SENSORY RECEPTION

I. Sensory receptors

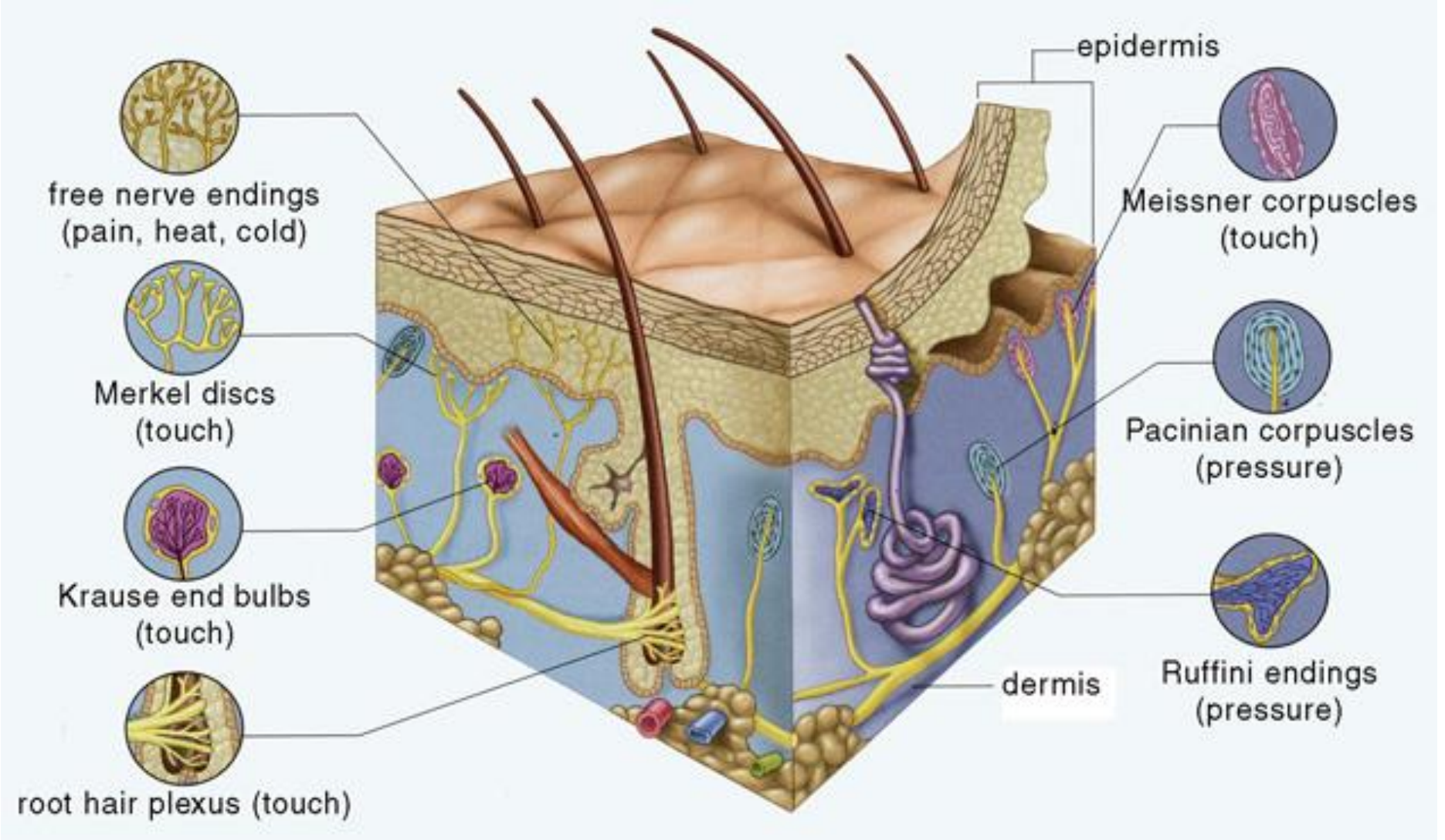
A. Transduce stimulus energy into changes in membrane potential (electrical energy)

B. classified by type of energy they are most sensitive to

1. Mechanoreceptors : mechanical deformation of membrane
2. Thermoreceptors : changes in temperature
3. Chemoreceptors : binding of molecules
4. Nociceptors : intense stimuli of above types (pain)
5. Photoreceptors : absorption of light

C. Law of specific nerve energies : each receptor, regardless of how it is activated, produces only type of sensation in CNS

Sensory receptors



SENSORY PATHWAYS

Dorsal Column

1. **Modalities** **a. types**
   - Fine touch
   - Fine pressure
   - Two point discri.
   - Vibration
   - Kinesthesia

   b. **RANGE**
   - Discrete

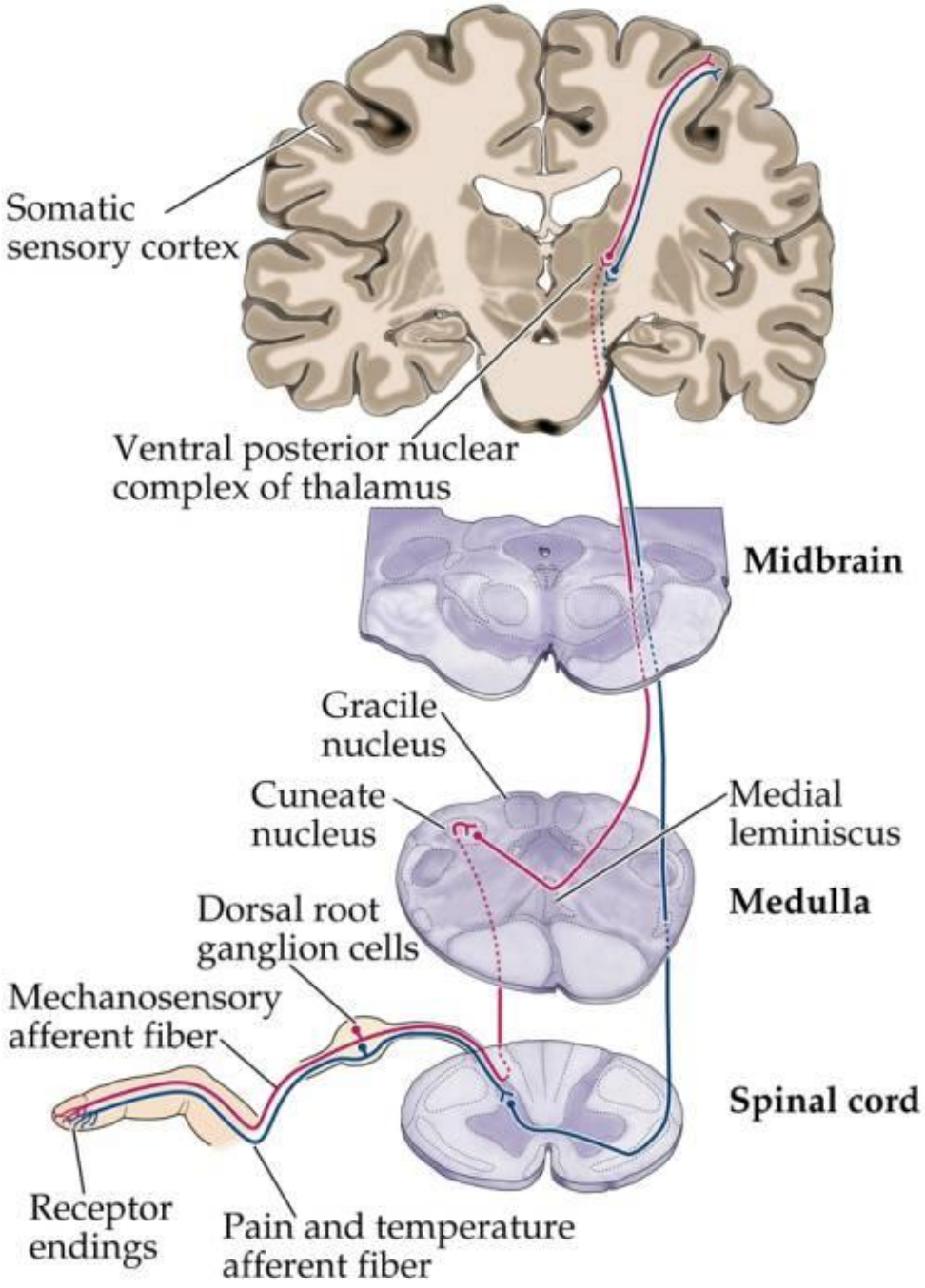
   c. **Gradation**
   - upto 100

Anterolateral

1. **Modalities**
   - Crude touch
   - Crude pressure
   - Pain
   - Temperature
   - Tickle+ Itch
   - Sexual Sensations

   b. Wide

   c. 10-20


Somatic
sensory cortex
Ventral posterior nuclear
complex of thalamus
Midbrain
Gracile
nucleus
Cuneate
nucleus
Medial
leminiscus
Medulla
Dorsal root
ganglion cells
Mechanosensory
afferent fiber
Spinal cord
Receptor
endings
Pain and temperature
afferent fiber

2.Syn	Discriminative	Non- discri.
3.Size of fibres	12-16um	Upto 4um
4.Types of fibre	A-alpha + A beta Thick mylinated	A-delta + C Thin mylinated
5.Speed of transmition	Fast 30-110 m/s	Slow 0.5-40 m/s
6. Ascent	Ipsilateral	Contralateral
1st Order neuron	Long-in spinal cord- N. Gracilis+cuneatus	Short- ends in dorsal spinal root
2nd Order neuron	Nuclei to thalamus	dorsal spinal root to thalamus
3rd Order neuron	thalamus to cortex	thalamus to cortex

Figure 15.9. Proprioreceptors. (*a*) a neuromuscular spindle; (*b*) a neurotendinous receptor (Golgi tendon organ).

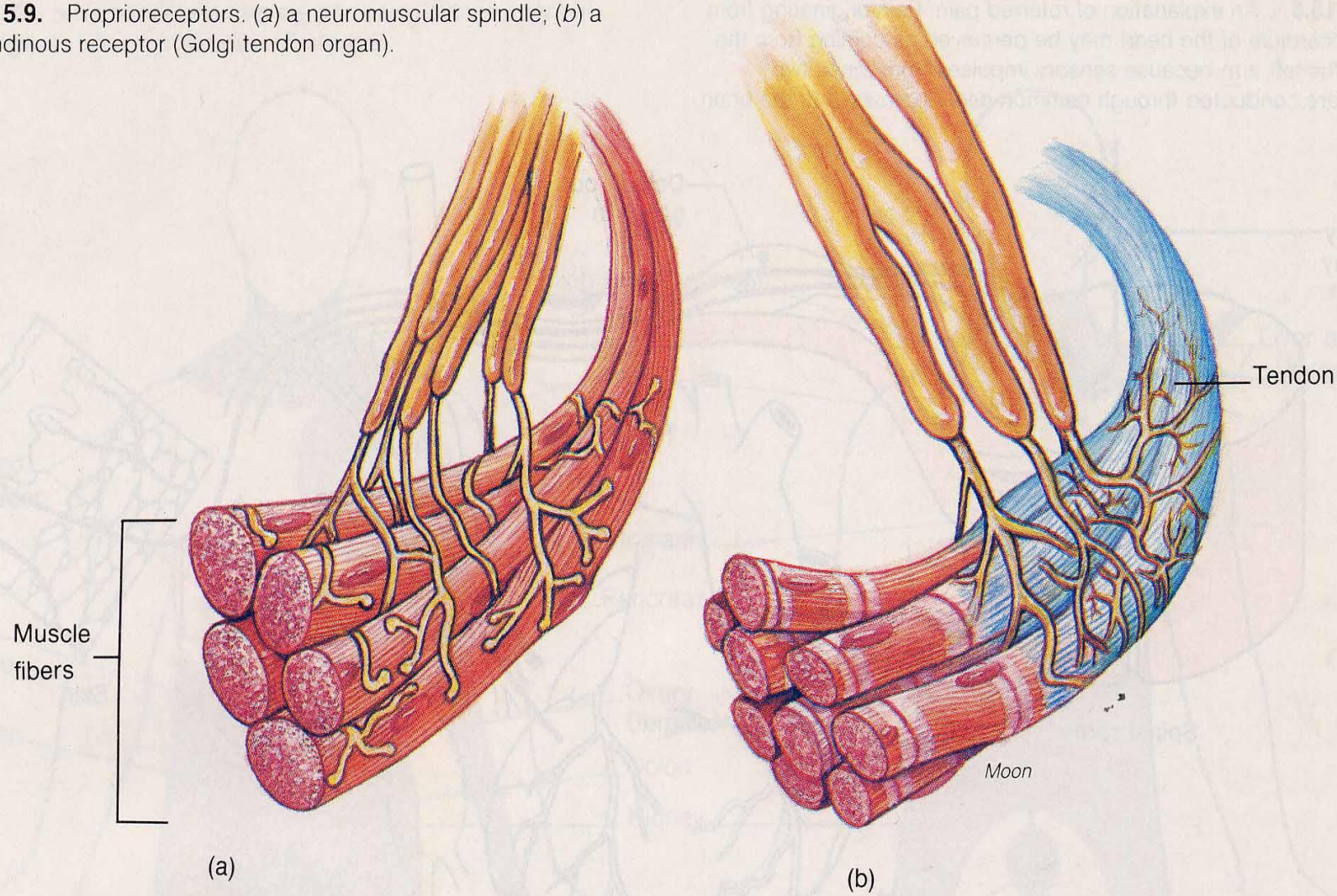
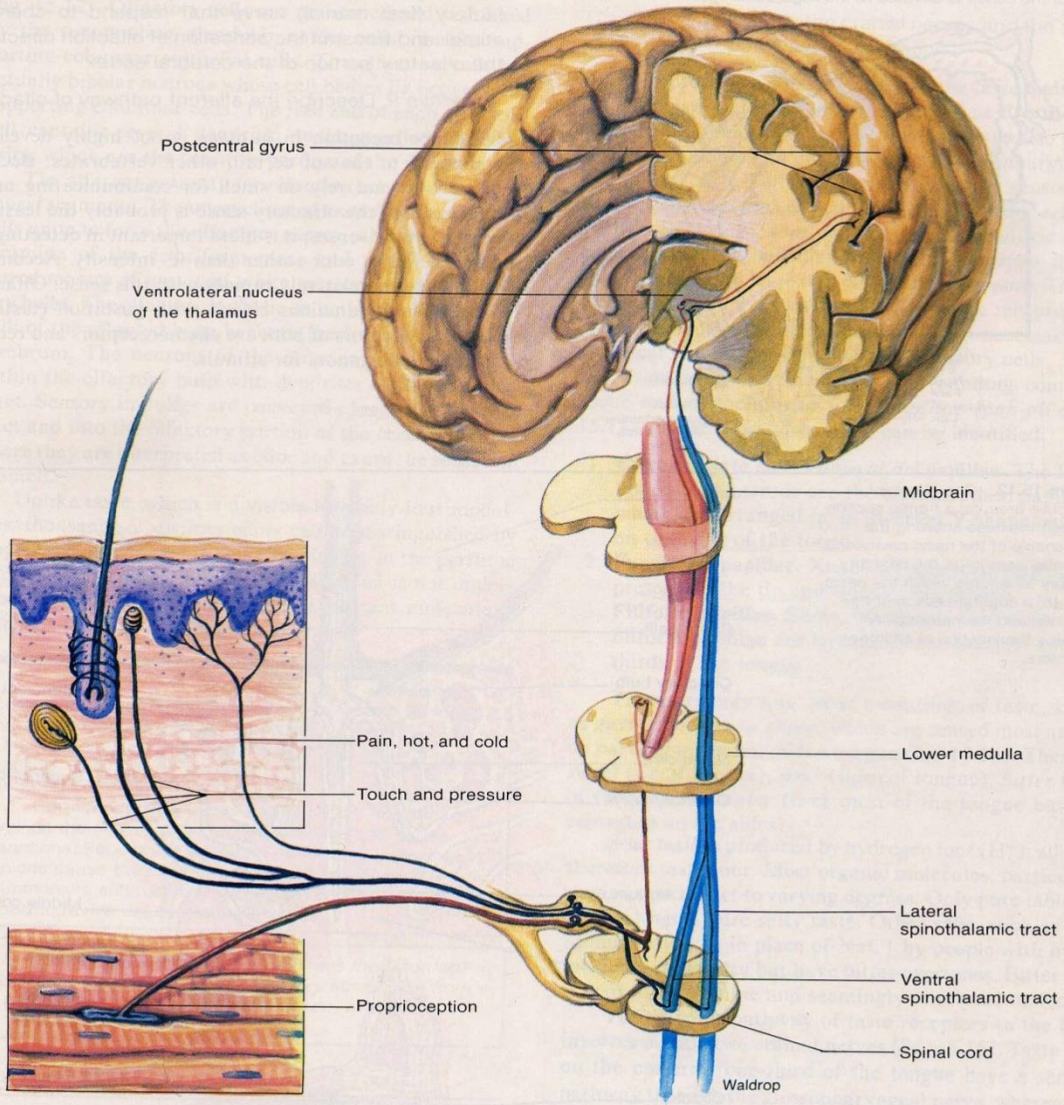
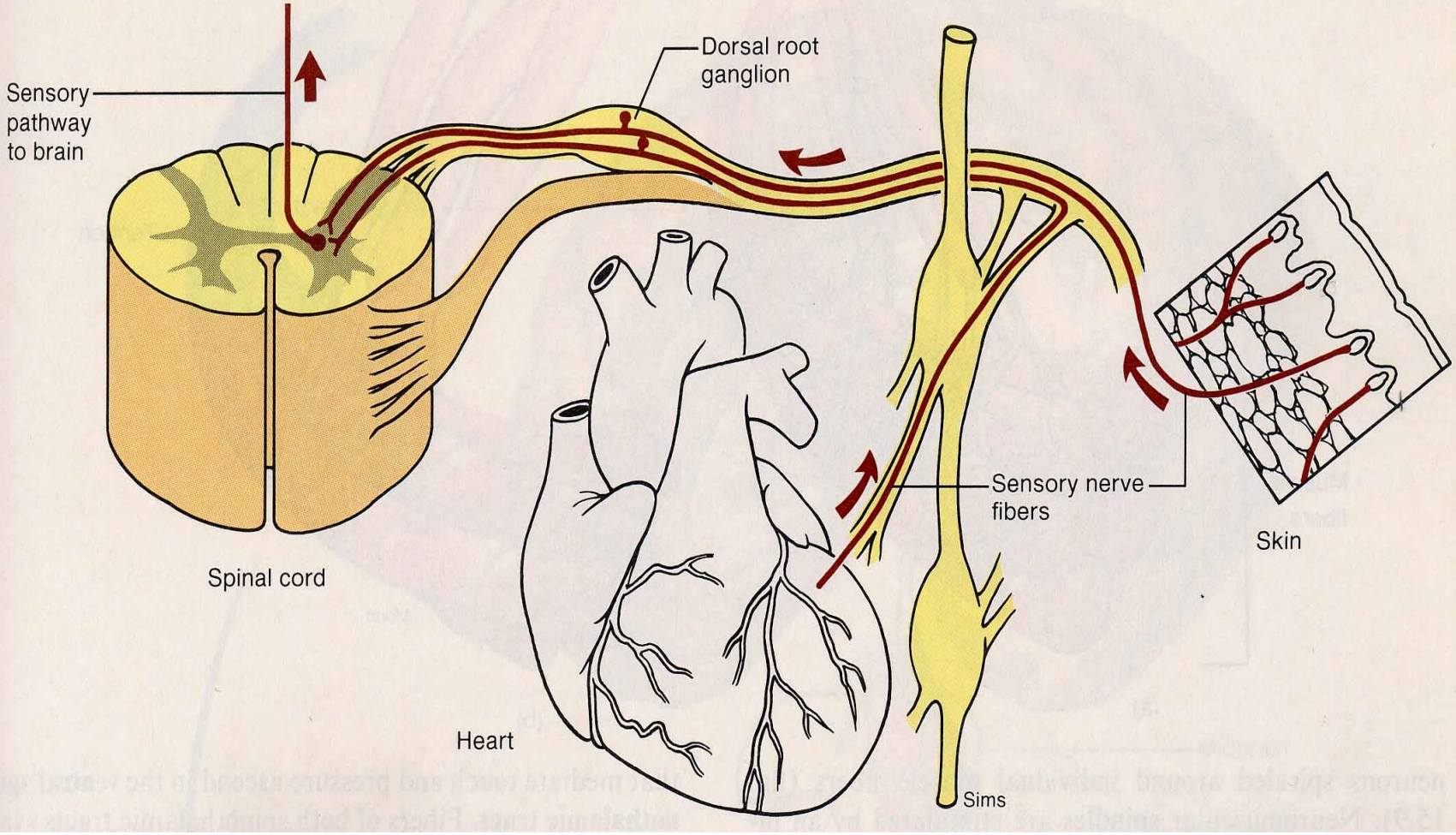


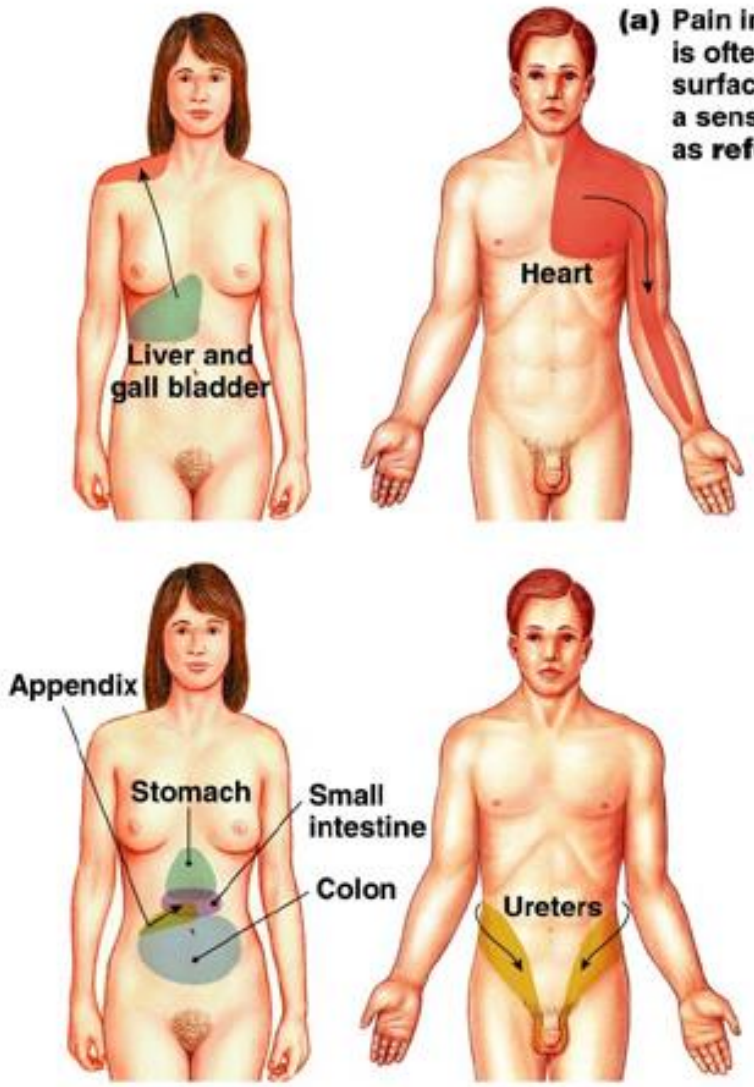
Figure 15.10. Pathways that lead from the cutaneous receptors and proprioreceptors into the postcentral gyrus in the cerebral cortex.



Referred Pain

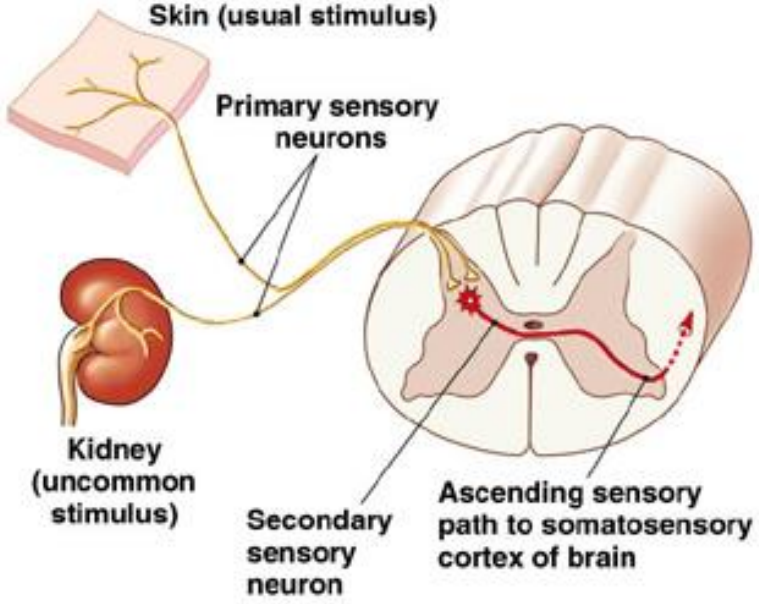
Figure 15.8. An explanation of referred pain. Pain originating from the myocardium of the heart may be perceived as coming from the skin of the left arm because sensory impulses from these two organs are conducted through common nerve pathways to the brain.





(a) Pain in internal organs is often sensed on the surface of the body, a sensation known as **referred pain.**

(b) One theory of referred pain says that nociceptors from several locations converge on a single ascending tract in the spinal cord. Pain signals from the skin are more common than pain from internal organs, and the brain associates activation of the pathway with pain in the skin. Adapted from H.L. Fields, *Pain* (McGraw Hill, 1987).



II. Mechanism of sensory transduction

A. Stimulus causes change in permeability of specific ion channels in receptor cell membrane

1. Usually an increase in permeability
2. May be caused by change in size of channels or binding of molecule

B. Ions diffuse across membrane

C. Membrane potential of receptor cell changes (receptor potential)

1. Usually a depolarization
2. Amplitude graded with stimulus intensity

D. Sensitivity over wide range of intensities

1. Weber-Fechner Principle

a. receptor potential amplitude is proportional to the logarithm of stimulus intensity

b. this means that the ratio of the stimulus change (poststimulus relative to prestimulus) is the important parameter for the intensity of sensory perception

c. not applicable in cases of low stimuli

E. Conversion of receptor potential to afferent impulses

1. Similar to PSPs
2. Action potentials are produced :
    a. in receptor cell that is also the primary afferent
    b. in primary afferent, postsynaptic to receptor
3. Encoding of stimulus properties
    a. for some receptors, afferent firing frequency is proportional to amplitude of receptor potential
    b. hence, intensity and dynamics of stimulus are encoded in frequency of afferent impulses

III. Transmission of afferent impulses into CNS

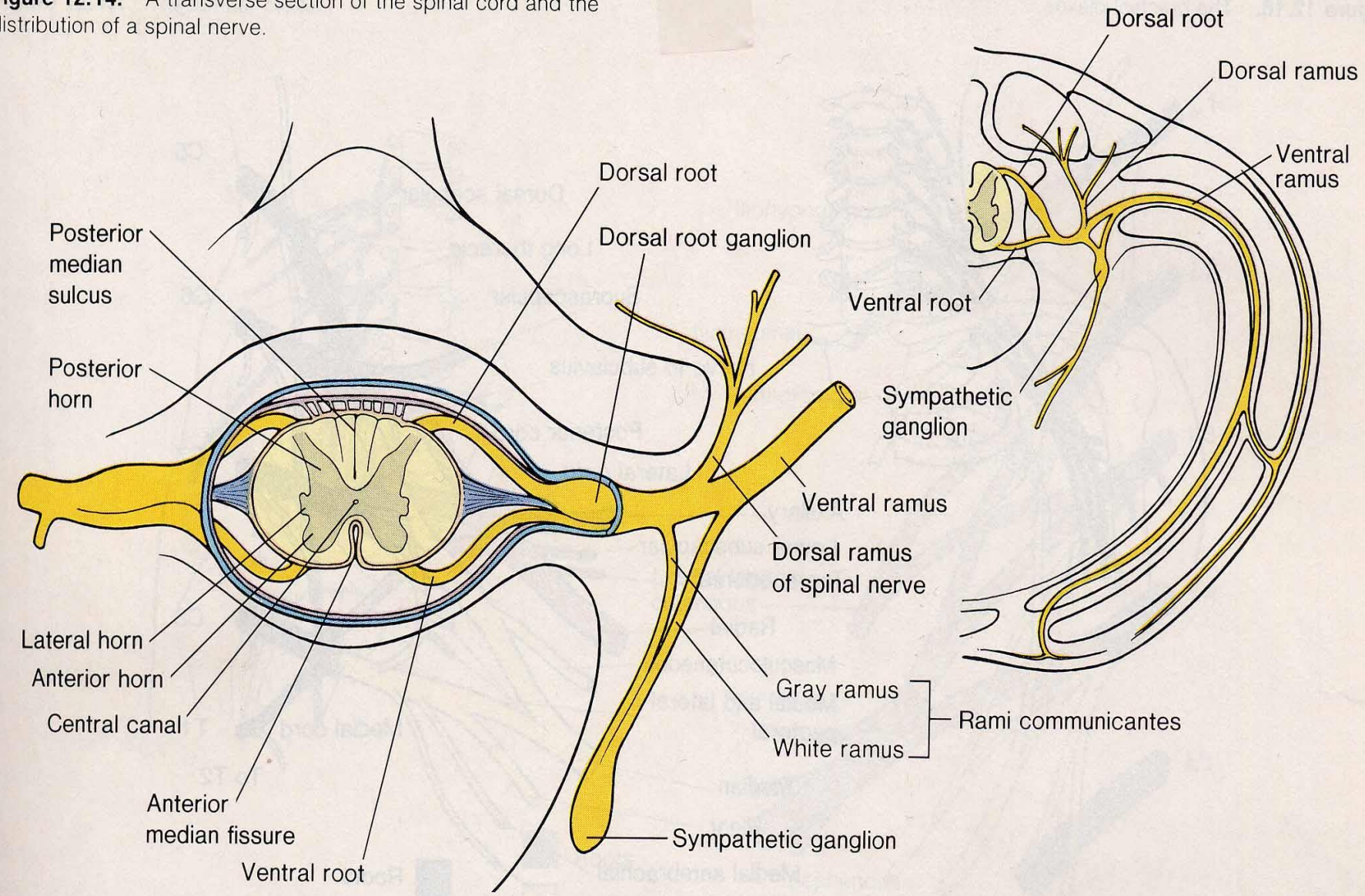
A. Sensory unit : one afferent neuron and all its receptors (or receptor endings)

B. receptive field : area innervated by a sensory unit

C. Cell bodies of afferent in dorsal root ganglia (DRG)

D. Afferent axon enters dorsal horn of spinal cord

Figure 12.14. A transverse section of the spinal cord and the distribution of a spinal nerve.



IV. Adaptation : amplitude decreases during maintained stimulus

A. Receptor types
   1. Tonic receptors : little adaptation (incomplete of not at all)
      a. position-sensitive receptors
   2. Phasic receptors : significant adaptation (rapid and complete)
      a. velocity- and acceleration-sensitive ; predictive value

B. Mechanisms
   1. Chemical
   2. Mechanical

V. Tactile cutaneous sensation

A. Types of Sensations

1. Pressure
    a. receptors : Merkel's disks, Ruffini ending
    b. Adaptation : some and only partial
2. Touch (very sensitive)
    a. receptors : Meissner's corpuscle, hair follicle
    b. adaptation : moderate, occurs within seconds
3. Vibration
    a. Receptor : pacinian corpuscle
    b. Adaptation : rapid, occurs within milliseconds
4. Tickle
    a. receptors : free nerve endings
    b. Adaptation : very little to none

B. Most afferent have myelinated axons, except tickling and itching which go by unmyelinated axons

C. Distribution of receptor types differs in hairy (hair follicles) vs. hairless (Meissner corpuscles) skin

D. Sensitivity

1. Greatest in tips of fingers and tongue
2. Can detect 10nm indentation of skin or movement of single hair follicle
3. Two-point discrimination measures spatial threshold
   a. depends on number, size, and distribution of receptive fields

VI. Thermal cutaneous sensation

A. Receptors
   1. Free nerve endings specialized to respond to temperature
   2. Very little adaptation

B. Separate receptors for cold and warm

C. Distribution
   1. More receptors for cold than for warm in most areas of body
   2. Not evenly distributed

D. Both types respond best to changes in temperature, but maintain low-frequency discharge at constant temperature
   1. Sensitivity : less than 0.01 degree Celsius change can be detected

E. Temperature extremes activate pain receptors

VII. Joint position sensation

A. Receptor types : Ruffini endings in joint capsule ; Golgi tendon organs and pacinian corpuscles in ligaments

B. Respond to velocity of joint rotation and final joint angle

C. Adaptation : poor for receptors in capsule (angle) and good for receptors in ligaments (velocity/acceleration)

AUTONOMIC NERVOUS SYSTEM

GENERAL PROPERTIES

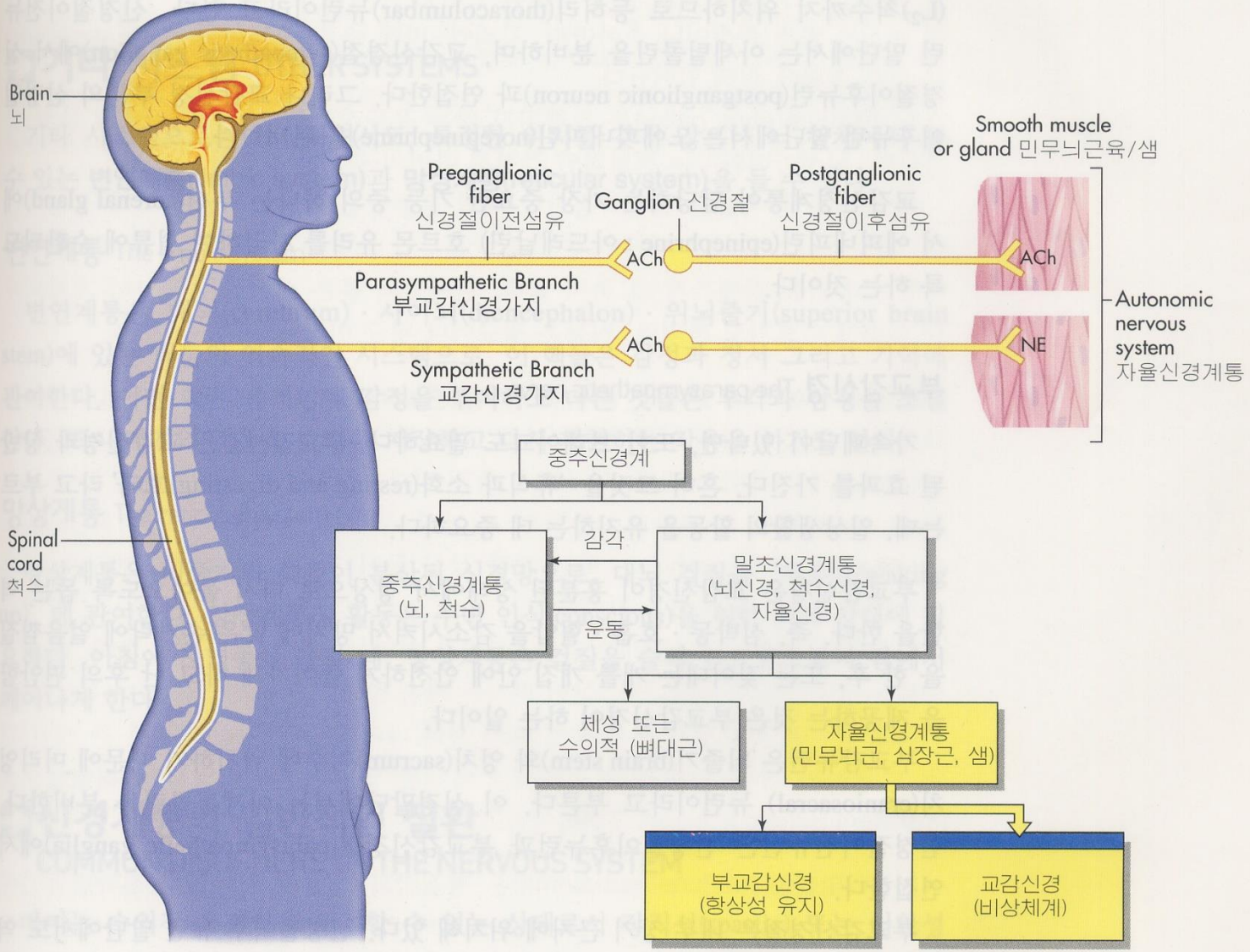
1. Control of visceral functions of body e.g. arterial pressure, gastrointestinal motility and secretion

2. Autonomic reflexes

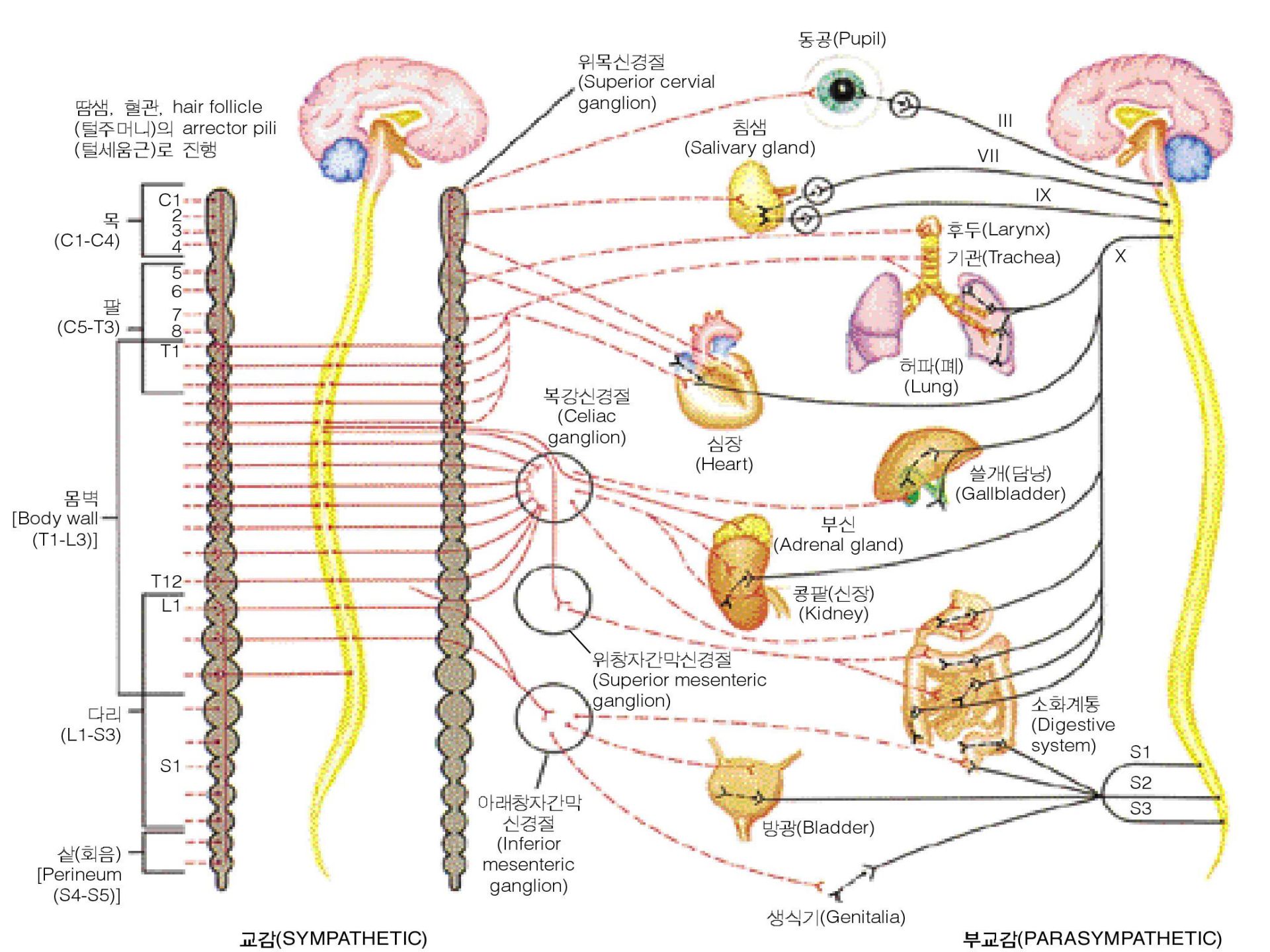
3. Differs from somatic motor system
    (a) somatic system
        (i) innervates skeletal muscles
        (ii) single nerve fiber originating in spinal cord
    (b) autonomic nervous system
        (i) smooth and cardiac muscle, glands
        (ii) two neuron chains that synapse at ganglia - pre- and post ganglionic neurons

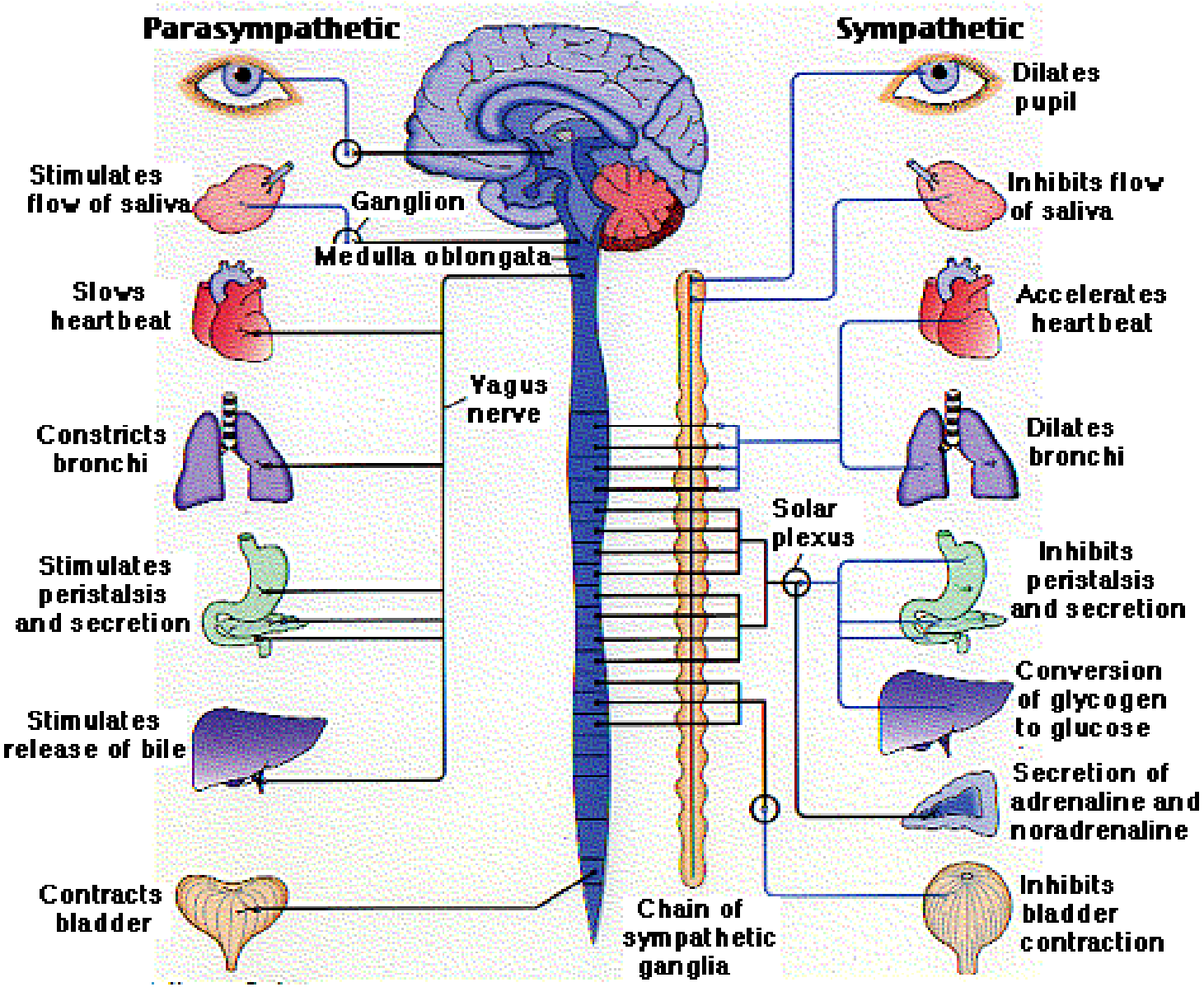
4. Centers for control of autonomic nervous system
    (a) spinal cord
    (b) brainstem
    (c) hypothalamus
    (d) limbic system - indirect via lower brain centers

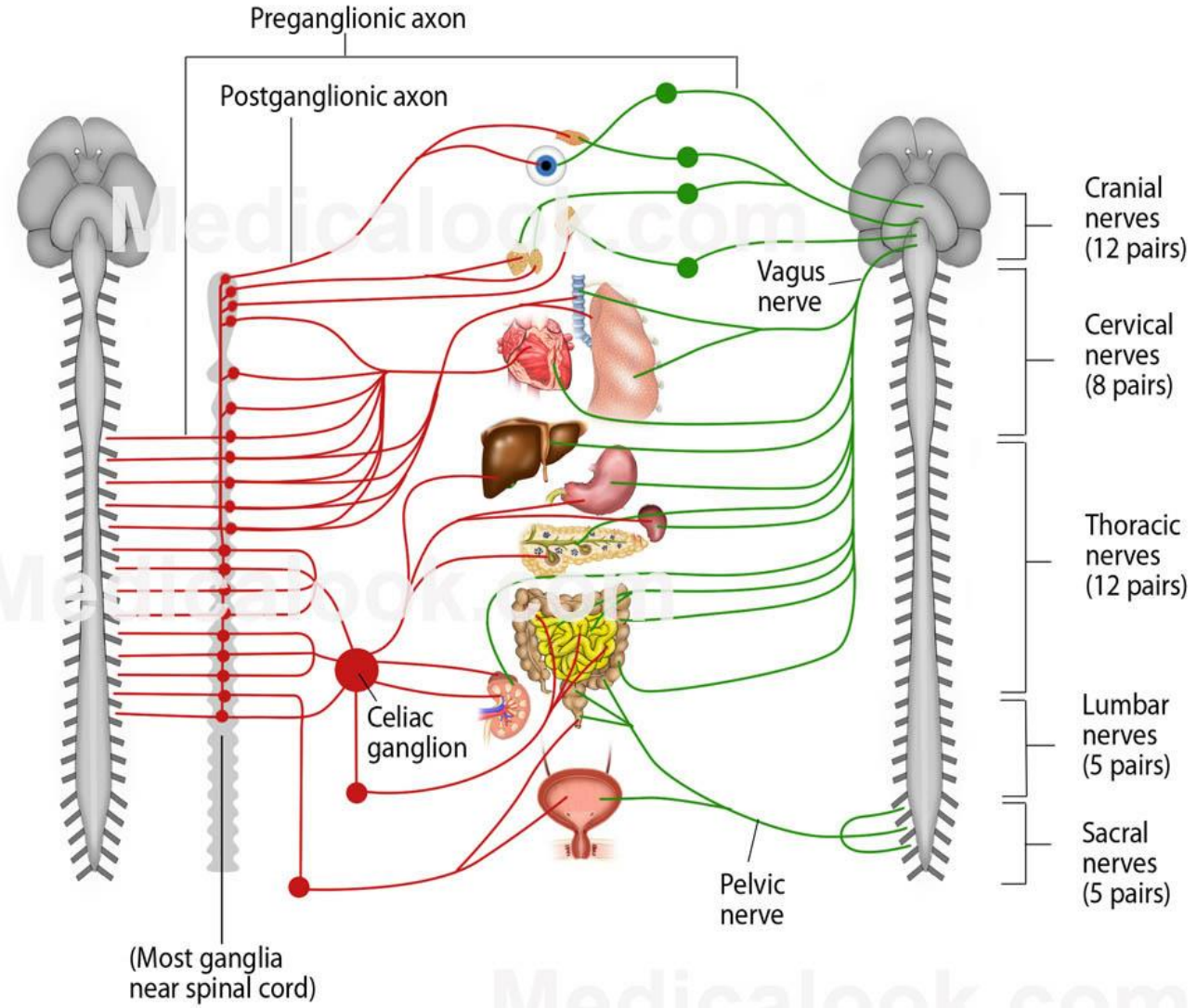
5. Major subdivisions are sympathetic and parasympathetic nervous systems
    (a) origin of pre-ganglionic fibers
    (b) position of ganglia
    (c) transmitter released from nerve ending



〈그림 9-10〉 자율신경계통의 일반적 기능

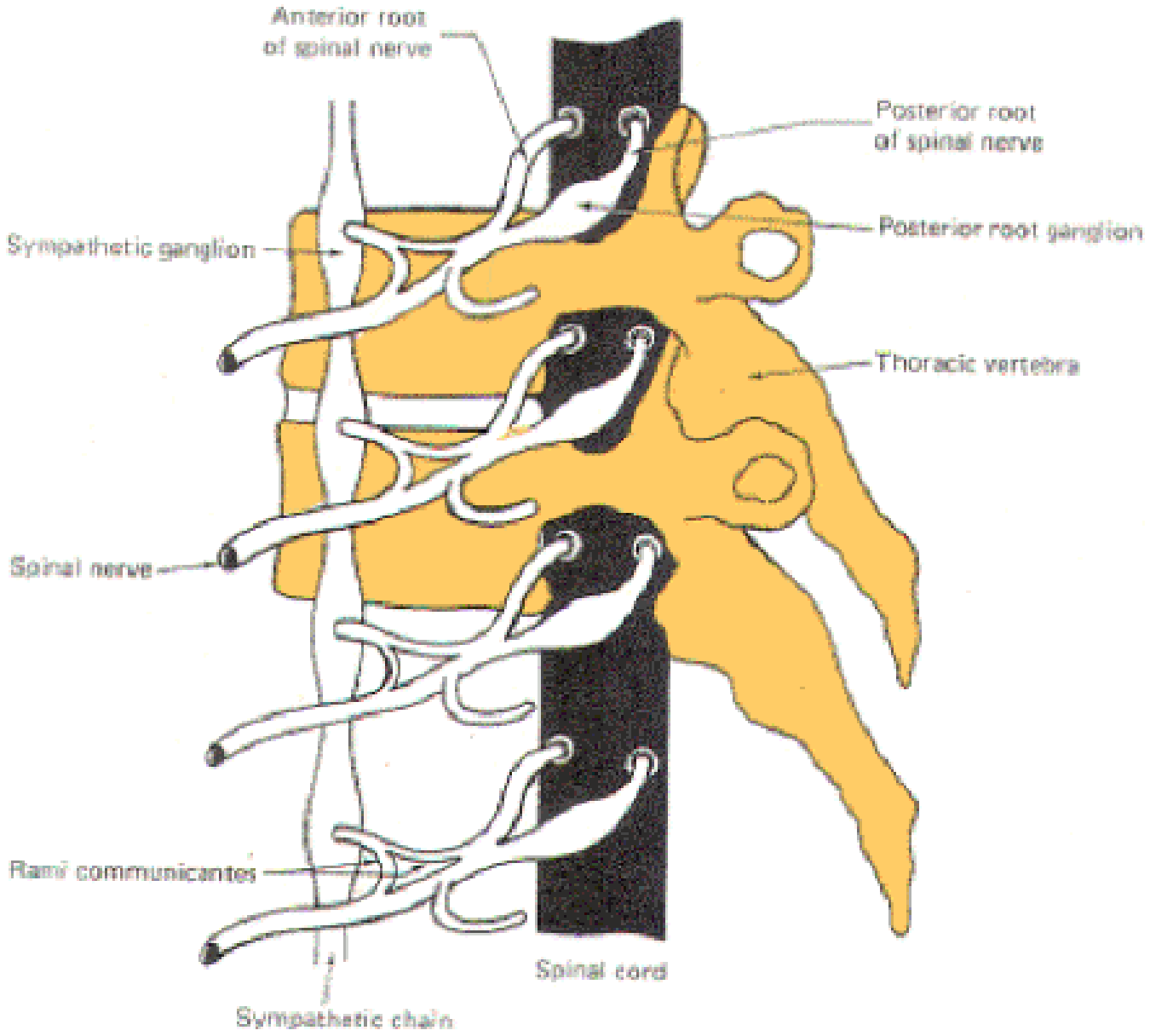

동공(Pupil)
위목신경절
(Superior cervial
ganglion)
땀샘, 혈관, hair follicle
(털주머니)의 arrector pili
(털세움근)로 진행
침샘
(Salivary gland)
III
VII
IX
X
후두(Larynx)
기관(Trachea)
허파(폐)
(Lung)
심장
(Heart)
복강신경절
(Celiac
ganglion)
쓸개(담낭)
(Gallbladder)
부신
(Adrenal gland)
콩팥(신장)
(Kidney)
위창자간막신경절
(Superior mesenteric
ganglion)
소화계통
(Digestive
system)
아래창자간막
신경절
(Inferior
mesenteric
ganglion)
방광(Bladder)
생식기(Genitalia)
목
(C1-C4)
팔
(C5-T3)
몸벽
[Body wall
(T1-L3)]
다리
(L1-S3)
샅(회음)
[Perineum
(S4-S5)]
C1
2
3
4
5
6
7
8
T1
T12
L1
S1
S1
S2
S3
교감(SYMPATHETIC)
부교감(PARASYMPATHETIC)

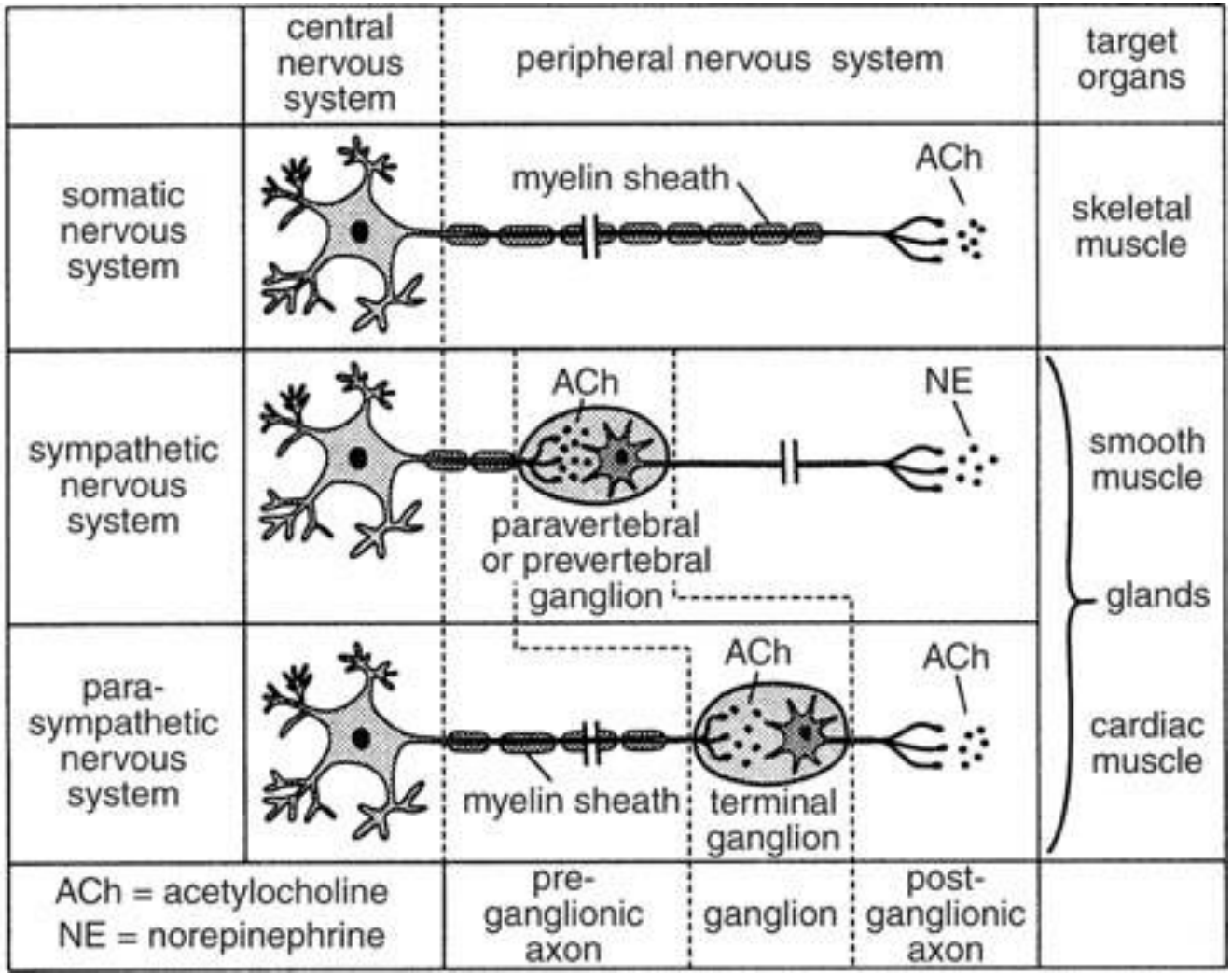

Parasympathetic
Sympathetic
Stimulates flow of saliva
Ganglion
Medulla oblongata
Slows heartbeat
Yagus nerve
Constricts bronchi
Stimulates peristalsis and secretion
Stimulates release of bile
Contracts bladder
Chain of sympathetic ganglia
Solar plexus
Dilates pupil
Inhibits flow of saliva
Accelerates heartbeat
Dilates bronchi
Inhibits peristalsis and secretion
Conversion of glycogen to glucose
Secretion of adrenaline and noradrenaline
Inhibits bladder contraction



Sympathetic outflow

Parasympathetic outflow


Anterior root
of spinal nerve
Posterior root
of spinal nerve
Posterior root ganglion
Sympathetic ganglion
Thoracic vertebra
Spinal nerve
Rami communicantes
Spinal cord
Sympathetic chain


central nervous system
peripheral nervous system
target organs
somatic nervous system
myelin sheath
ACh
skeletal muscle
sympathetic nervous system
ACh
NE
paravertebral or prevertebral ganglion
smooth muscle
glands
para-sympathetic nervous system
ACh
ACh
myelin sheath
terminal ganglion
cardiac muscle
ACh = acetylocholine
NE = norepinephrine
pre-ganglionic axon
ganglion
post-ganglionic axon

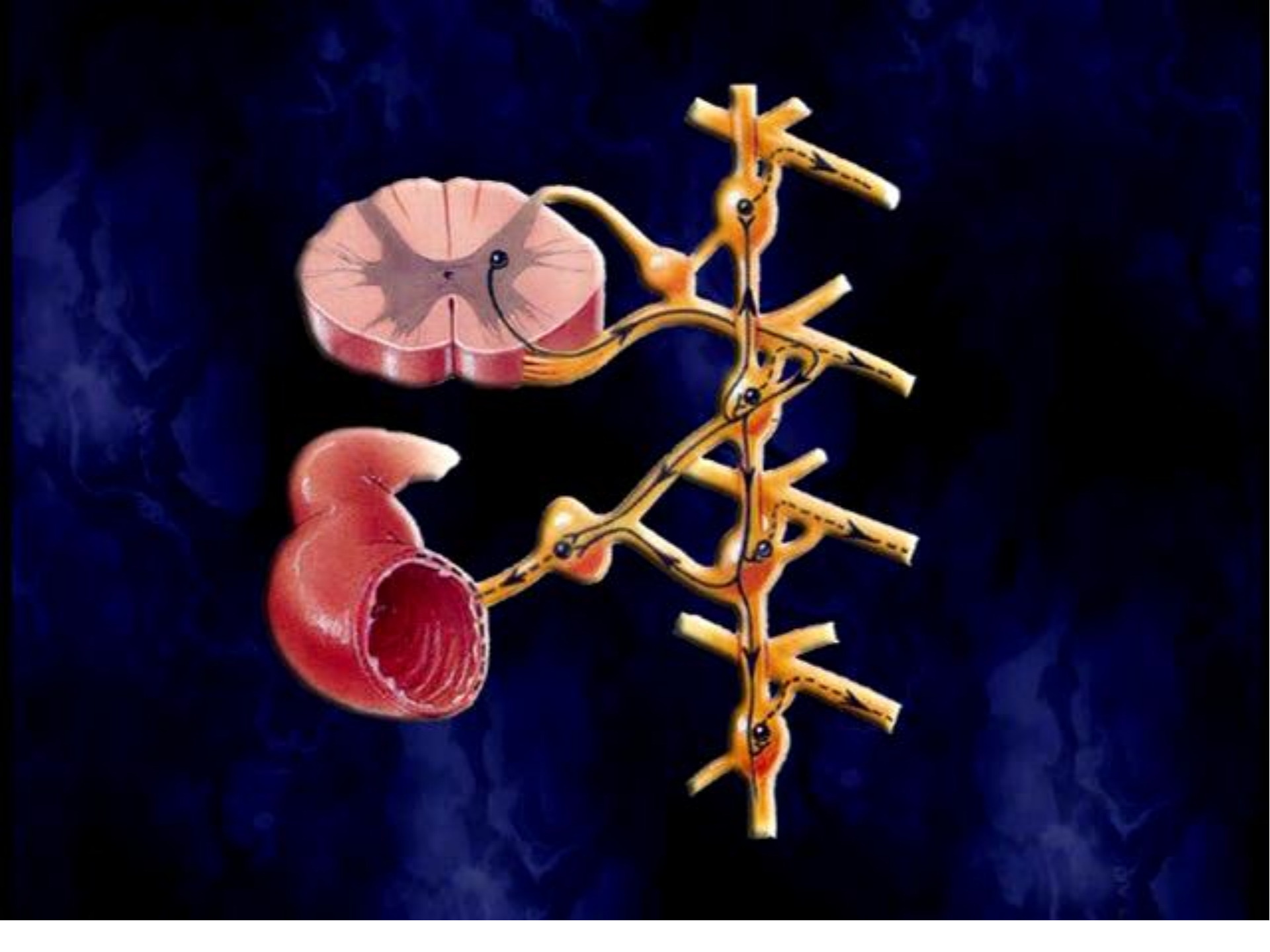
SYMPATHETIC NERVOUS SYSTEM

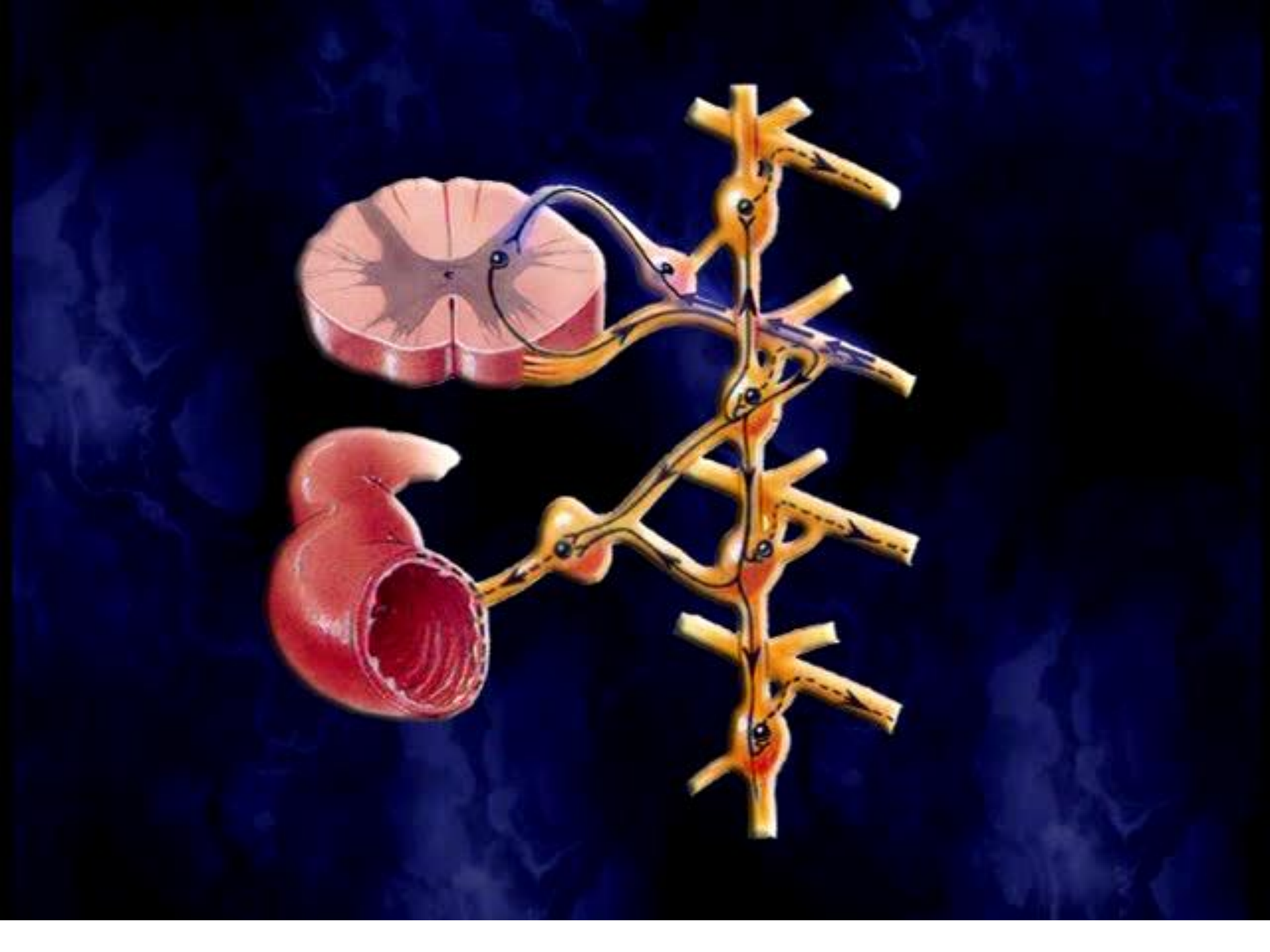
1. Sympathetic chains lie on each side of spinal cord
2. Sympathetic nerves originate in spinal cord between
   T1 and L2
   (a) preganglionic fiber originates in intermediolateral horn of cord
   (b) passes through anterior root to ganglion of sympathetic chain
   (c) pre-ganglionic neuron synapses with post- ganglionic fiber
      (i) in ganglion of sympathetic chain
      (ii) in outlying sympathetic ganglion after passage through sympathetic chain ganglion

3. Special case of adrenal medulla

(a) Pre-ganglionic neuron synapses with specialized cells that secrete epinephrine and norepinephrine

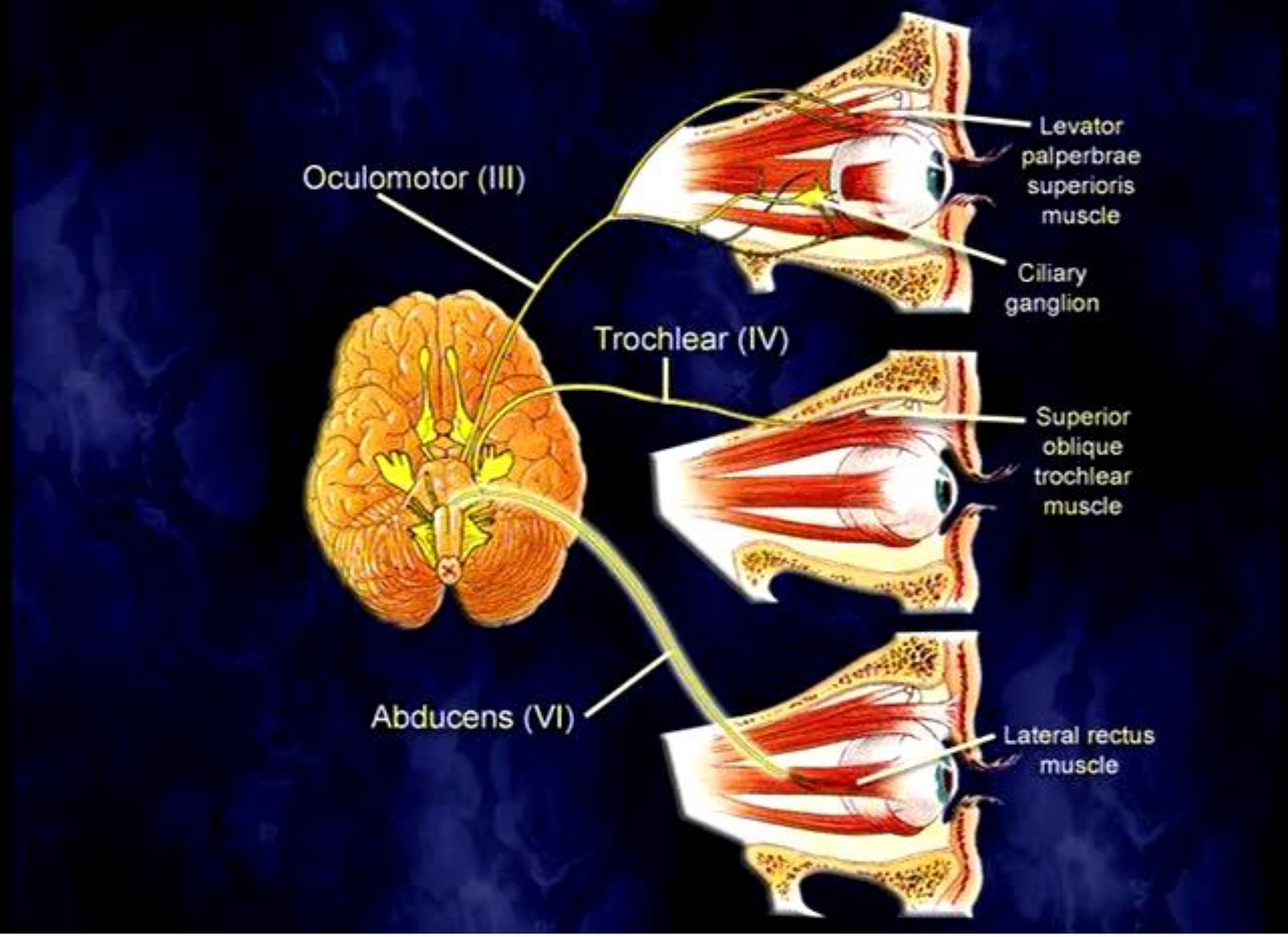
(b) these secretory cells are analogous to postganglionic neurons

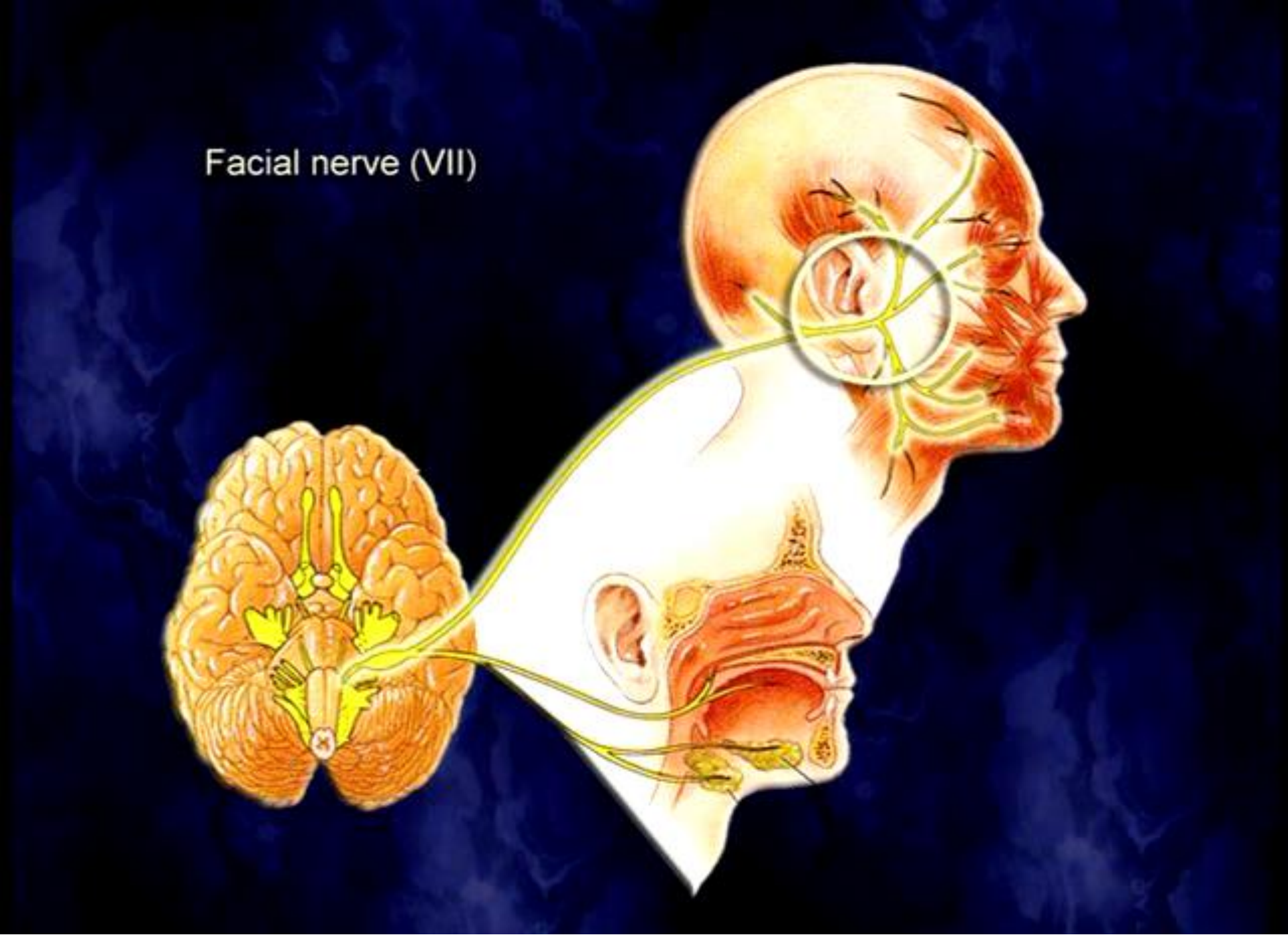


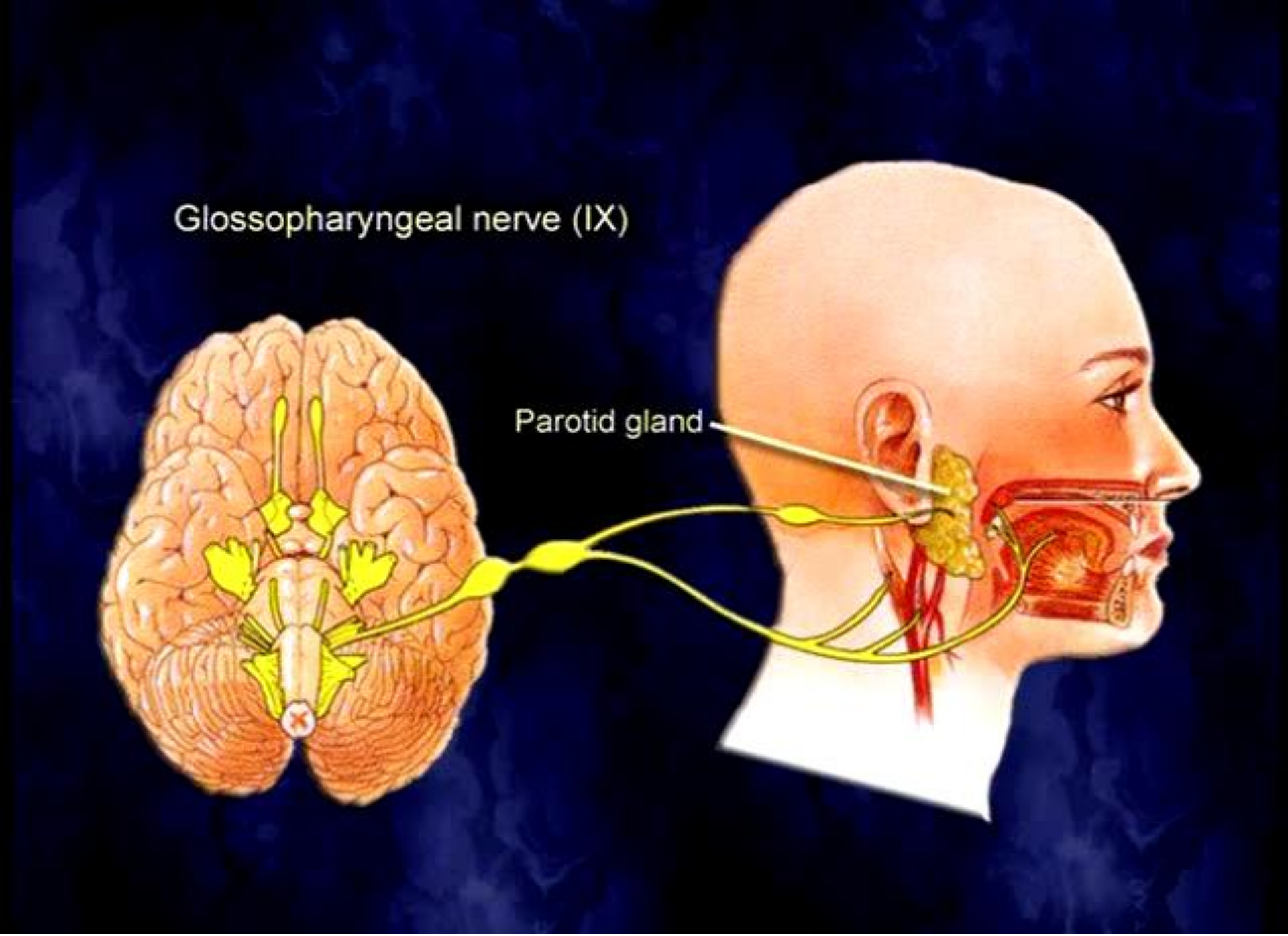


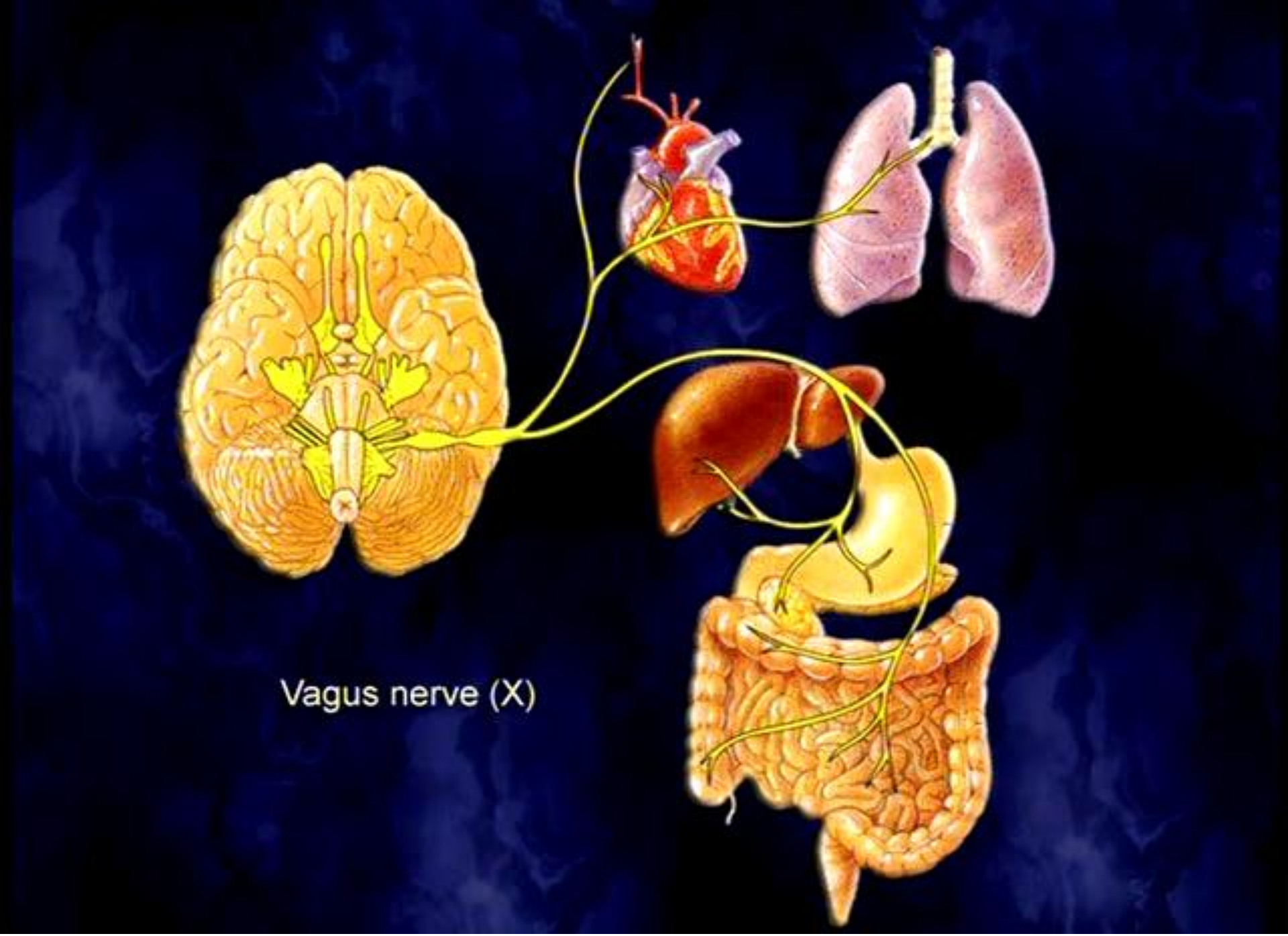
PARASYMPATHETIC NERVOUS SYSTEM

1. Origin of parasympathetic nerves
   (a) cranial nerves III, VII, IX, X
      : Xth cranial nerve (vagus nerves) supply about 75% of all parasympathetic fibers - supply heart, lungs, GI tract
   (b) sacral nerves S2 to S4
2. Pre- and postganglionic fibers
   (a) preganglionic fibers usually pass to target organ
   (b) synapse with postganglionic neuron in wall of target organ: postganglionic neurons are short


Oculomotor (III)
Levator palperbrae superioris muscle
Ciliary ganglion
Trochlear (IV)
Superior oblique trochlear muscle
Abducens (VI)
Lateral rectus muscle


Facial nerve (VII)


Glossopharyngeal nerve (IX)
Parotid gland


Vagus nerve (X)

SECRETION OF NEUROTRANSMITTERS

1. Neurons may be cholinergic or adrenergic
    (a) cholinergic neurons secrete acetylcholine
        (cf. skeletal neuromuscular junction)
            (i) preganglionic neurons of sympathetic and parasympathetic systems
            (ii) postganglionic neurons of parasympathetic system
            (iii) some sympathetic postganglionic neurons
    (b) adrenergic neurons secrete norepinephrine (noradrenalin)
            (i) most sympathetic postganglionic neurons

2. Fate of secreted neurotransmitters

(a) acetylcholine rapidly hydrolyzed by acetylcholinesterase

(b) norepinephrine is removed by

(i) reuptake into nerve terminals

(ii) diffusion away from nerve endings and enzymic breakdown

3. Receptors for neurotransmitters in effector organs

(a) acetylcholine receptors may be nicotinic or muscarinic

(i) nicotinic receptors occur at sympathetic and parasympathetic ganglia (also skeletal neuromuscular junction)

(ii) muscarinic receptors occur at postganglionic parasympathetic neurons, postganglionic cholinergic sympathetic neurons

(b) adrenergic receptors may be alpha or beta

(i) norepinephrine activates alpha receptors and to less extent beta

(ii) epinephrine activates alpha and beta equally

4. Effects of transmitter binding to receptors

(a) opening of ion channel

(nicotinic acetylcholine receptors)

(i) membrane depolarization

(ii) effect of ions on enzymatic activities

(b) change in activity of coupled enzymes (muscarinic, adrenergic receptors)

(i) rise in concentration of intracellular second messengers e.g. cyclic AMP

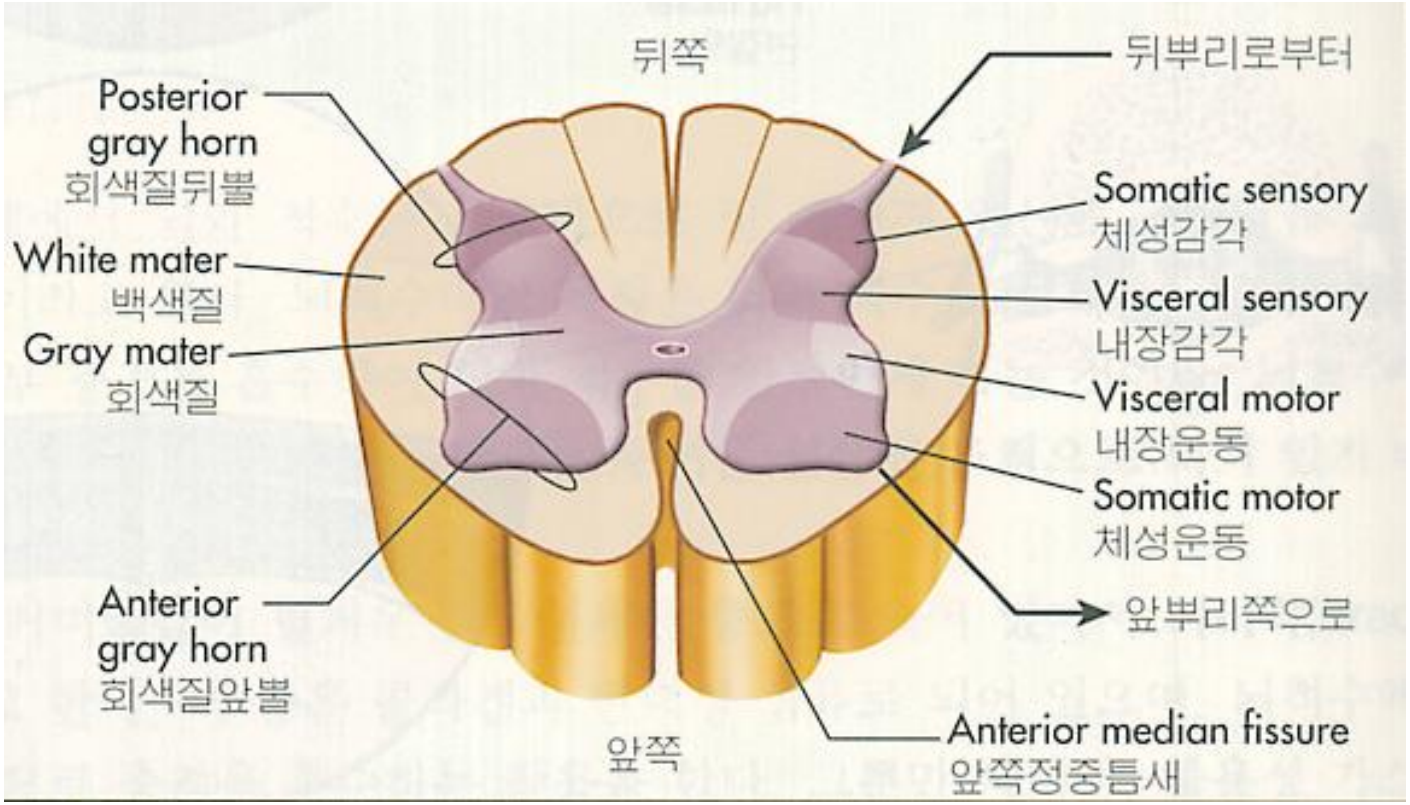
COMPARISON OF SYMPATHETIC AND PARASYMPATHETIC SYSTEMS

SYMPATHETIC

1. Widespread or discrete responses
   Mass discharge stress response
   Unit discharge e.g. adrenal medulla
2. Closely related cells of origin
3. Ganglia mostly in sympathetic cord
4. Slow removal of transmitter (reuptake, diffusion)
5. Short preganglionic neurons
   Long postganglionic neurons
6. Ganglion transmitter is AcCh
7. Transmitter is usually norepinephrine ; AcCh for sweat glands, skeletal muscle, blood vessels
8. Blocked by adrenergic blocking agents e.g. dibenzyline

PARASYMPATHETIC

1. Discrete localized responses e.g. nutrition excretion
2. Cells of origin in distinct nuclei
3. Ganglia close to organs
4. Rapid destruction of transmitter (acetylcholinesterase)
5. Long preganglionic neurons
Short postganglionic neurons
6. Ganglion transmitter is AcCh
7. Transmitter is AcCh
8. Blocked by muscarinic blocking agents e.g. atropine


뒤쪽
뒤뿌리로부터
Posterior
gray horn
회색질뒤뿔
White mater
백색질
Gray mater
회색질
Somatic sensory
체성감각
Visceral sensory
내장감각
Visceral motor
내장운동
Somatic motor
체성운동
앞뿌리쪽으로
Anterior
gray horn
회색질앞뿔
Anterior median fissure
앞쪽정중틈새
앞쪽