure 5.6

Hormone types

Classification via chemical structure:

- **Peptide**—short string of amino acids
- **Amine**—modified amino acid (monoamine hormone)
- **Steroid**—four rings of carbon atoms (derivatives of cholesterol)



Hormone action

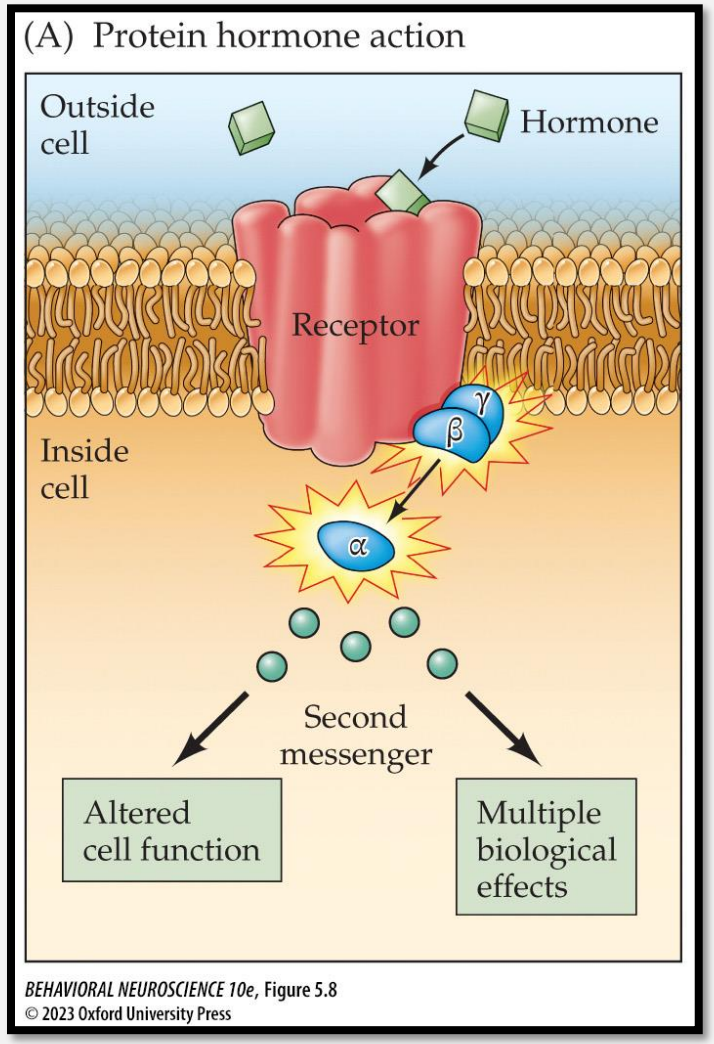
Main modes of action:

- Protein and amine hormones bind to receptors on the cell surface, which causes release of a second messenger, which brings about changes in cellular function.
- Steroid hormones pass through the cell membrane and bind to receptors inside the cell.

Hormone action

Protein and amine hormones act rapidly.

- When they bind to the extracellular part of a receptor, the receptor changes shape.
- The intracellular part then activates a second messenger.



Hormones

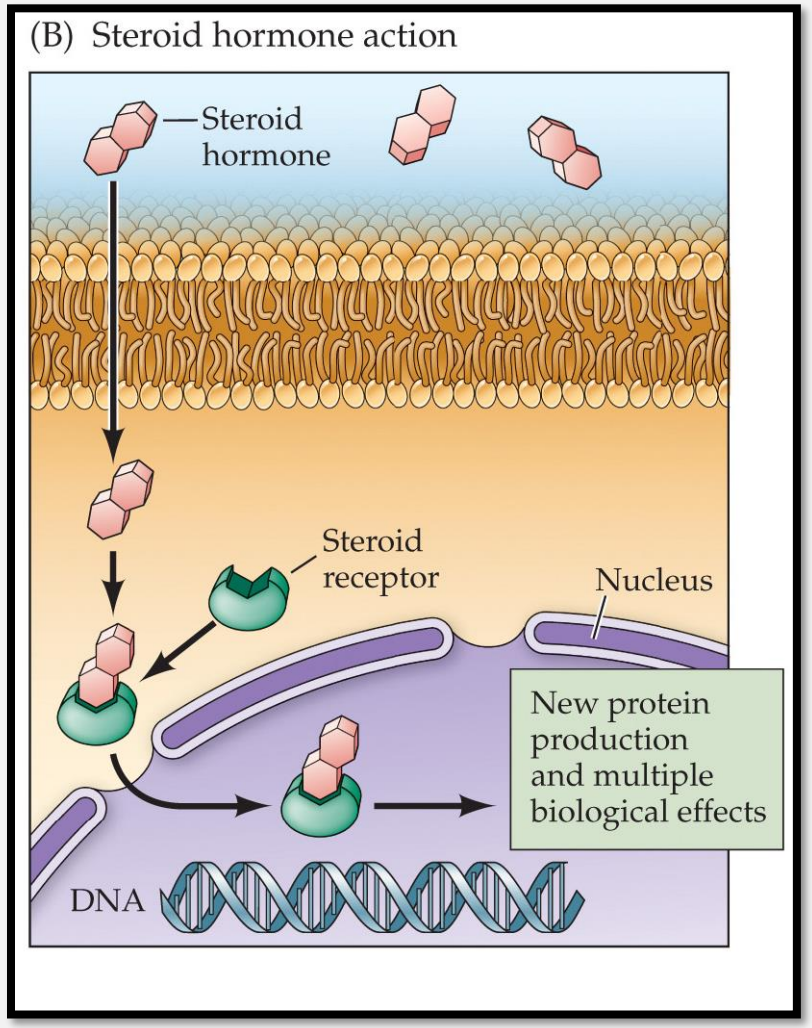
Second messengers:

- **Cyclic adenosine monophosphate** (cyclic AMP or cAMP)
- **Cyclic guanosine monophosphate** (cyclic GMP or cGMP)
- **Inositol triphosphate**

Hormones

Steroid hormones act slowly

- Receptors are within target cells.
- When steroid-receptor complexes form, they alter protein production, producing long-lasting effects.
- The steroid-receptor complex binds to DNA and acts as a transcription factor—controlling gene expression.



Hormones

- **Steroid receptor cofactors** may be necessary for the cell to respond to the steroid-receptor complexes.
- Some steroids act on more than one receptor—called receptor isoforms—with functional differences.

Hormones

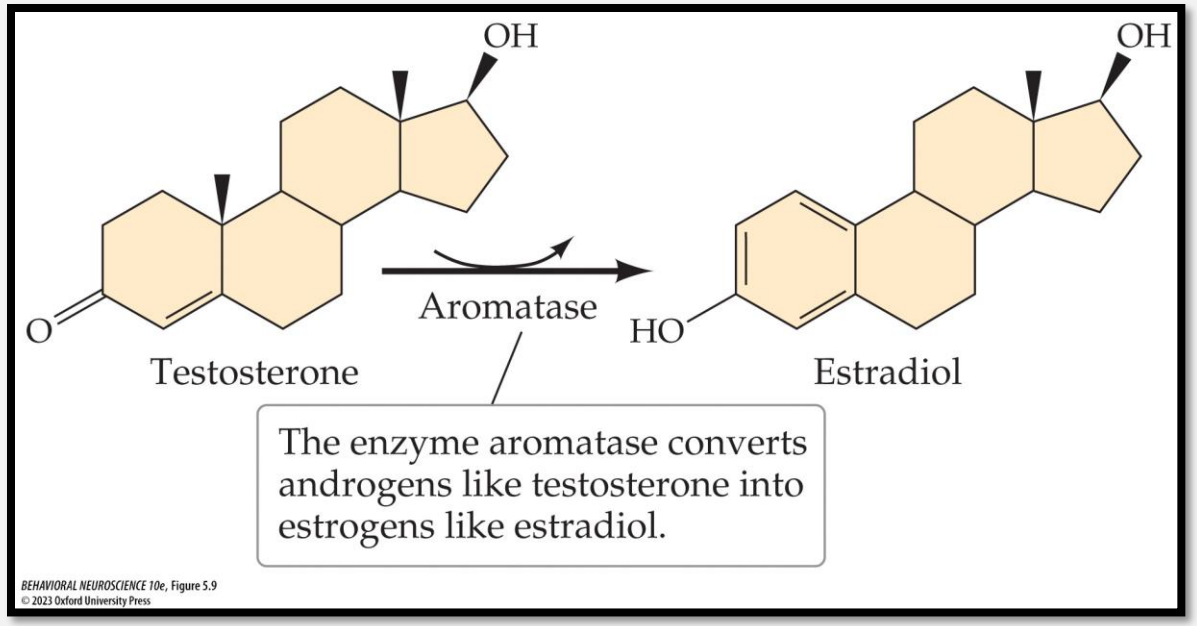
Other effects of steroids

- Estradiol can have a **nongenomic effect**—a rapid, brief effect involving neuronal membrane receptors.
  - Promote cell growth
  - Alter metabolism
  - Influence NT release
  - Modulate ion channels (like Ca2+, K+, Na+, and Cl-)
  - Provide neuroprotection by preventing apoptosis
  - Promote vasodilation
- Testosterone has rapid effects on receptors located in axons and other sites distant from the nucleus.
  - Similar to estradiol effects

Hormones

Neuro-steroids:

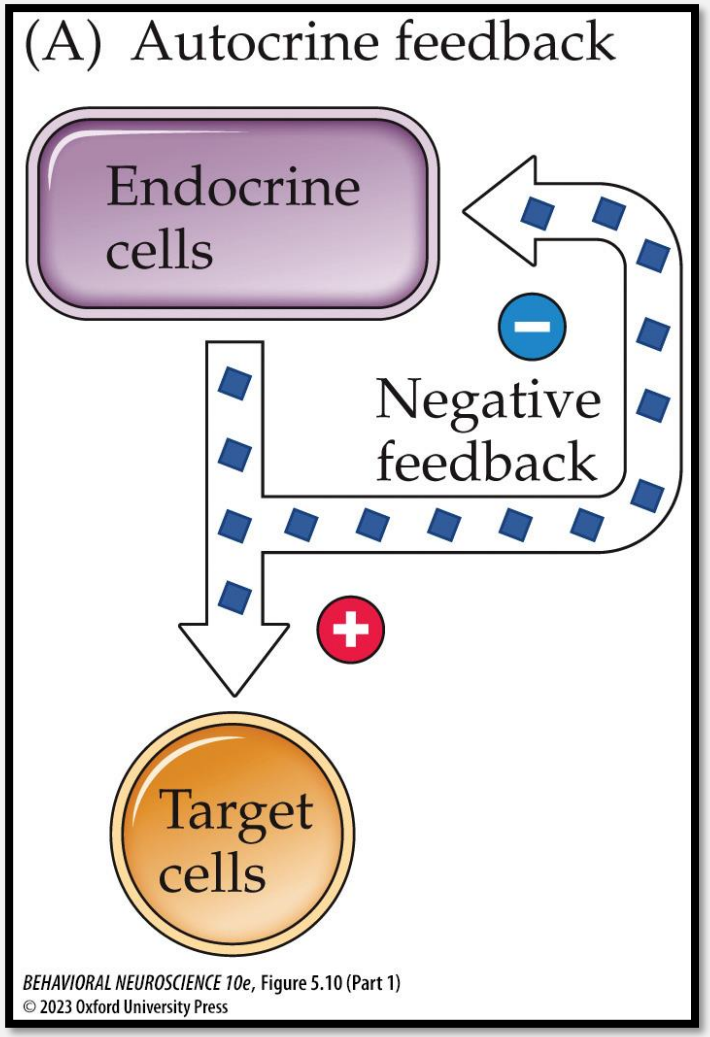
- steroids made in the brain.
- Progesterone-like neurosteroids, reduce anxiety (non-competitive agonist to GABA receptors)
- The brain also produces an enzyme, **aromatase**, that can convert testosterone entering the brain into estrogens.
- Aromatase abundant in hypothalamus
- Testosterone is the major precursor for making estrogens. Ovaries have a lot of aromatase, thus release a lot of estrogen. (testes have very little)
- No steroid hormone is found exclusively in one sex



Hormone regulation

Hormones are regulated by feedback systems.

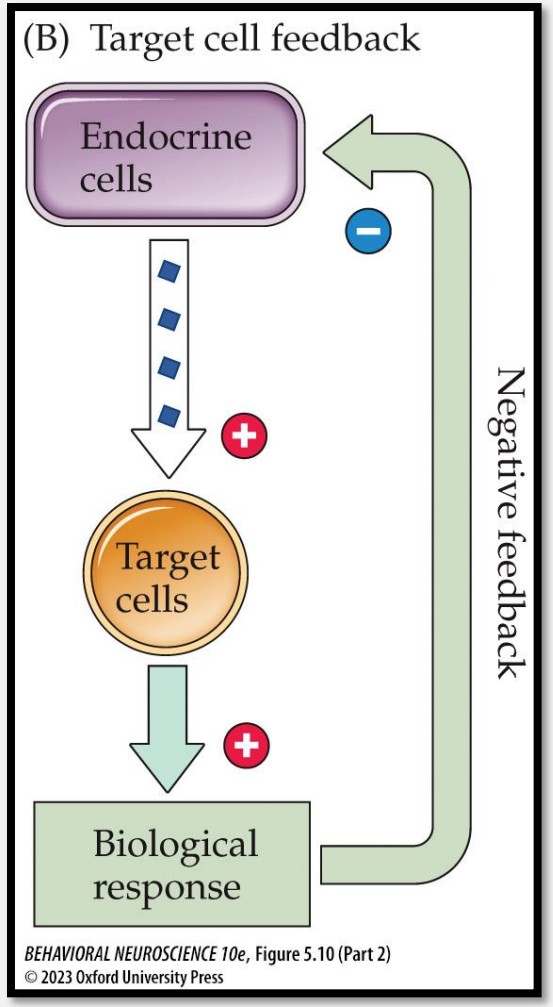
- **Negative feedback**—output feeds back and inhibits further secretion:
- Autocrine feedback loop: endocrine cells release a hormone whose presence feeds back on the endocrine cells to inhibit further secretion.



Hormones

Target cell feedback:

- hormone acts on its target cells; the biological effect is detected by the endocrine gland and further release is inhibited.



Hormone regulation

- Brain regulation involves the hypothalamus which can direct hormone release from endocrine glands.
- The brain detects the hormone's effects and exerts negative feedback on the hypothalamus.

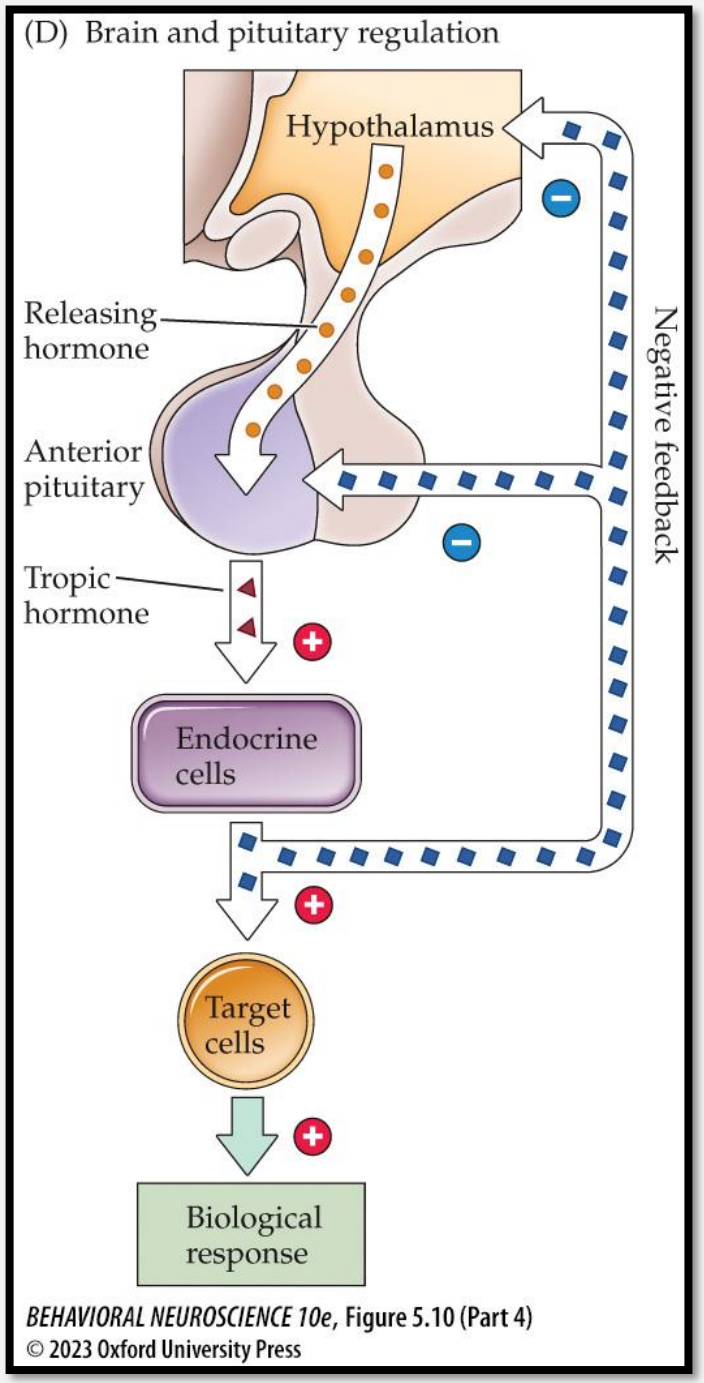
Hormones

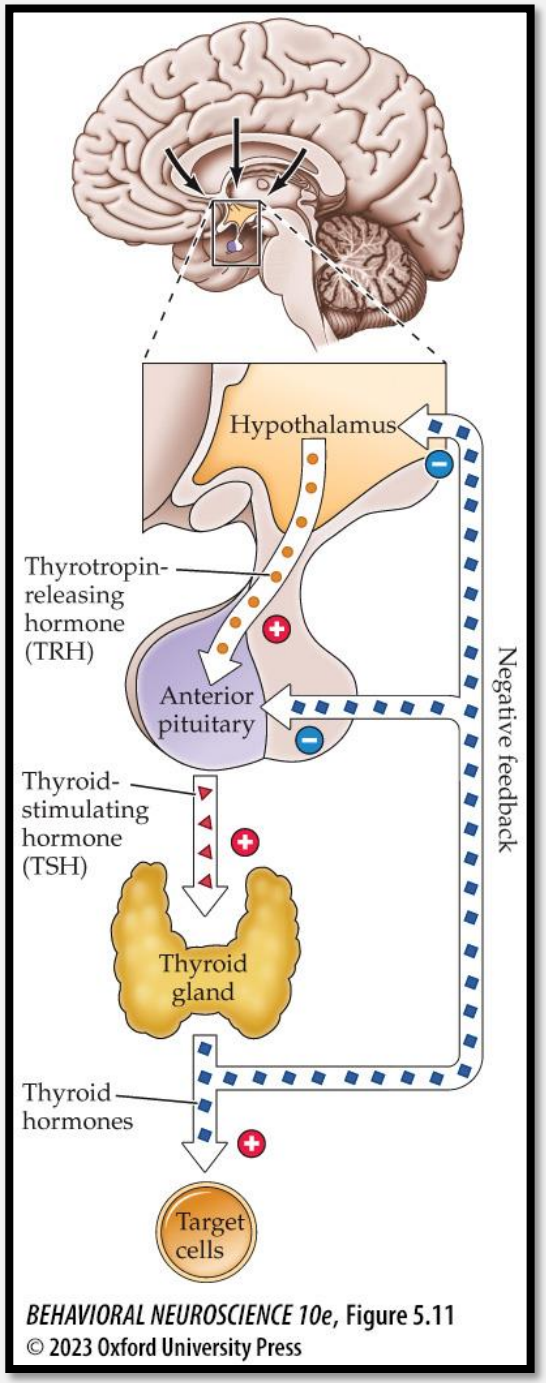
The hypothalamus

- uses **releasing hormones** to regulate the pituitary's release of tropic hormones.
- Negative feedback goes to both the pituitary and the hypothalamus.

Anterior pituitary gland

- releases **tropic hormones** that affect other endocrine glands.





Designing a behavioural endocrine study

More on the HPA axis later.

Behavioural Endocrinology

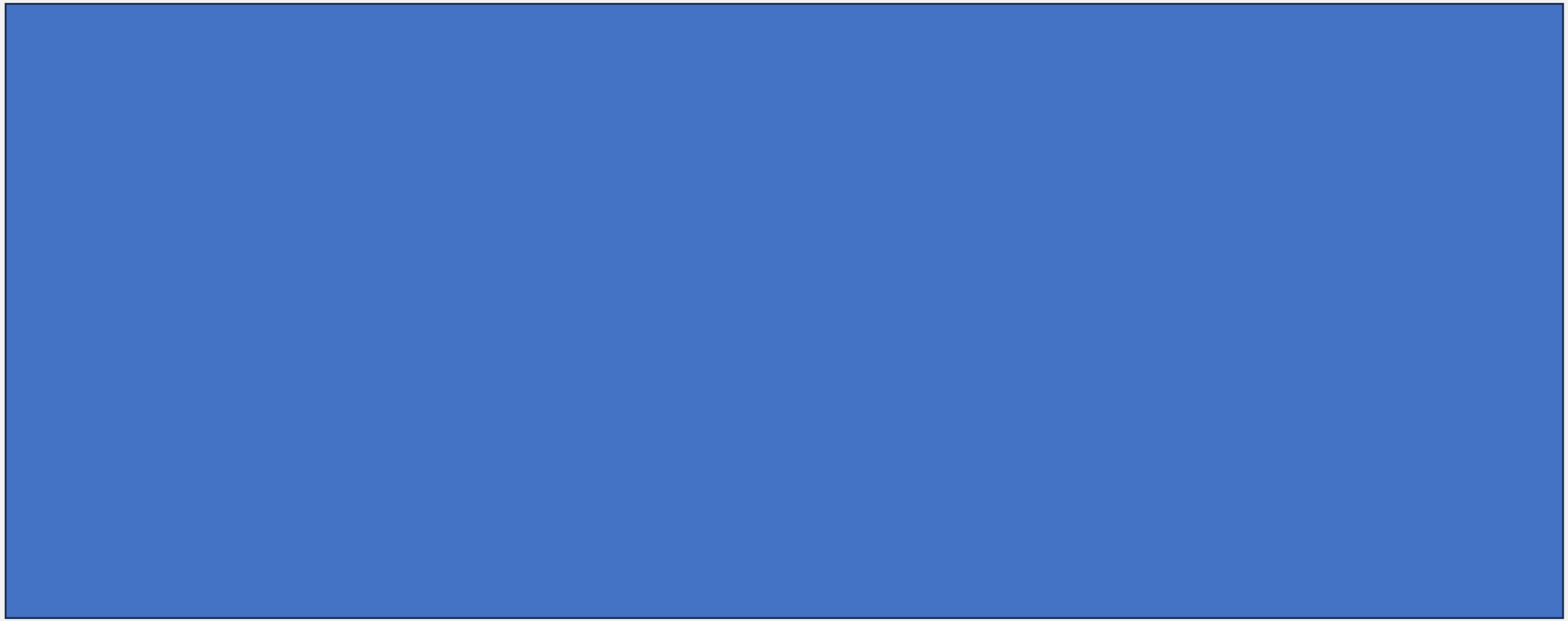
Designing an experiment

- Goal: Establish a relationship between a particular hormone and behaviour
- Where to start?
- Design an experiment!

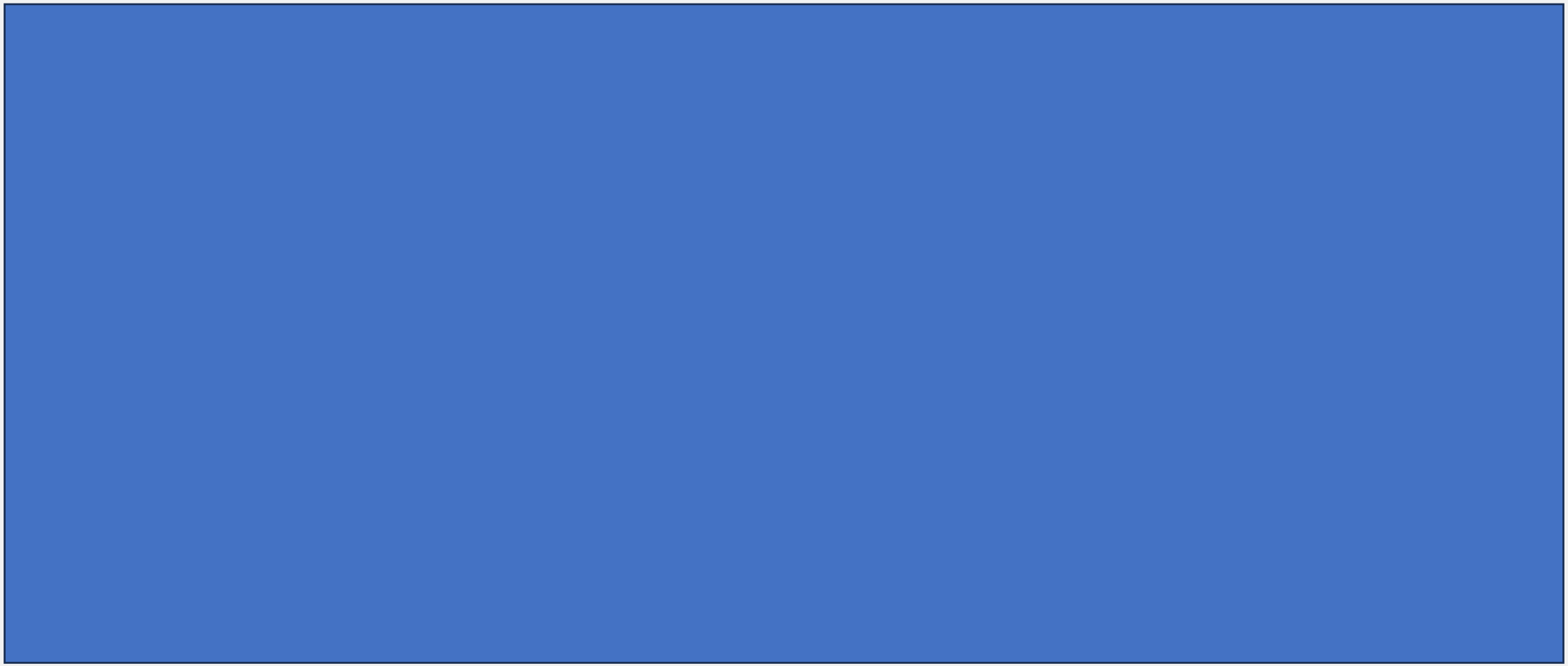
Behavioural Endocrinology today

Designing an experiment

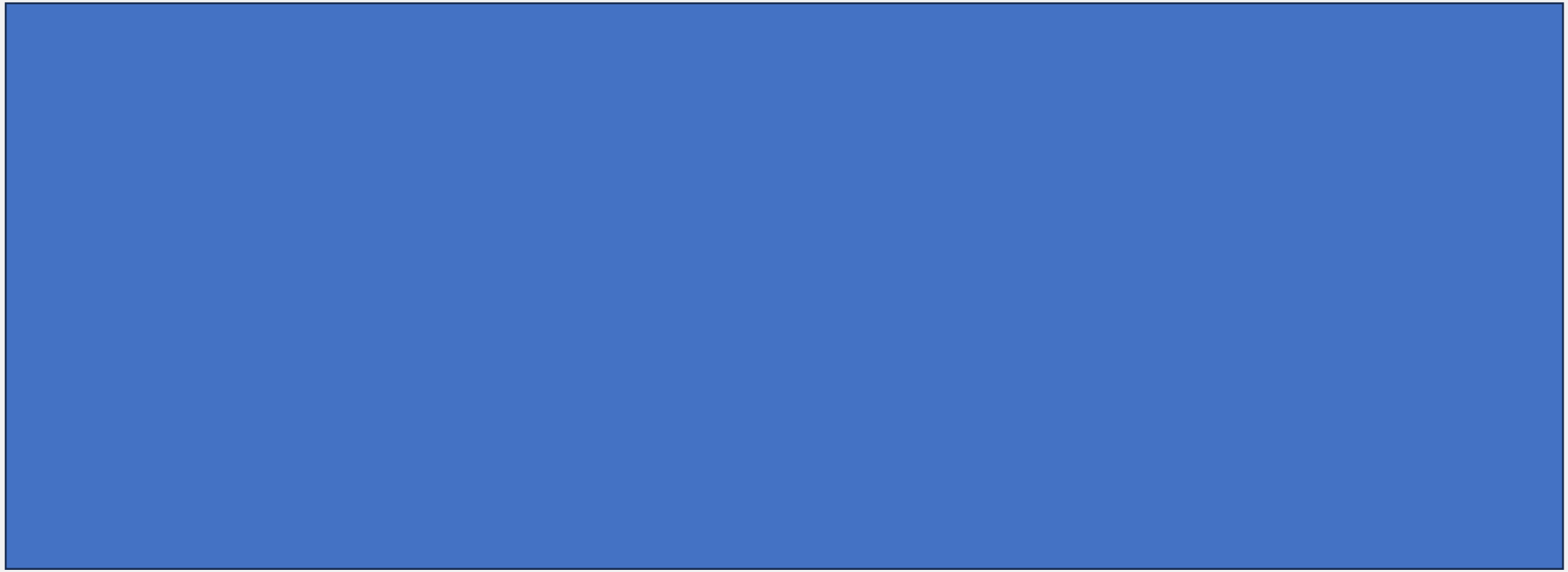
Behavioural Endocrinology



Behavioural endocrinology



Behavioural endocrinology

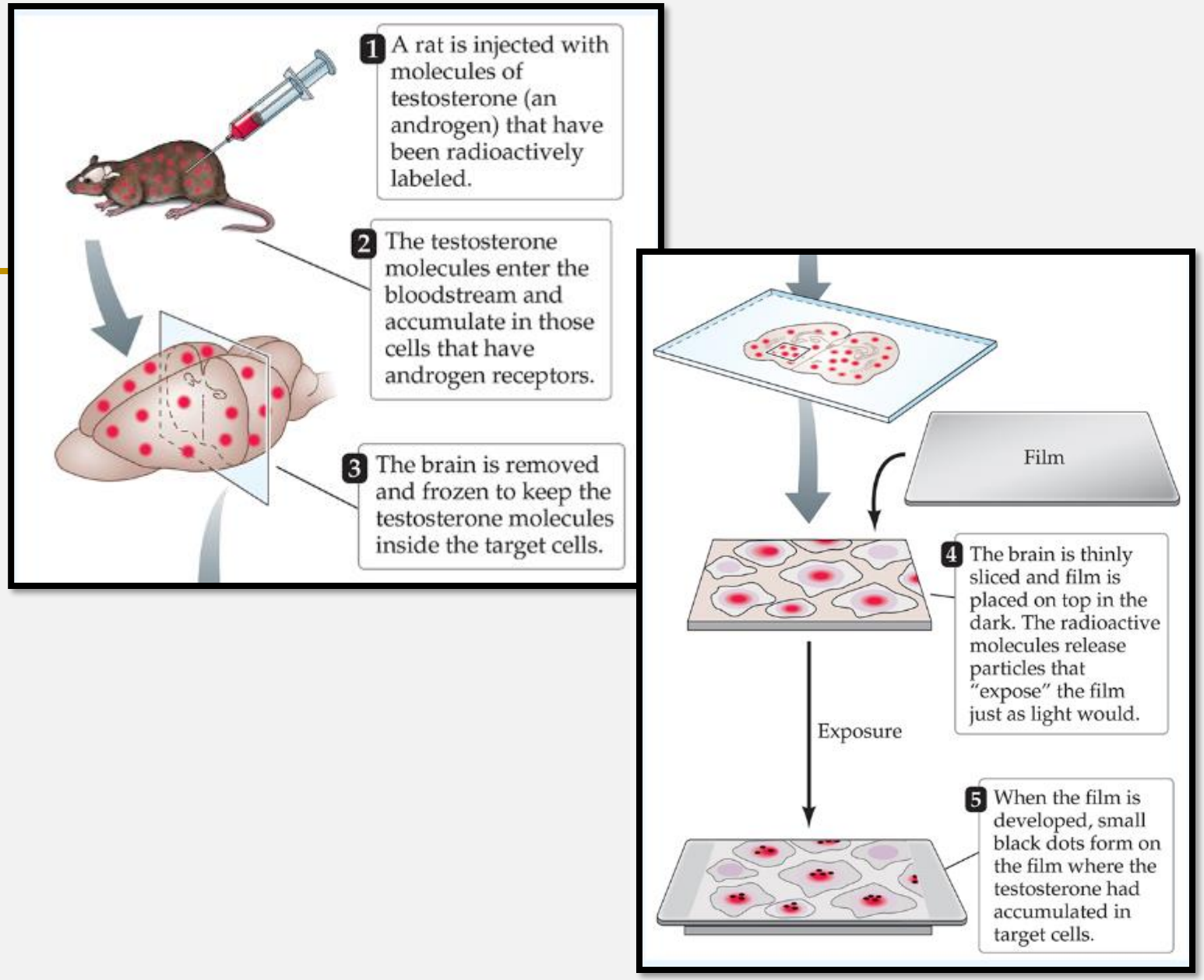


Behavioural endocrinology

Perhaps a side question?

- How does testosterone permit sexual behaviour?
- Where in the brain does testosterone have an effects?
- ***Autoradiography (as imaged)***
- ***Immunohistochemistry***
- ***In-situ hybridization***

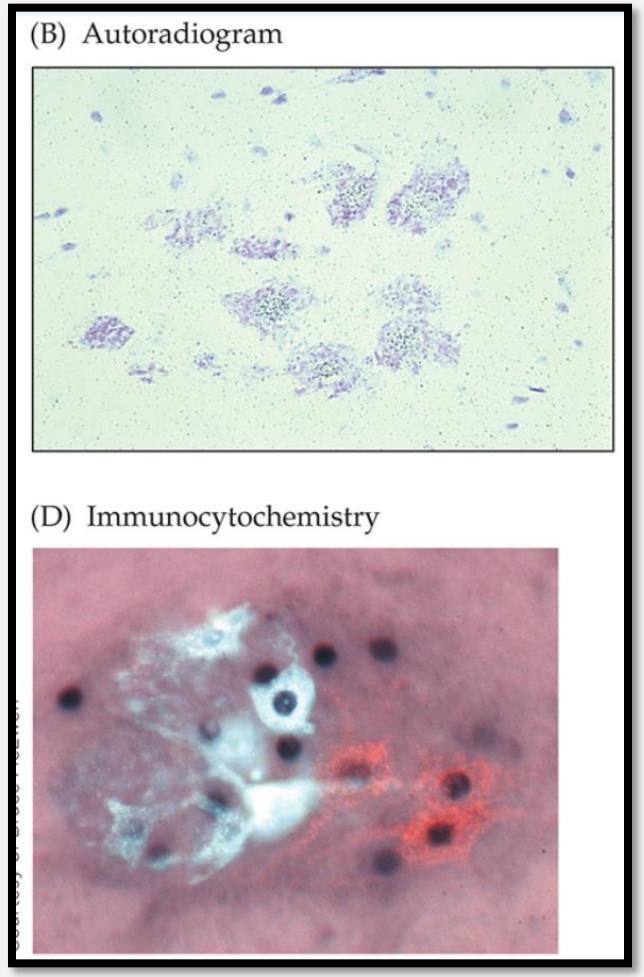
Labelled mRNA complimentary to mRNA making receptors for testosterone



Behavioural endocrinology

Autoradiograms & immunohistochemistry

- Locate the active sites for testosterone in the brain
- Then…
  - Place small pellets of testosterone in those areas of the brain in castrated mice and observe recovery of behaviour of interest
- In male mice – Preoptic area of the hypothalamus (mPOA)
- Then….
  - Study the mPOA – how does testosterone effect change (anatomically, physiologically, protein production, etc.)



Endocrine glands

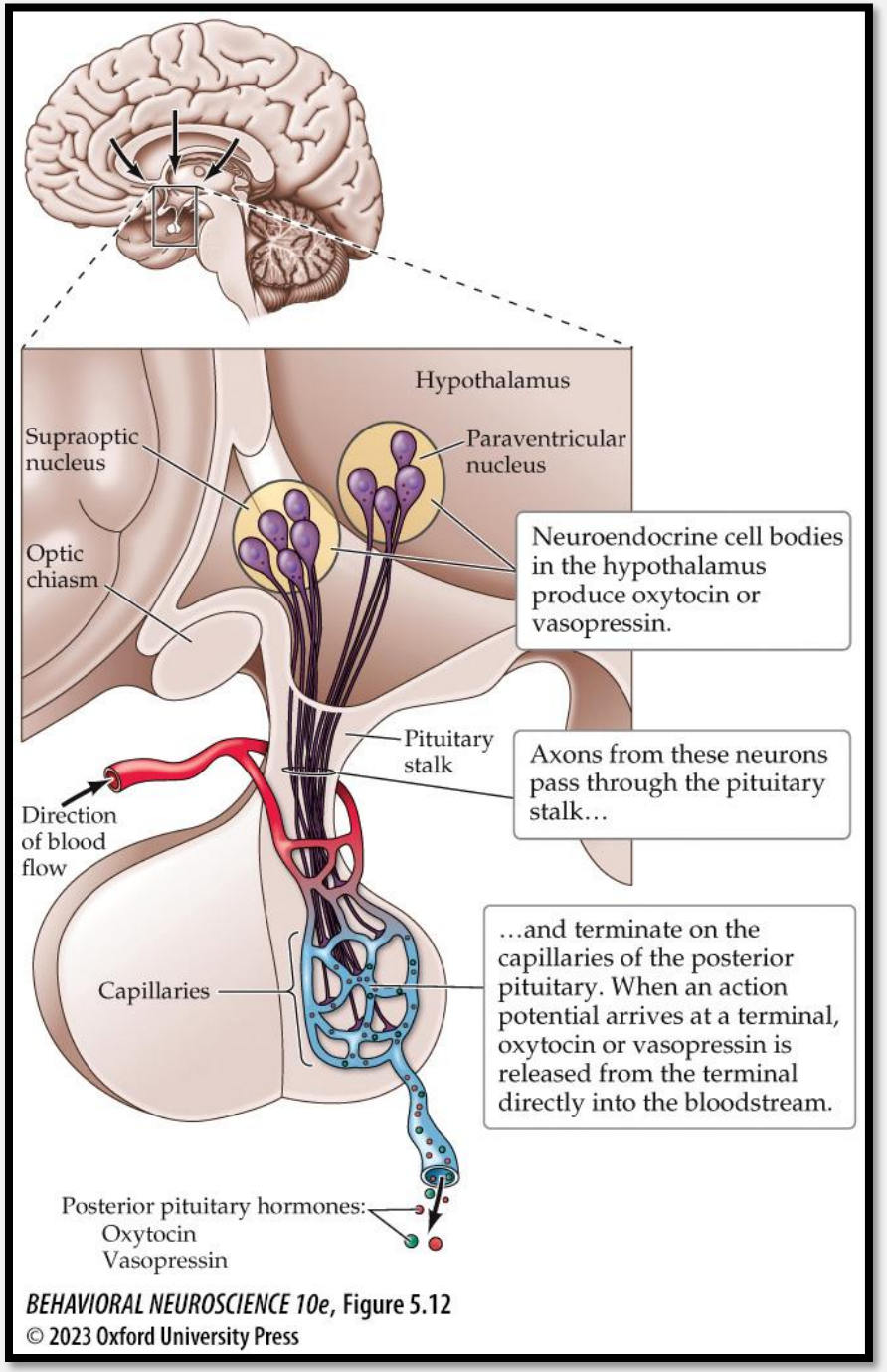
Endocrine glands

The pituitary gland (hypophysis)

- **Anterior pituitary** (adenohypophysis)
- **Posterior pituitary** (neurohypophysis)
- The two parts are separate in function.

The pituitary stalk (infundibulum)

- connects the pituitary to the hypothalamus; contains many axons that extend only to the posterior pituitary.
- Blood vessels carry information only to the anterior pituitary.



Endocrine Glands

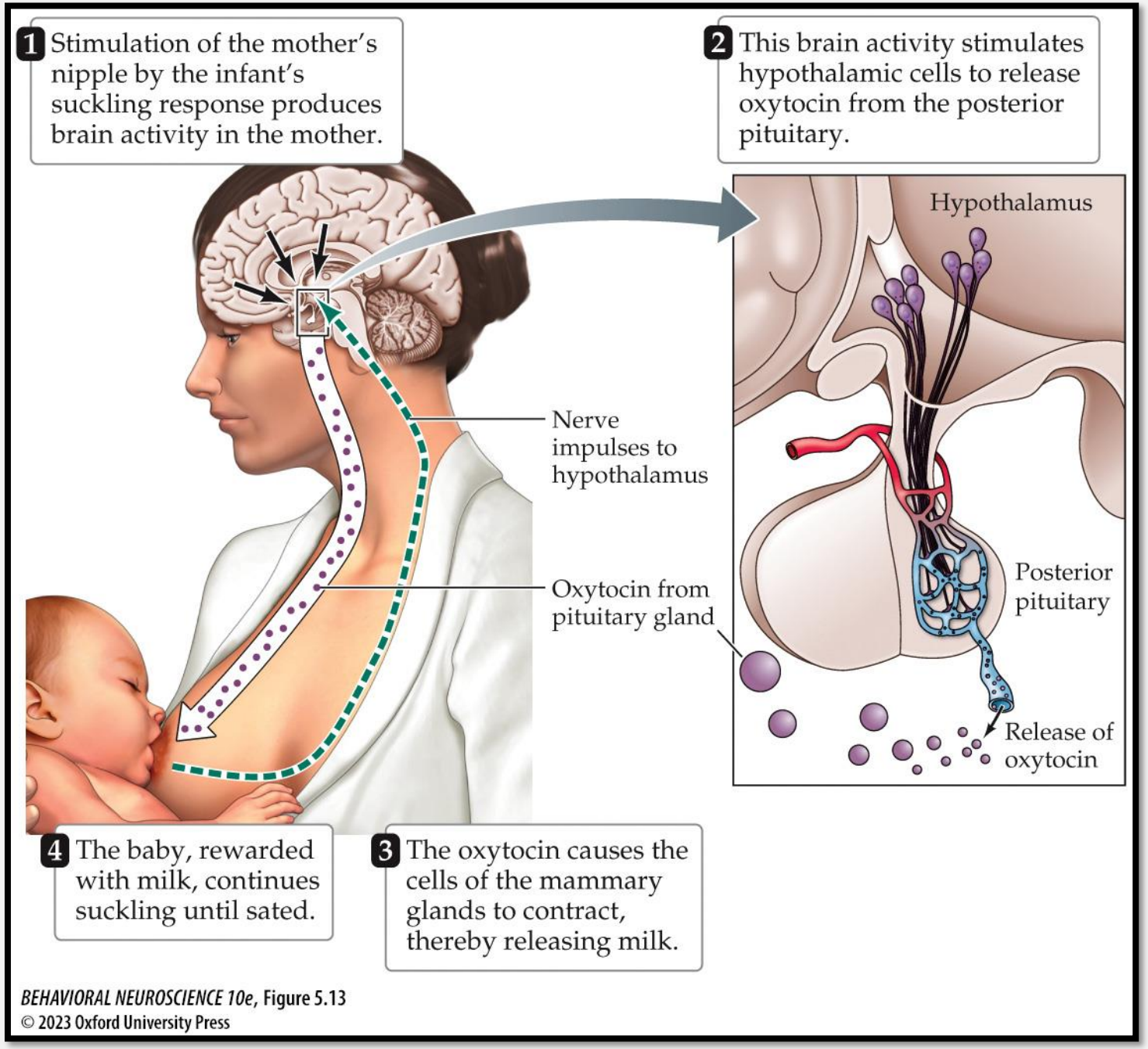
Posterior Pituitary

- secretes oxytocin and vasopressin.
- Neurons in the supraoptic nuclei and paraventricular nuclei of the hypothalamus synthesize these hormones and transport them along the axons in the stalk.

Endocrine Glands

Posterior pituitary

- **Oxytocin** is involved in reproductive and parenting behavior, uterine contraction, and the **milk letdown reflex**.
- Reflex can be conditioned to a baby's cries



BEHAVIORAL NEUROSCIENCE 10e, Figure 5.13

Endocrine glands

Arginine vasopressin (AVP), or vasopressin, or antidiuretic hormone (ADH)

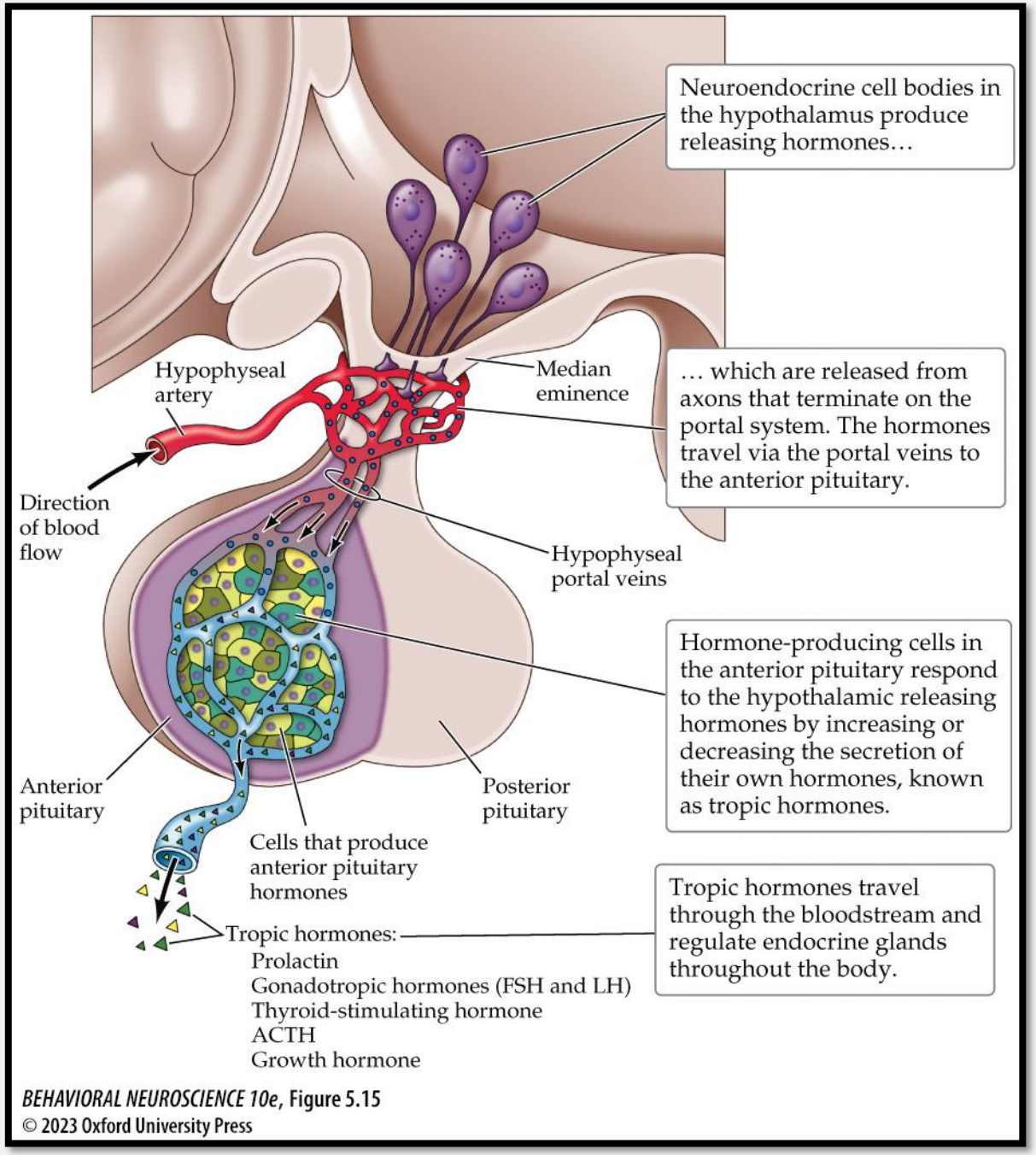
- increases blood pressure and inhibits urine formation.

Vasopressin and oxytocin can also serve as neurotransmitters from hypothalamic cells projecting widely through the nervous system.

Endocrine Glands

Hypothalamic neurons

- synthesize **releasing hormones.**
- Axons from these cells converge on the **median eminence**, above the pituitary stalk.
- Releasing hormones are secreted into blood vessels called the **hypophyseal portal system**, and are carried to the anterior pituitary, which then releases tropic hormones.



Endocrine Glands

Hypothalamic neuroendocrine cells

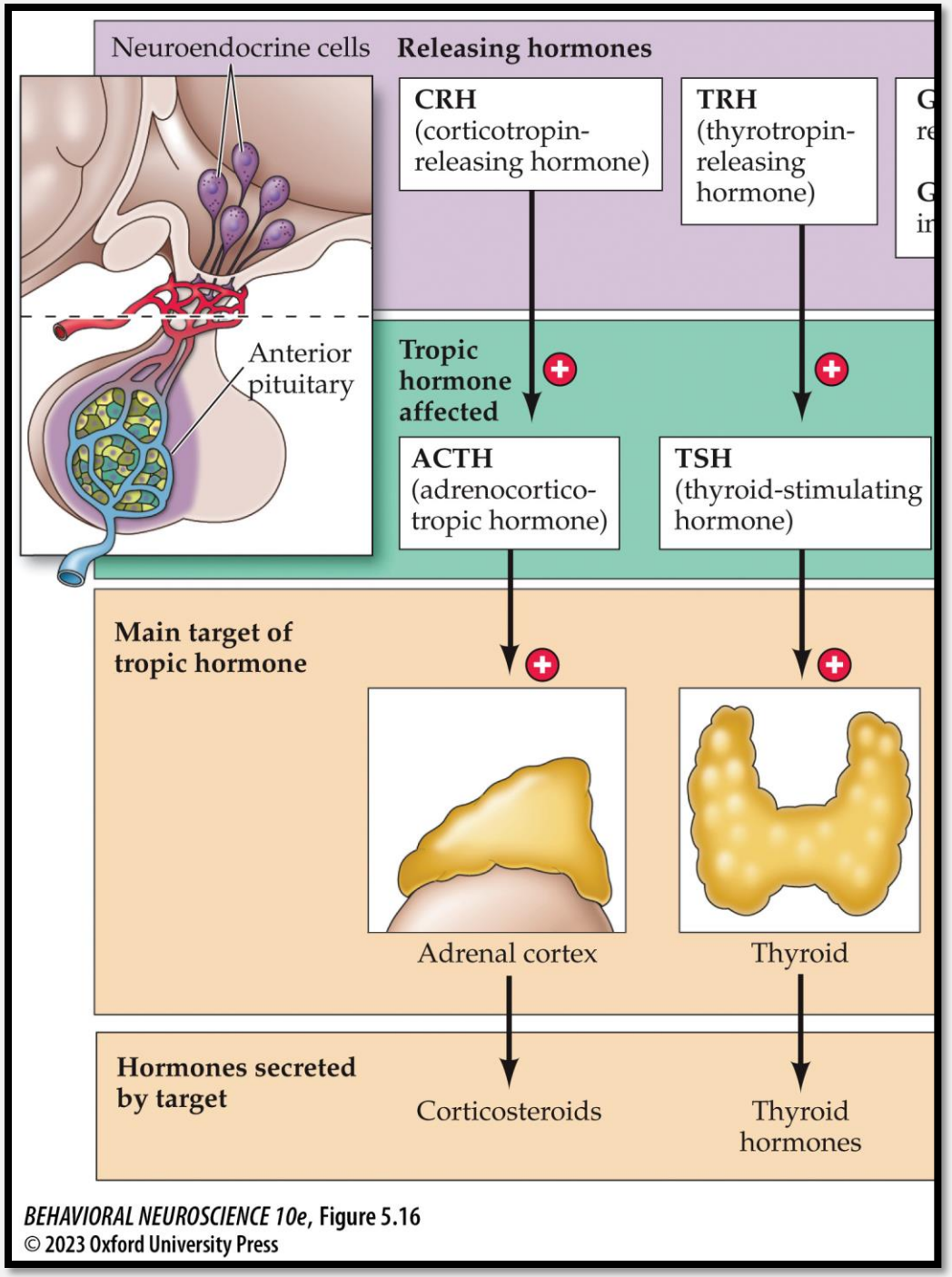
- Influenced by circulating messages, such as other hormones, blood sugar, and immune system products
- Synaptic inputs from other brain areas.

Endocrine Glands

The anterior pituitary

- releases six tropic hormones:

1. **Adrenocorticotropic hormone** (**ACTH**) controls production and release of adrenal cortex steroid hormones.
2. **Thyroid-stimulating hormone** (**TSH**) increases thyroid hormone release.

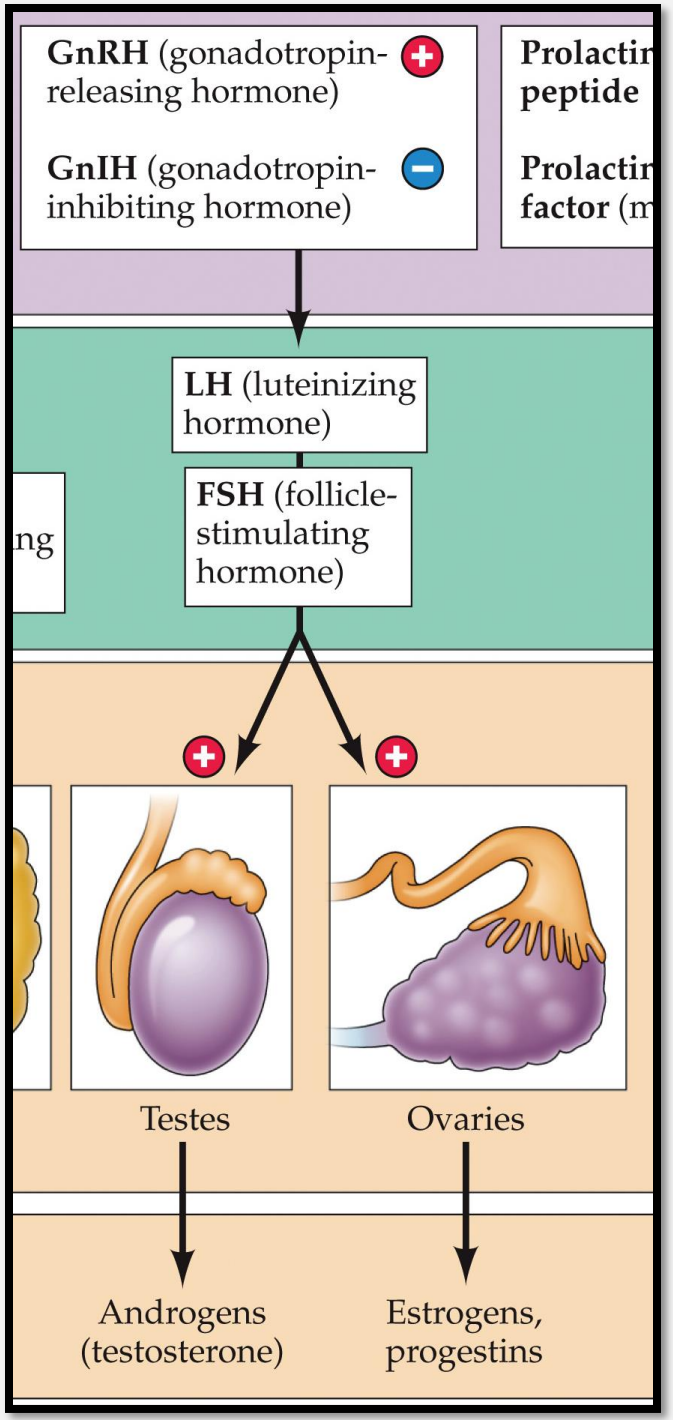


BEHAVIORAL NEUROSCIENCE 10e, Figure 5.16

Endocrine Glands

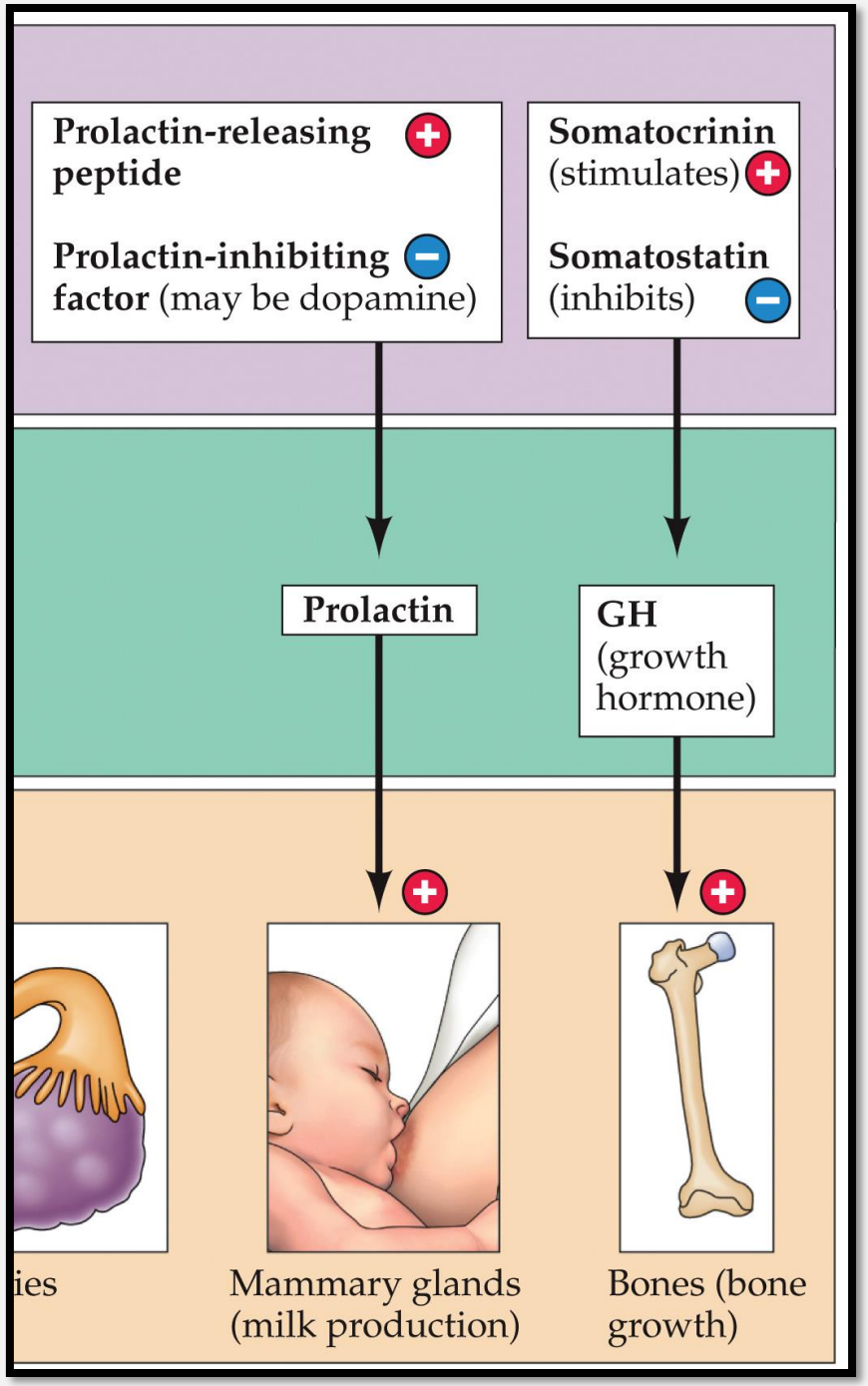
Gonadotropins influence the gonads:

3. **Follicle-stimulating hormone** (**FSH**) stimulates egg-containing follicles in ovaries or sperm production in males.
4. **Luteinizing hormone** (**LH**) stimulates follicles to form the corpora lutea in ovaries and testosterone production by the testes.



Endocrine Glands

5. **Prolactin** stimulates lactation in females and is involved in parental behavior.
6. **Growth hormone** (**GH**) (somatotropin) influences growth, mostly during sleep. The stomach hormone ghrelin also evokes GH release.



Major endocrine glands

Endocrine Glands

Adrenal glands

- are located on top of each kidney.

Adrenal cortex

- secretes steroid hormones (**adrenocorticoids**).
- **Glucocorticoids** are a subgroup involved with glucose metabolism.
- **Cortisol** is a glucocorticoid stress hormone that increases blood glucose and breaks down protein.

Adrenal medulla

- releases the amine hormones **epinephrine** (adrenaline) and **norepinephrine** (noradrenaline).
- These are controlled by the sympathetic nervous system.

Endocrine Glands

Mineralocorticoids affect ion concentrations in tissues.

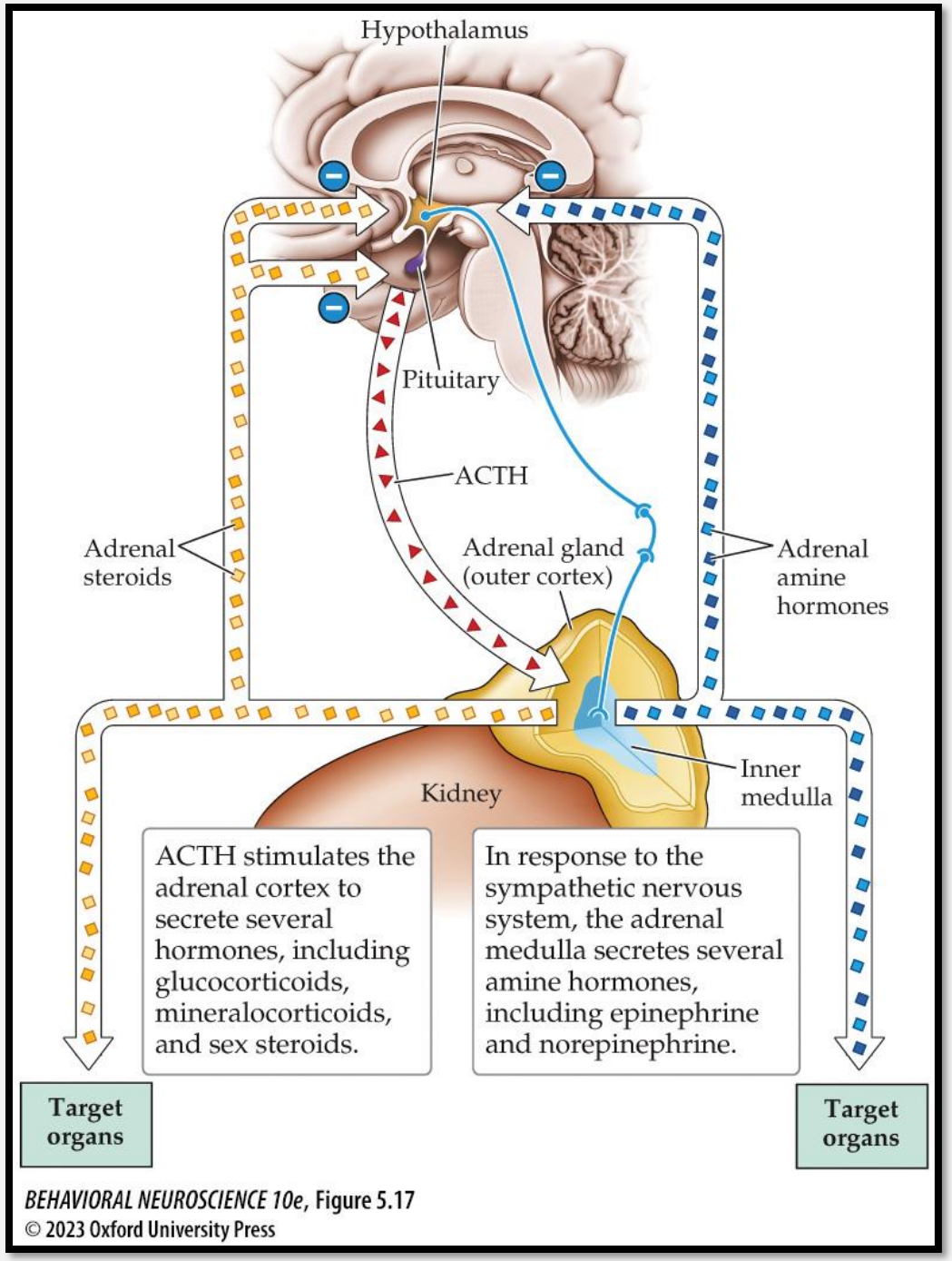
Aldosterone acts on the kidneys to retain sodium.

Sex steroids, such as androstenedione, contribute to the adult pattern of body hair in men and women.

Endocrine glands

Regulation of adrenal cortical hormones:

- ACTH promotes steroid synthesis in the adrenal gland. The steroids in turn exert a negative feedback effect on ACTH release.



Each Endocrine Glands

Thyroid-stimulating hormone (TSH)

- is secreted by the pituitary.
- release is controlled by negative feedback from blood levels and by **thyrotropin-releasing hormone** (**TRH**) from the hypothalamus.

Endocrine Glands

TSH

- causes the thyroid gland to produce **thyroid hormones**: thyroxine (tetraiodothyronine) and triiodothyronine.
- The thyroid gland also produces calcitonin, which promotes calcium deposition in bones.

Endocrine Glands

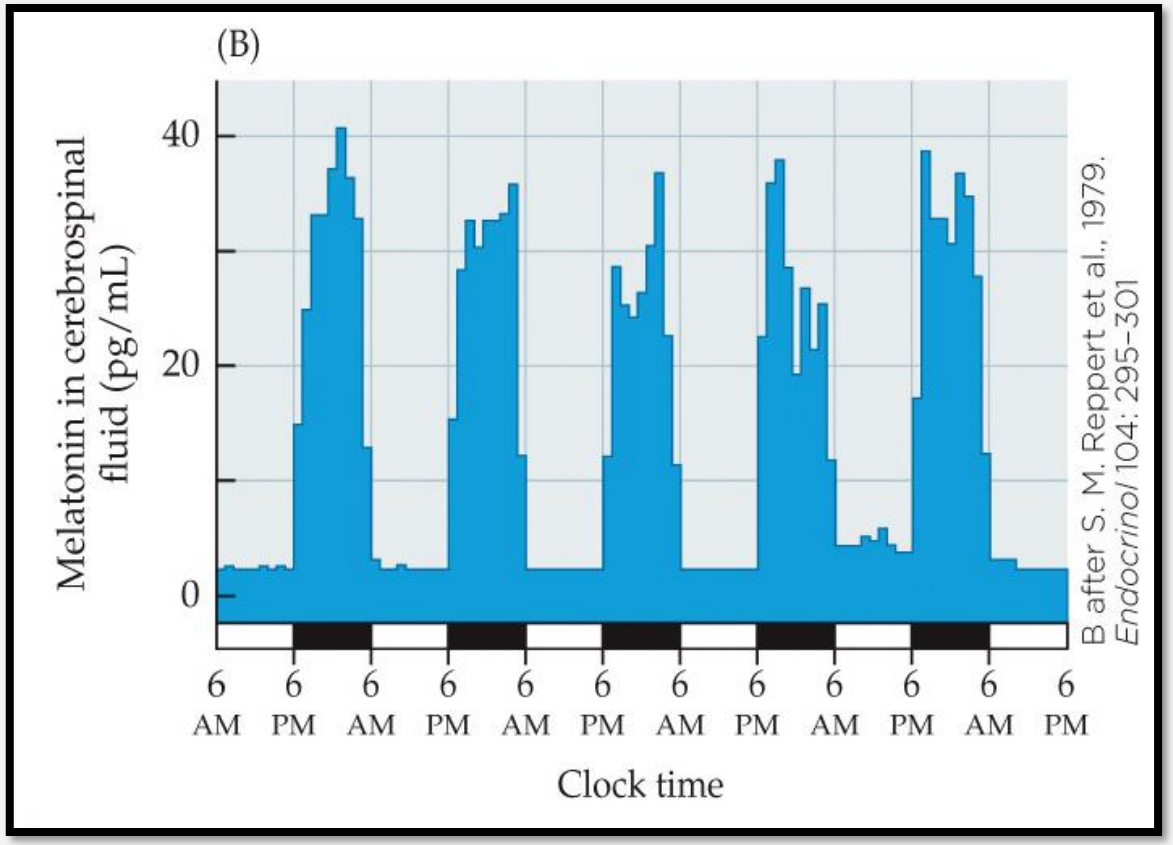
Thyroid hormones

- contain iodine and depend on its supply.
- **Goiter** is a swelling of the thyroid gland resulting from iodine deficiency.
- Early thyroid deficiency can result in cretinism, or **congenital hypothyroidism**, accompanied by intellectual disability.

Endocrine Glands

Pineal gland:

- secretes an amine hormone, **melatonin**, almost exclusively at night.
- Melatonin provides a signal that tracks day length and the seasons and plays a role in biological rhythms.
- Innervated by the sympathetic nervous system.



Endocrine Glands

Gonads—ovaries and testes

- produce sex steroids.
- The hypothalamus controls gonadal hormone production by releasing **gonadotropin releasing-hormone** (**GnRH**).
- GnRH stimulates the anterior pituitary to release FSH or LH.

Endocrine Glands

GnRH neurons

- are stimulated by a hypothalamic peptide, **kisspeptin**, involved in the onset of puberty.
- The hypothalamus also uses **gonadotropin-inhibiting hormone** (**GnIH**) to inhibit gonadotropic secretion.

Endocrine Glands

Testes

- produce and secrete **testosterone**, one of many male hormones called **androgens**.
- Testosterone is regulated by LH which is regulated by gonadotropin releasing-hormone (GnRH).
- Sperm production is regulated by FSH.

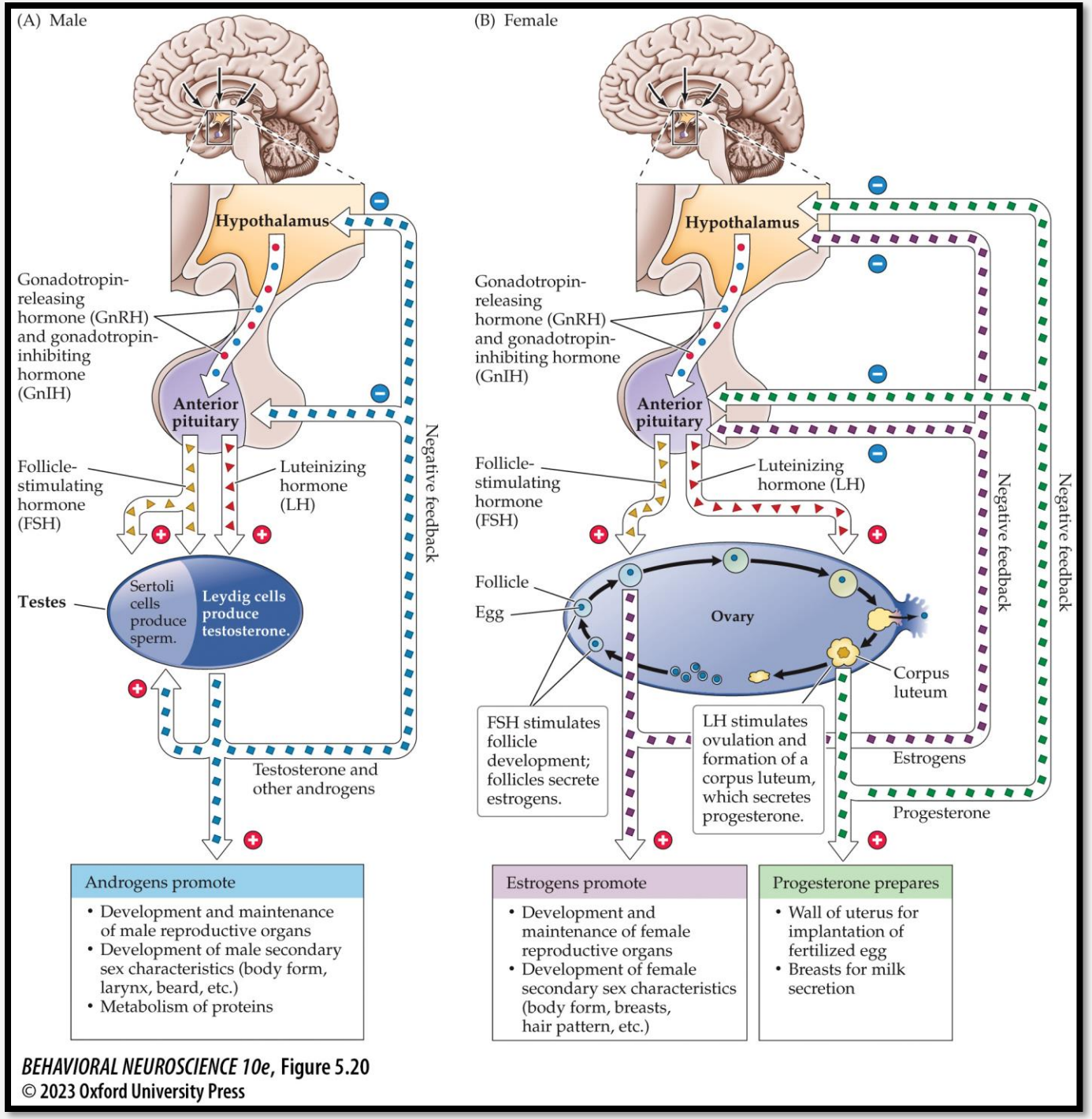
Endocrine Glands

Ovaries

- produce hormones in cycles: **progestins**, such as progesterone, and **estrogens** such as **17β-estradiol**.
- Ovarian hormone release is controlled by LH and FSH, which are controlled by GnRH.

Regulation of Gonadal Steroid Hormones

- No steroid is found exclusively in either males or females;
- Rather, the two sexes differ in the proportion of these steroids.



BEHAVIORAL NEUROSCIENCE 10e, Figure 5.20

Hormones and behaviour

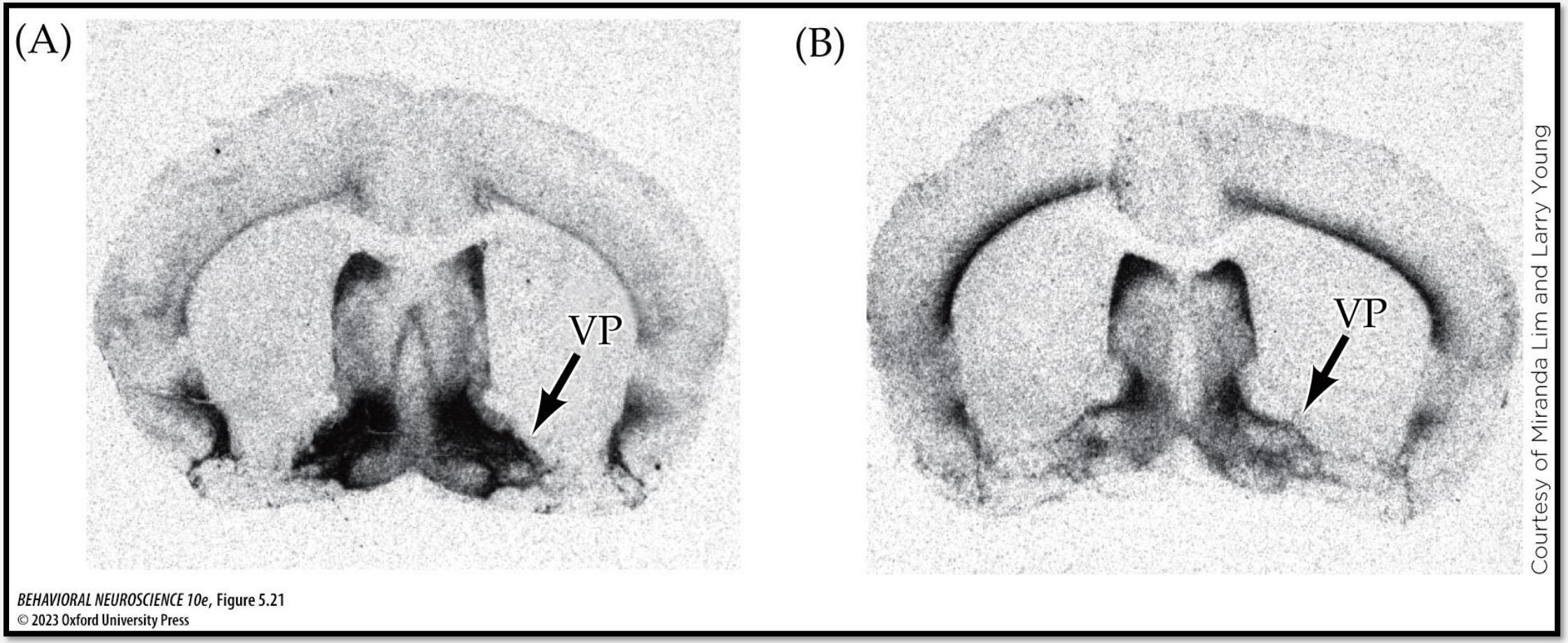
Oxytocin

- is released during nursing and during orgasm; in female prairie voles, it promotes pair-bonds

Vasopressin

- facilitates formation of pair-bonds in male prairie voles.
- In closely related meadow voles that don’t form pair bonds, males have far fewer vasopressin receptors in the brain.

Vasopressin and the Monogamous Brain

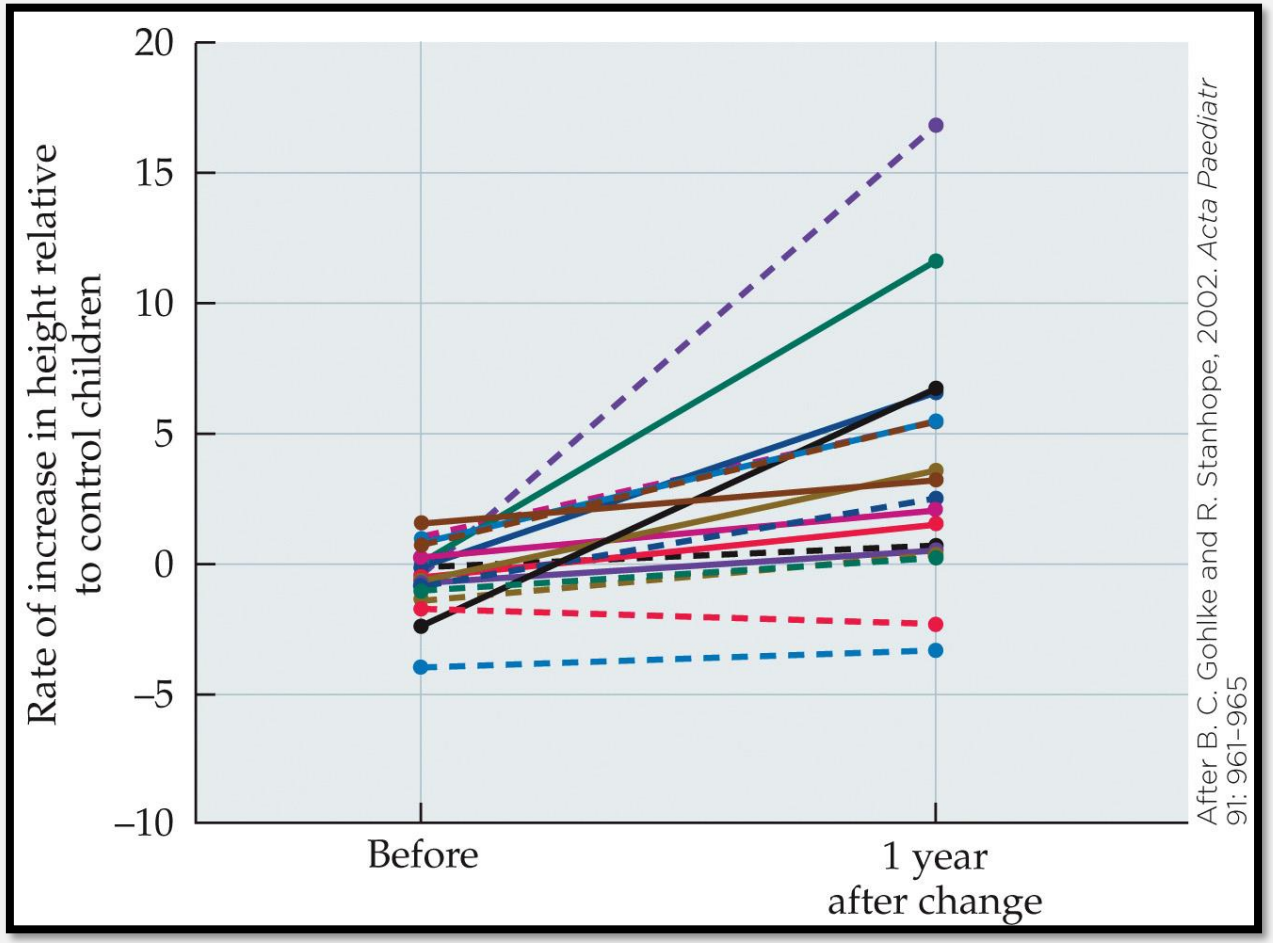


BEHAVIORAL NEUROSCIENCE 10e, Figure 5.21

Hormones and behaviour

Psychosocial dwarfism:

- growth failure due to stress and neglect in early childhood; mediated through the CNS and its control over endocrine functions.
- Removal of the stress allows normal growth to resume.
- Growth impairments appear to be mediated by changes in cortisol, GH, and *somatomedins* (normally released by the liver in response to GH).



Hormonal-neuronal interactions

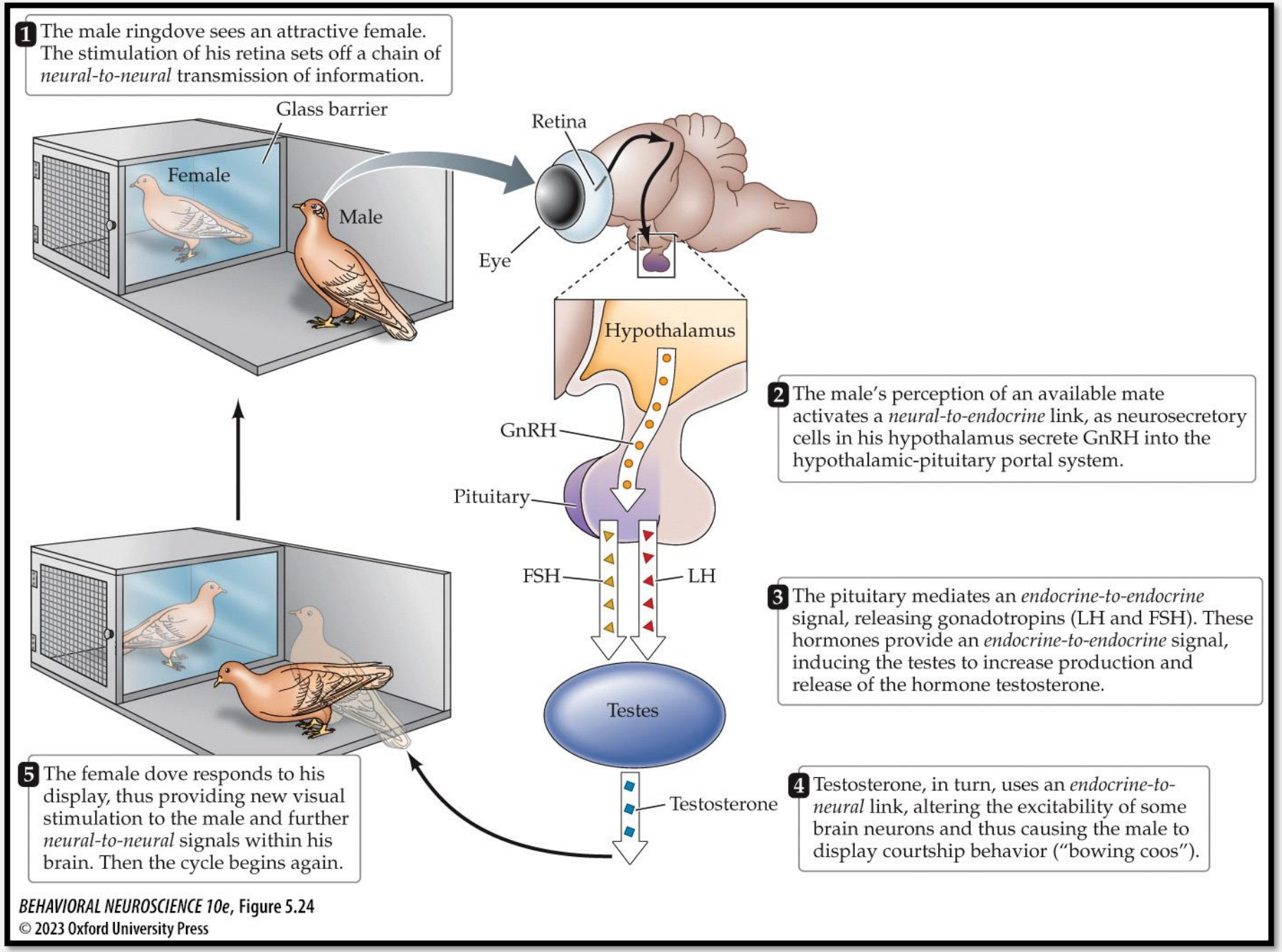
- Hormonal and neural systems interact to produce responses.
  Example: the milk letdown reflex.

Communication signals can be:

- Neural-to-neural
- Neural-to-endocrine
- Endocrine-to-endocrine
- Endocrine-to-neural

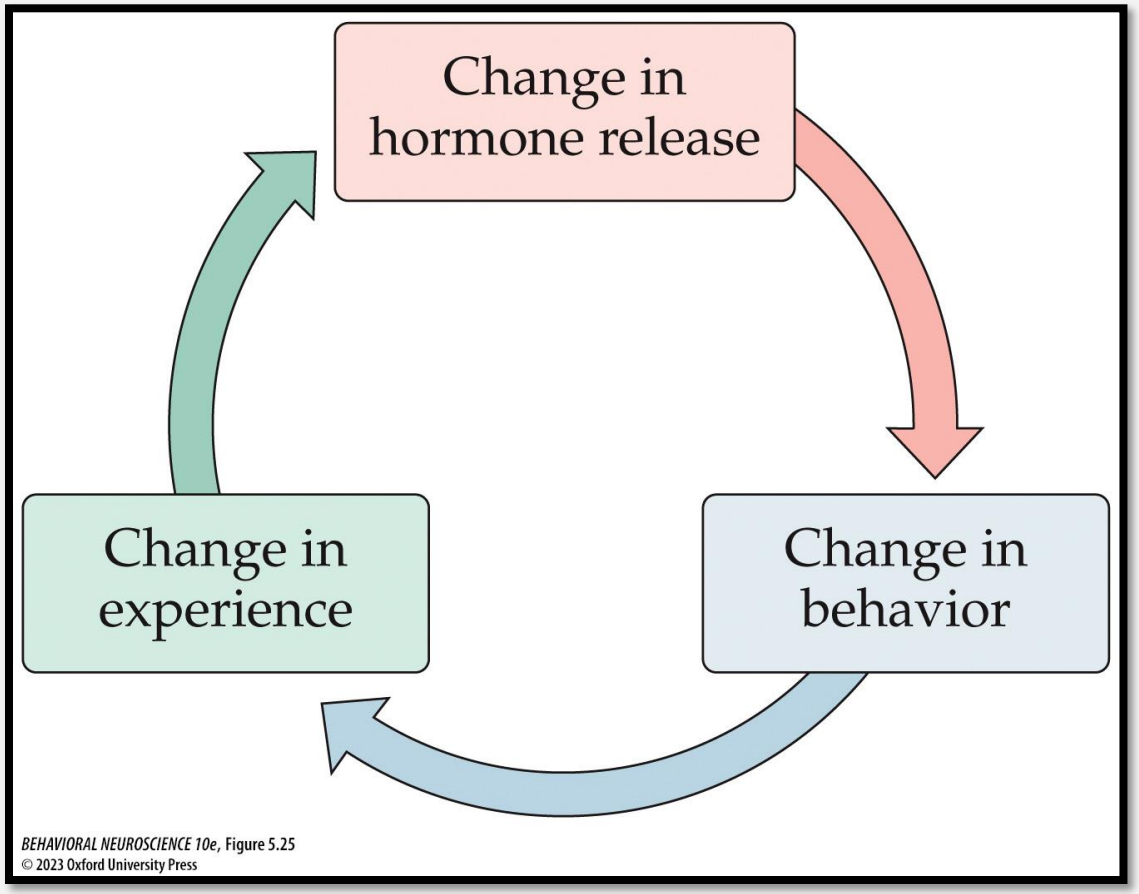
- All are illustrated in courtship behavior of ringdoves.

FIGURE 5.24 Interactive Signals between the Nervous System and the Endocrine System (1)



Hormonal-neuronal interaction

- The hormonal and neural systems exert reciprocal influences on each other.
- Experience affects hormone secretion, hormones affect behavior, and behavior affects future experiences.



Cutting edge research

- Research with mice shows that bone cells secrete a peptide hormone called *lipocalin 2*, after a meal. It can cross the blood-brain barrier and binds to cells in the hypothalamus.
- Treating mice with lipocalin 2 reduces their food intake.
- In mouse knockouts for the lipocalin receptor, lipocalin treatment had no effect on food intake.