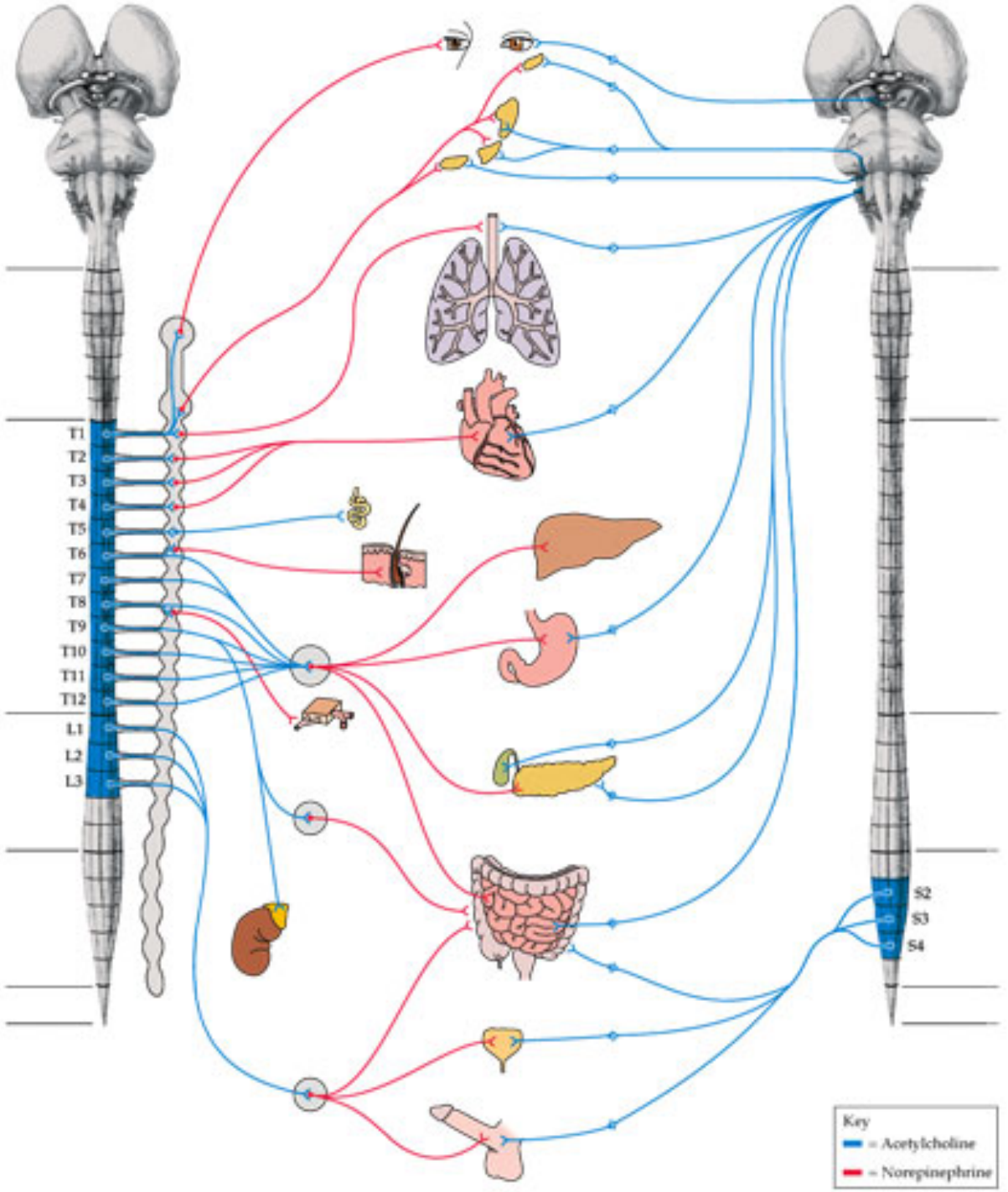
The *Not So* Autonomic Nervous System

The Visceral Motor Neurons and Visceral Sensation



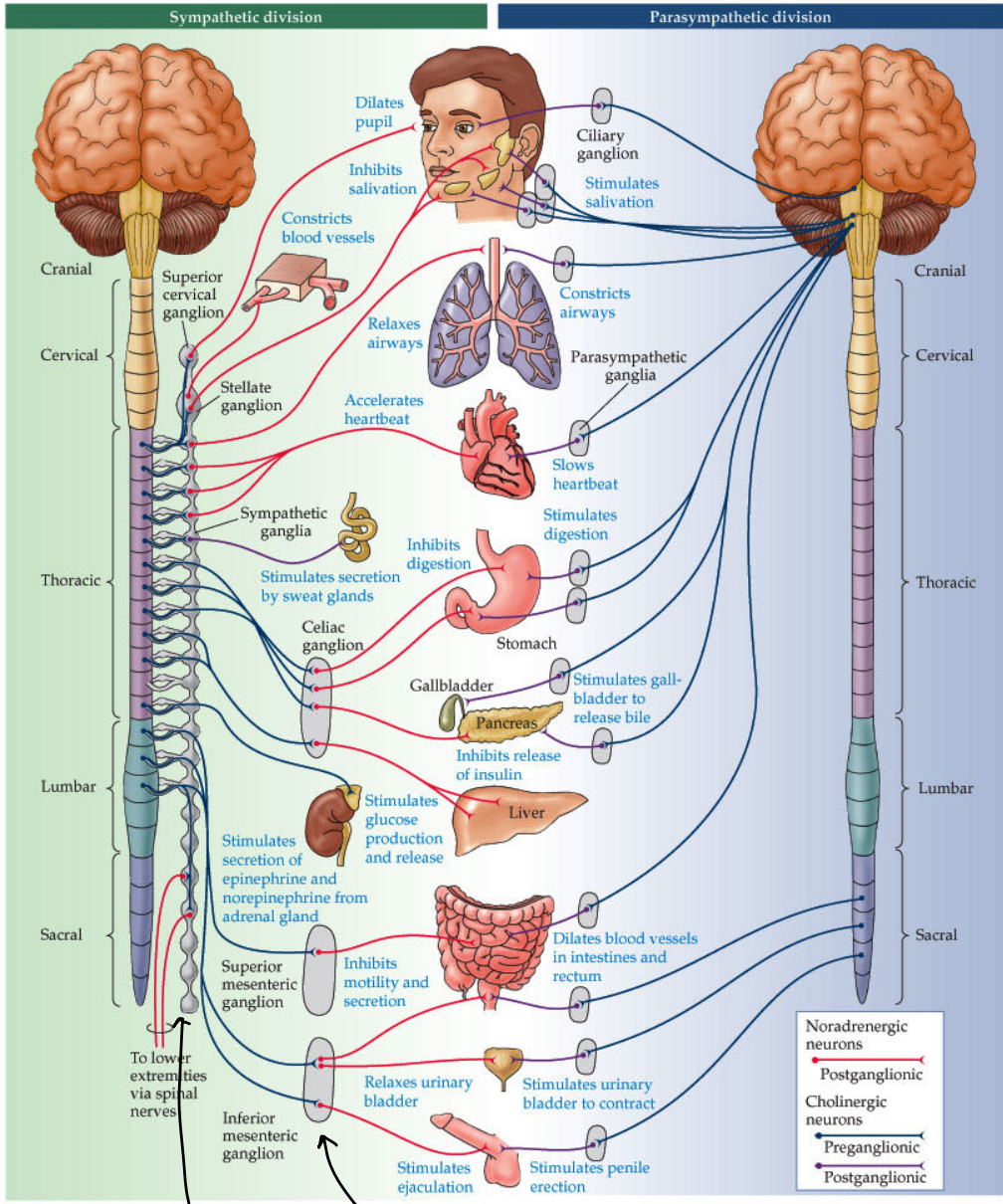
Why is the autonomic nervous system called the autonomic nervous system?

Describe the basic anatomy of the autonomic nervous system (ANS). How does this differ from somatic motor system? What are the main anatomical and neurotransmitter differences between the sympathetic and parasympathetic parts of the ANS?

Why are pre and post ganglionic ANS neurons not Lower Motor Neurons since they project to muscles?

"Autonomous" NS

- Motor Nerves with Motor Ganglia
  - CNS Projects indirectly to Organs and Glands
  - Sympathetic – Thoracolumbar
    - Chain and Collateral Ganglia (outside of organs)
  - Parasympathetic –Craniosacral
    - Ganglia within organs or near organs
- Autonomic is Autonomous
  - CNS damage does not stop movements of visceral organs
    - Heart in a dish
    - Peristaltic waves in gut
  - Organs can function effectively w/o inputs from CNS
- Not Totally Autonomous
  - All together now... raise your ...
    can control organs through volitional control
  - Lack of volitional control by cortex
    - However Clinicians use relaxation techniques to lower BP



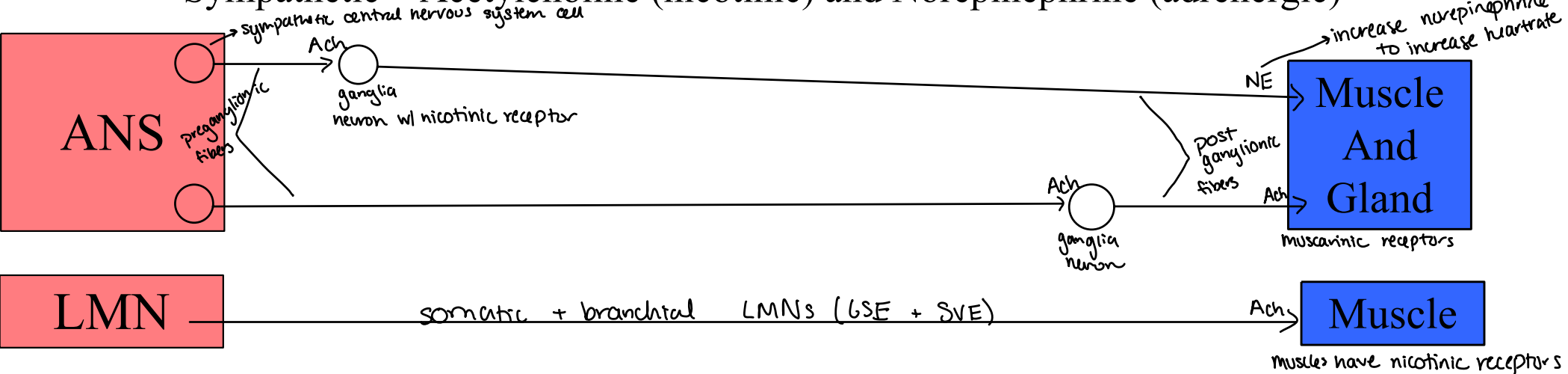
urth Edition, Figure 21.1

collateral ganglia

sympathetic chain ganglia

Somatic/Branchial Versus Visceral Motor (GSE and SVE vs. GVE)

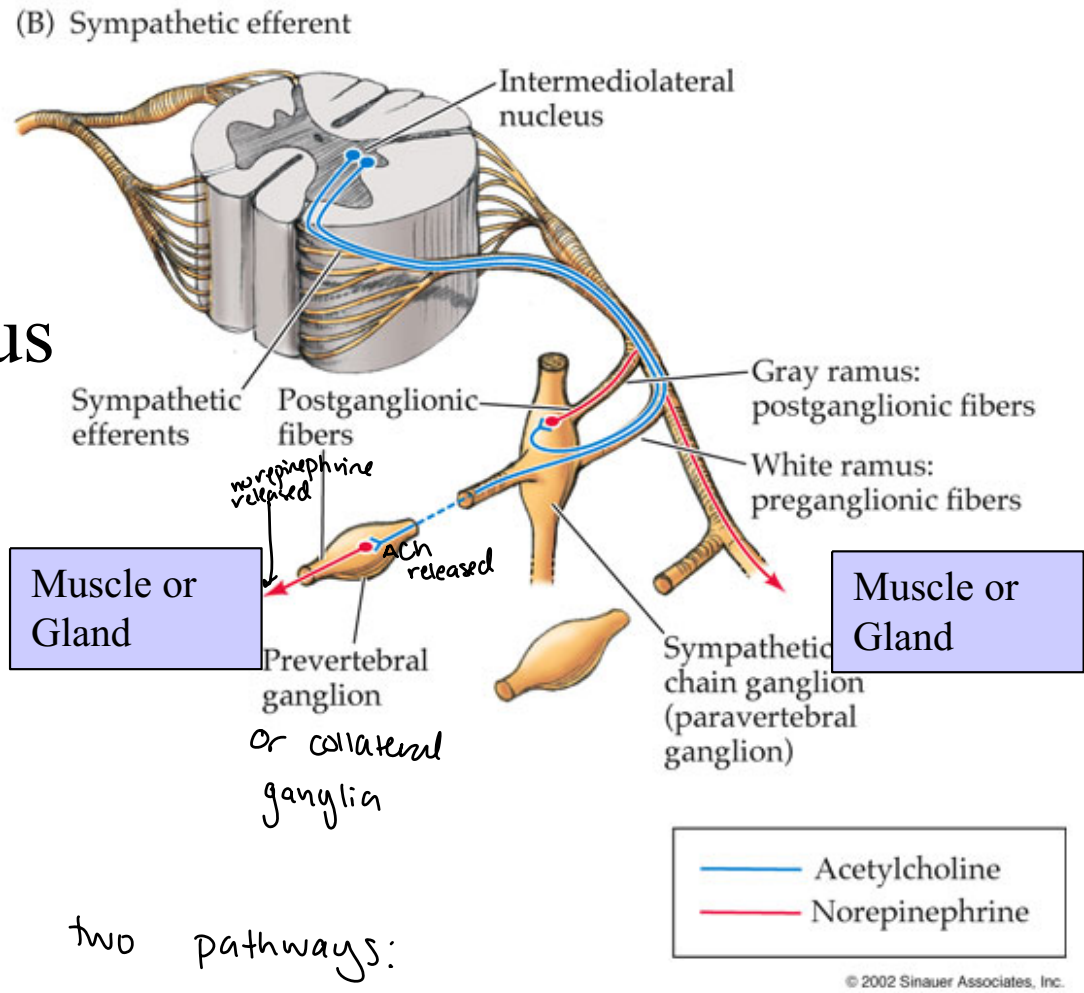
- CNS – Lower Motor Neurons (Somatic Motor (GSE) or Branchial Motor Neurons (SVE)) ACH-Nicotinic → all
- CNS – Autonomic Visceral Motor Neurons – Preganglionic Neurons (GVE)
  - Preganglionic Fibers (ACH - Nicotinic)
    - Short = Sympathetic (thoracolumbar CNS)
    - Long = Parasympathetic (craniosacral CNS)
  - NOT Lower Motor Neurons
- PNS - Motor Ganglia Neurons
  - Chain Ganglia, Collateral Ganglia, Enteric Ganglia
  - Postganglionic fibers –Long (Sympathetic) Short (Parasympathetic)
- Neurotransmitters
  - Parasympathetic – Acetylcholine (nicotinic) and Acetylcholine (muscacrinic)
  - Sympathetic – Acetylcholine (nicotinic) and Norepinephrine (adrenergic)



Describe the anatomy of the sympathetic nervous system. Where is it, and how does it control the sympathetic ANS?

CNS neurons project to Muscles ... Eventually

- Lateral Horn
  - Intermediolateral Nucleus
    - Projects to Sympathetic Ganglia
- Sympathetic Ganglia Neurons
  - Chain and Collateral
  - Project to smooth and cardiac muscles and glands

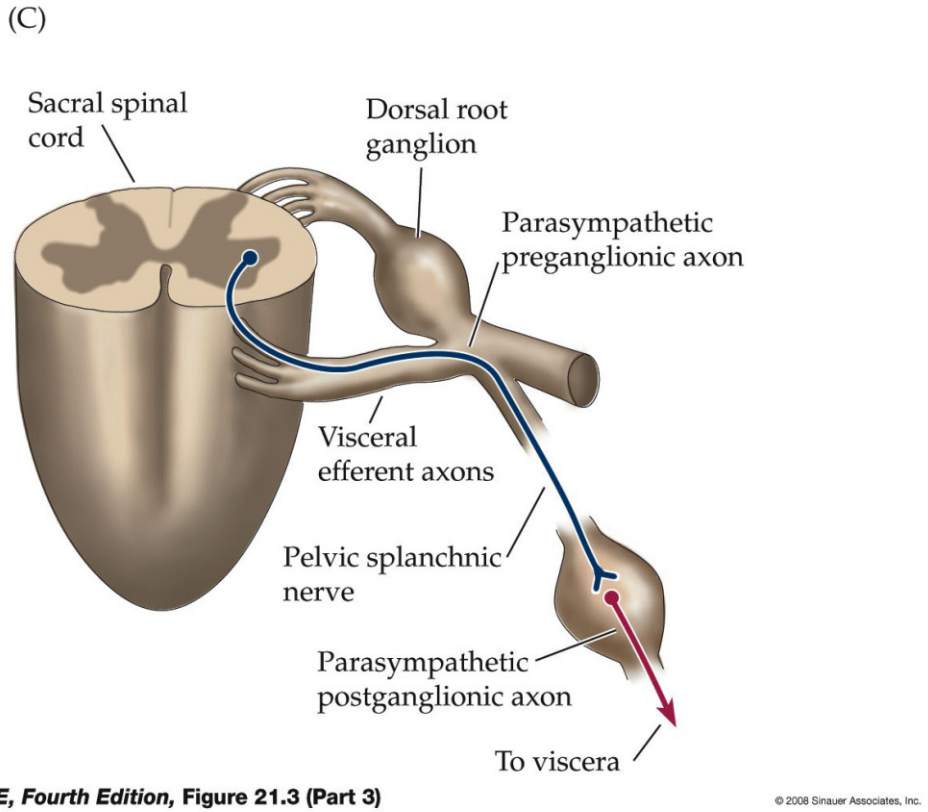


Other than the Cranial Nerves, where are CNS neurons of the parasympathetic system?

What organs do these spinal parasympathetic neurons control?

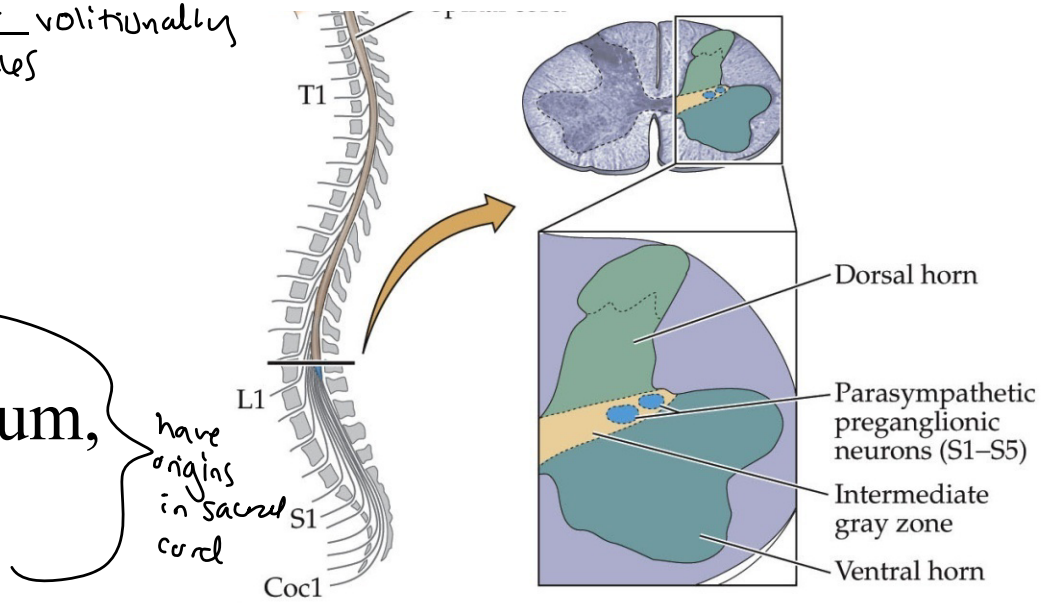
Sacral Parasympathetic --

Pre and Post Ganglionic Fibers



NEUROSCIENCE, Fourth Edition, Figure 21.3 (Part 3)

- Sacral Spinal Cord
  - Sacral "intermediolateral nucleus"
  - Are these LMNs? no doesn't volitionally control muscles
- Preganglionic to parasympathetic ganglia
  - Within Pelvis
  - Bladder, lower colon, rectum, reproductive system



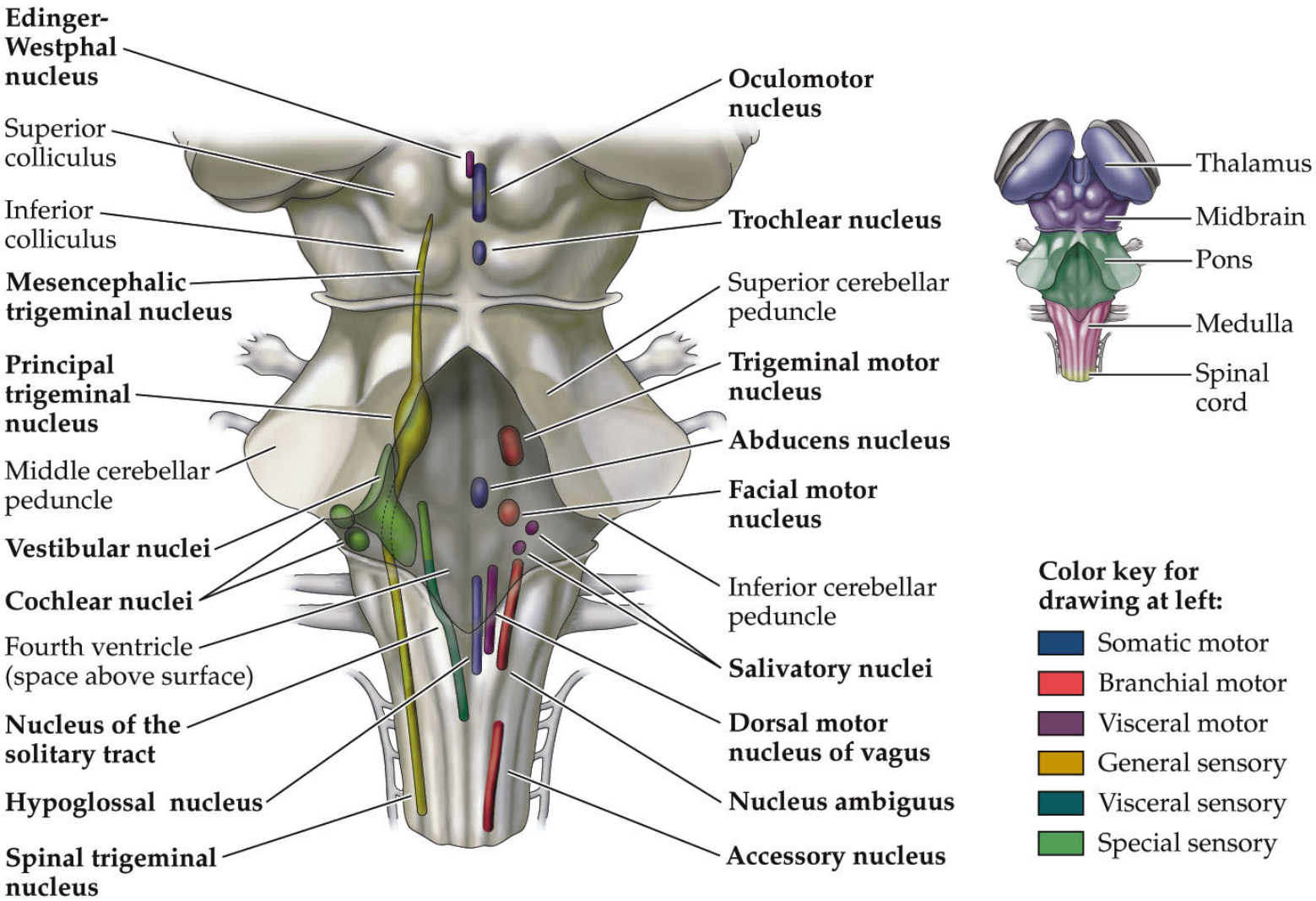
NEUROSCIENCE, Fourth Edition, Figure 21.3 (Part 4)

Which cranial nerves contain parasympathetic visceral motor fibers (GVE)?

What cranial nerve nuclei contain preganglionic neurons? Where are their parasympathetic ganglia and what do these neurons control?

Since the parasympathetic vagal neurons makes the small intestine contract, are these vagal neurons LMNs?

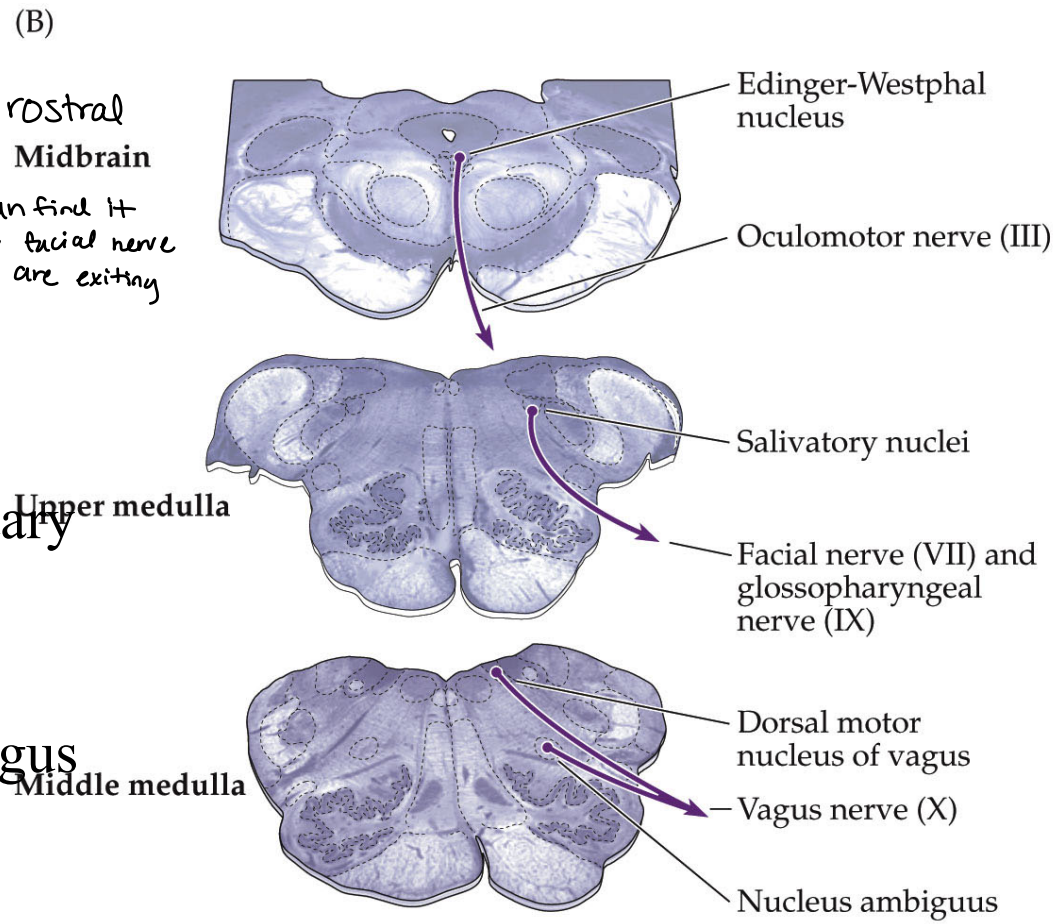
Visceral Motor Nerves (GVE)
General Visceral Efferent



***NEUROSCIENCE, Fourth Edition,* Appendix, Figure A8**

Visceral Motor Nuclei

- Oculomotor Nerve
  - Edinger Westphal Nucleus
  - Midbrain
- Facial Nerve
  - Superior Salivatory Nucleus → can find it where facial nerve fibers are exiting
  - Pons, Middle (not shown)
- Glossopharyngeal Nerve
  - Inferior Salivatory Nucleus
  - Medulla (rostral open, near solitary nucleus)
- Vagus
  - Dorsal Motor Nucleus of the Vagus
  - Caudal open medulla

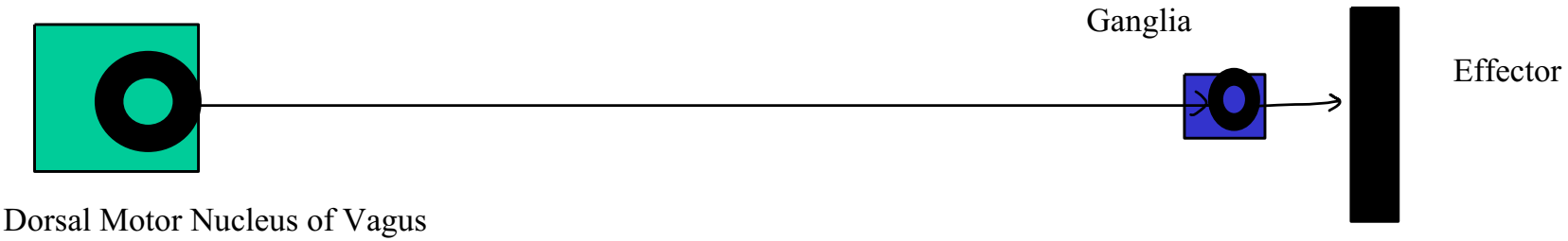


***NEUROSCIENCE, Fourth Edition,* Figure 21.3 (Part 2)**

nucleus ambiguous → projects to muscles of speech + swallowing (branchial motor)

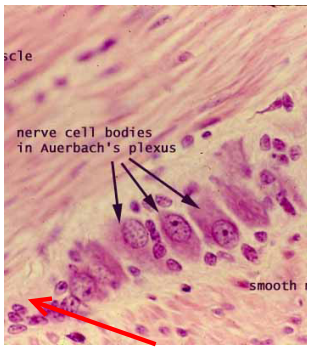
Vagus Nerve

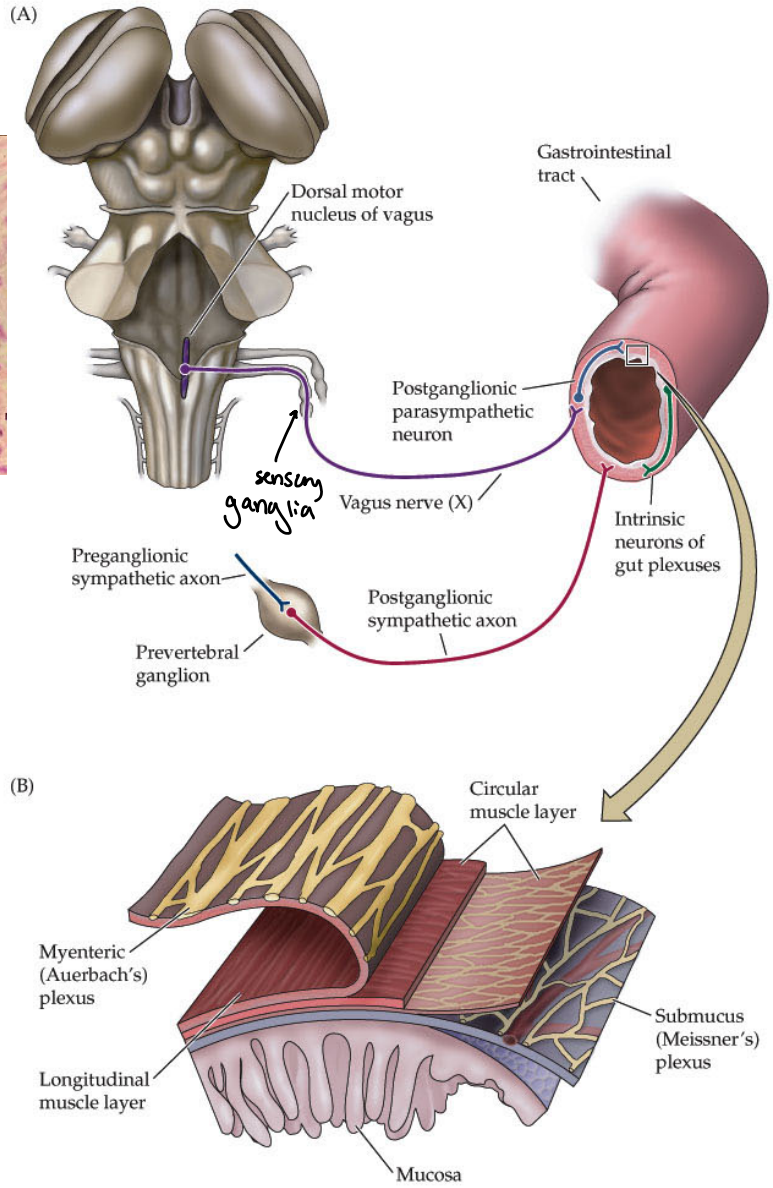
- Nucleus - Dorsal Motor Nucleus of Vagus
  → projects to ganglia not directly to muscles
- Motor Ganglia –Thoracic and abdominal parasympathetic ganglia
  - Parasympathetic Activation



Vagus Nerve Small Intestine Control

- Dorsal Motor Nucleus of the Vagus Nerve
  - Medulla
- Neurons make preganglionic fibers
  - project to thorax and abdomen
- Ganglia within organs
  - e.g. Auerbach's plexus in small intestine
  - Lone preganglionic axon
- Ganglia neurons to smooth muscle
  - Short postganglionic axon!



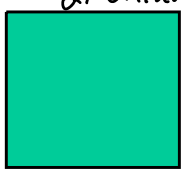


***NEUROSCIENCE, Fourth Edition,* Figure 21.4**

Oculomotor Nerve

- Nucleus - Edinger-Westphal (starts in)
- Motor Ganglia - Ciliary (projects to) ganglia - found on top of eye
- Function1 - Ciliary muscles (Lens accommodation)
- Function2 - Iris Muscles (pupil constriction)

- oculomotor nerve originates in edinger-westphal nucleus
- visceral sensory fibers project to motor ganglia called ciliary ganglia - found on top of eye
- the post ganglionic fibers project to
  1. iris muscles → contraction constricts pupils
  2. ciliary muscles → contraction makes lens more convex, resulting in closer focus



Edinger-Westphal

Ciliary Ganglia

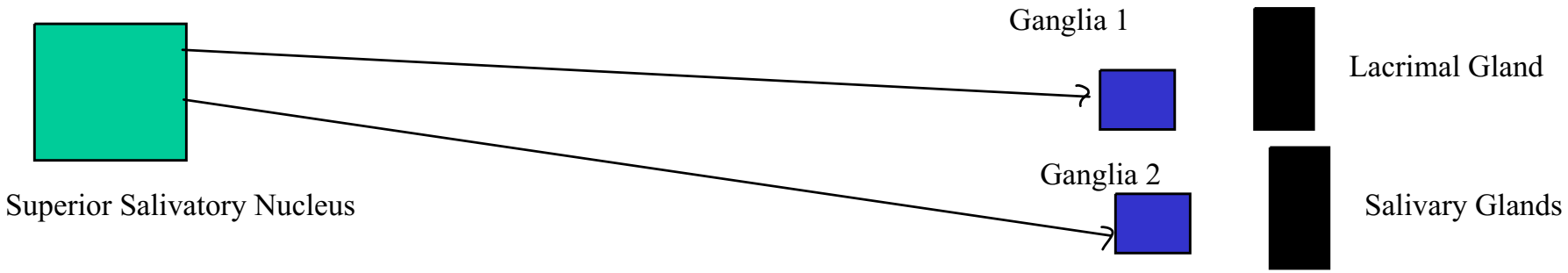
Ciliary Muscles

Iris Muscles

damage → pupils are dilated + trouble w/ near focus

Facial Nerve

- Nucleus - Superior Salivatory Nucleus
- Motor Ganglia 1 - Pterygopalatine Ganglia
  - Lacrimal Gland – Tear production
- Motor Ganglia 2 - Submandibular Ganglia
  - Sublingual and submandibular glands – Saliva production



Visceral Motor Function - Facial Nerve

- nucleus → superior salivatory nucleus
- facial nerve then projects to two motor ganglia
    1. pterygopalatine ganglia, which projects to the lacrimal glands (tear production)
    2. submandibular ganglia → projects to sublingual (→ under tongue) and submandibular glands (involved in saliva production)
- damage → results in dry eyes and dry mouth (anterior)

Glossopharyngeal Nerve

- nucleus - inferior salivatory nucleus
- projects to otic motor ganglia (inside parotid gland), which then projects to parotid gland (involved in salivation)

Glossopharyngeal Nerve

- Nucleus - Inferior Salivatory Nucleus
- Motor Ganglia - Otic
  - Parotid Gland - Salivation

Inferior Salivatory Nucleus

Otic Ganglia

Effector

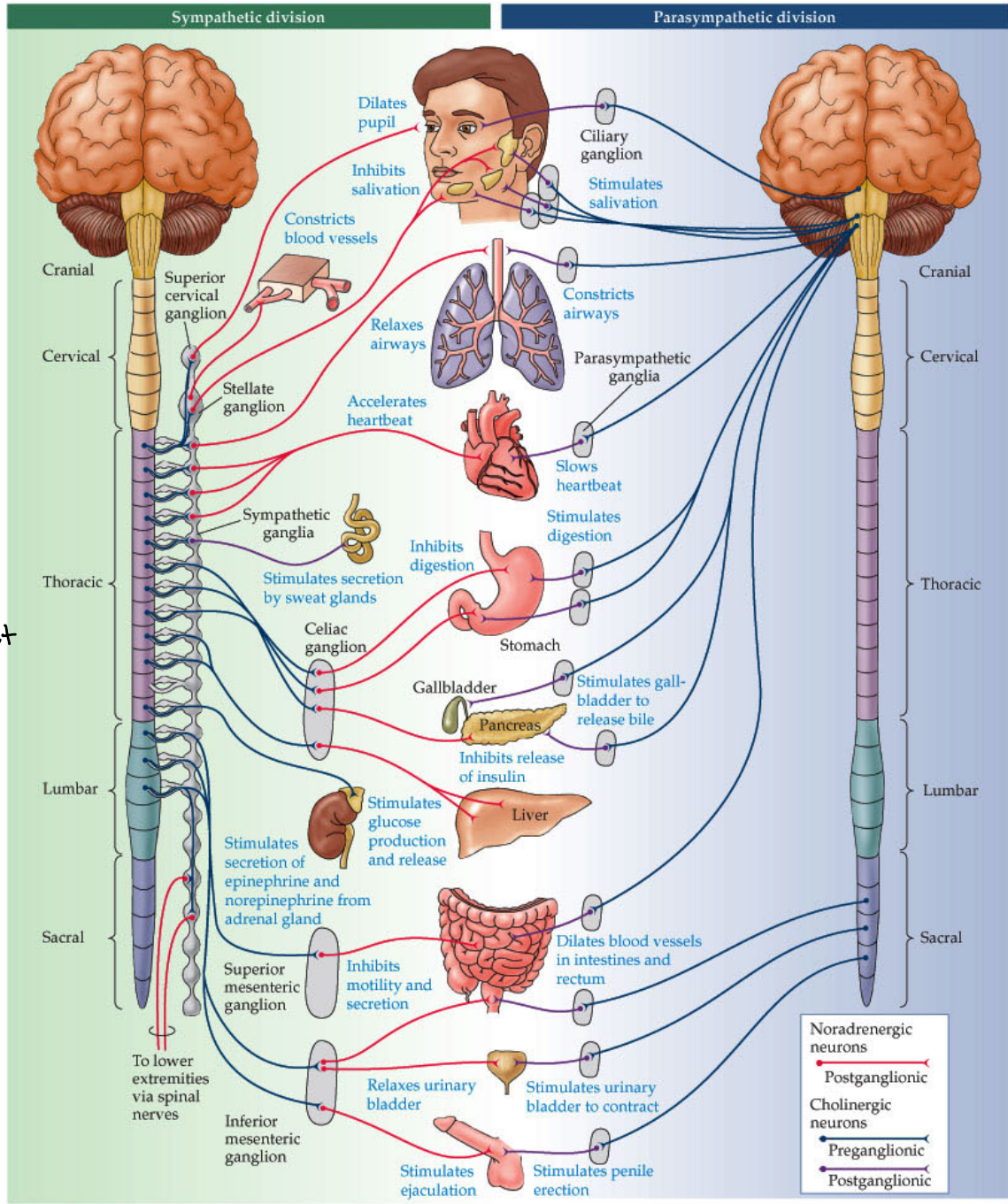
Parotid Gland

What is ANS homeostasis?
What is the main effect (increase or decrease activity) of sympathetic and parasympathetic activation on each of the following organ systems?

Homeostasis

Autonomic nervous system maintains homeostasis

- Homeostasis
  - Balancing visceral function with environmental demands
- Sympathetic → activated in fight / flight (use energy)
  - Increased blood flow, respiration, etc
  - Fight or Flight, Use Energy
- Parasympathetic
  - The opposite effect, mostly
  - Rest & Relaxation, Store Energy



NEUROSCIENCE, Fourth Edition, Figure 21.1

Late One Stormy Night

Functions of the ANS

autonomic nervous system

- Heart Rate
  - Sympathetic Parasympathetic
- Cardiac Artery Diameter
  - Sympathetic Parasympathetic
- Skin Artery Diameter
  - Sympathetic Parasympathetic
- Bronchi Diameter
  - Sympathetic Parasympathetic __

More Functions of the ANS

- Pupil Diameter
  - Sympathetic ?? Parasympathetic ??
- Sweat Gland Activity
  - Sympathetic ?? Parasympathetic __
- Piloerector Muscles
  - Sympathetic ?? Parasympathetic __
- Bladder Tone
  - Sympathetic ?? Parasympathetic __

Activate Sympathetic

- heart rate increases
- cardiac artery diameter increases
- skin artery diameter decreases
- bronchi diameter increases
- increased pupil diameter
- increased sweat gland activity
- pilo erector muscle (hair stand on end → goosebumps) activated
- bladder tone decreases
- saliva/mucous secretion decreases
- muscle activity in gut decreases (constipation)

Parasympathetic Activation

Still More Functions of the ANS

- Saliva and Mucous Secretion
  - Sympathetic ?? Parasympathetic ??
- Muscle activity in the Gut
  - Sympathetic ?? Parasympathetic ??

How does visceral sensory information enter the CNS.

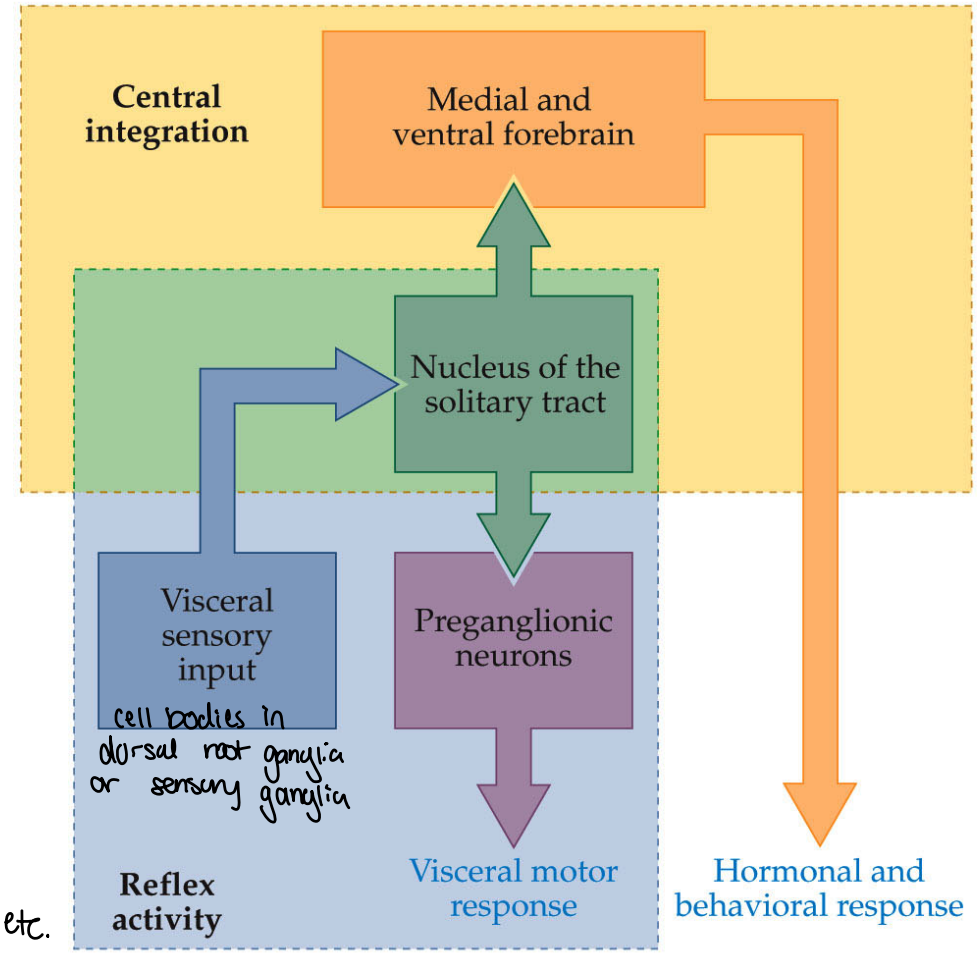
How does this produce autonomic regulation of cardiac function?

How is taste sensation transmitted to the cortex?

Visceral Sensory Fibers --General and Special Visceral Afferents (GVA and SVA)

taste + olfaction

- Sensory Receptors in Visceral Organs (GVA)
  - Pressure, Chemical, pH Temperature, Pain
- Arrive (sensations) via spinal and cranial nerves
  - Visceral Sensory Ganglia
- Synapse in Nucleus of Solitary Tract
  - Visceral motor reflexes



NEUROSCIENCE, Fourth Edition, Figure 21.5

fibers travel through gracilus, cuneatus, ALF, etc. to get to solitary tract. MLF, ALF fibers come off and go into the solitary tract.

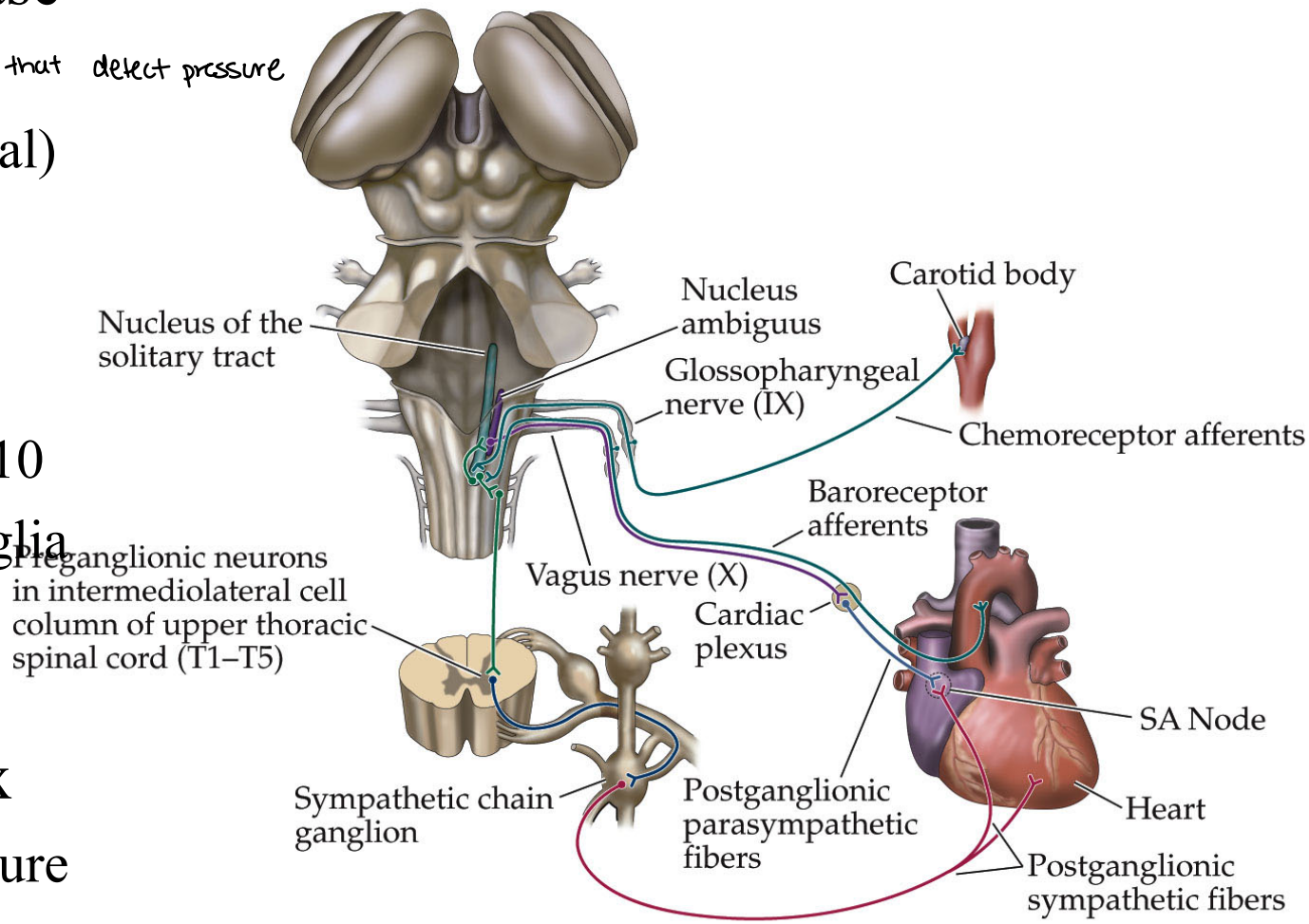
- nucleus of solitary tract projects to preganglionic neurons resulting in visceral motor reflexes and to

the medial/ventral forebrain (medial prefrontal/singulate cortex). Forebrain projections to hormonal releases

· solitary nucleus → involved in visceral motor reflexes + higher level control

Cardiac Visceral Control

- Blood Pressure Increase detected by receptors that detect pressure
  - Carotid Body (chemical) and Baroreceptors (pressure)
- Visceral Sensory
  - Cranial Nerves 9 and 10
  - Visceral Sensory Ganglia
  - Synapse in Solitary Nucleus
- Visceral Motor Reflex
  - Increased Blood Pressure
  - Sensory input to vagus motor output
  - Slow heart rate



NEUROSCIENCE, Fourth Edition, Figure 21.8

blood pressure goes up (signal sent to solitary nucleus) → slow heart rate
neuron in solitary nucleus projects to dorsal motor nucleus of the vagus.
Neuron travels via vagus nerve from dorsal motor nucleus of the vagus

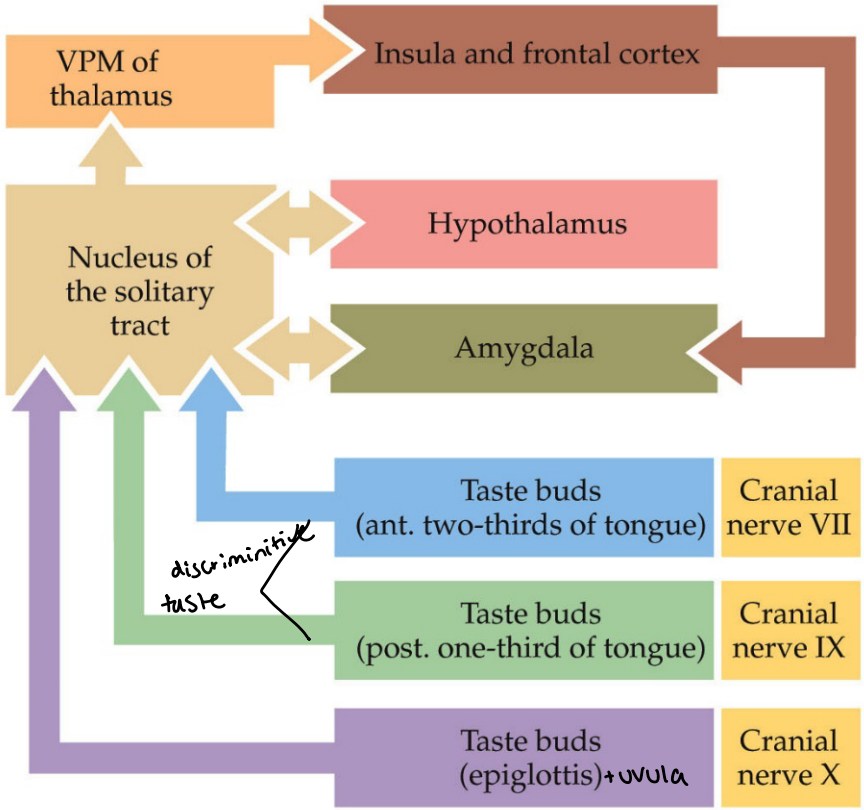
to end in cardiac plexus (motor ganglia) to release neurotransmitters to slow the heart

to increase heart rate → sensory input sent to solitary nucleus from carotid body via CN 9. integrated circuits in solitary nucleus have circuits that go down spinal cord to lateral horn, to activate sympathetic system to increase heart rate

Taste Special Visceral (SVA)

taste buds transduce chem stim to action potentials

- Cranial Nerves 7-9-10
  - Facial – anterior 2/3 of tongue (B)
  - Glossopharyngeal Posterior 1/3
  - Vagus – epiglottis and uvula
- Solitary Nucleus
- VPM
- Insula and <u>medial and ventral</u> frontal cortex



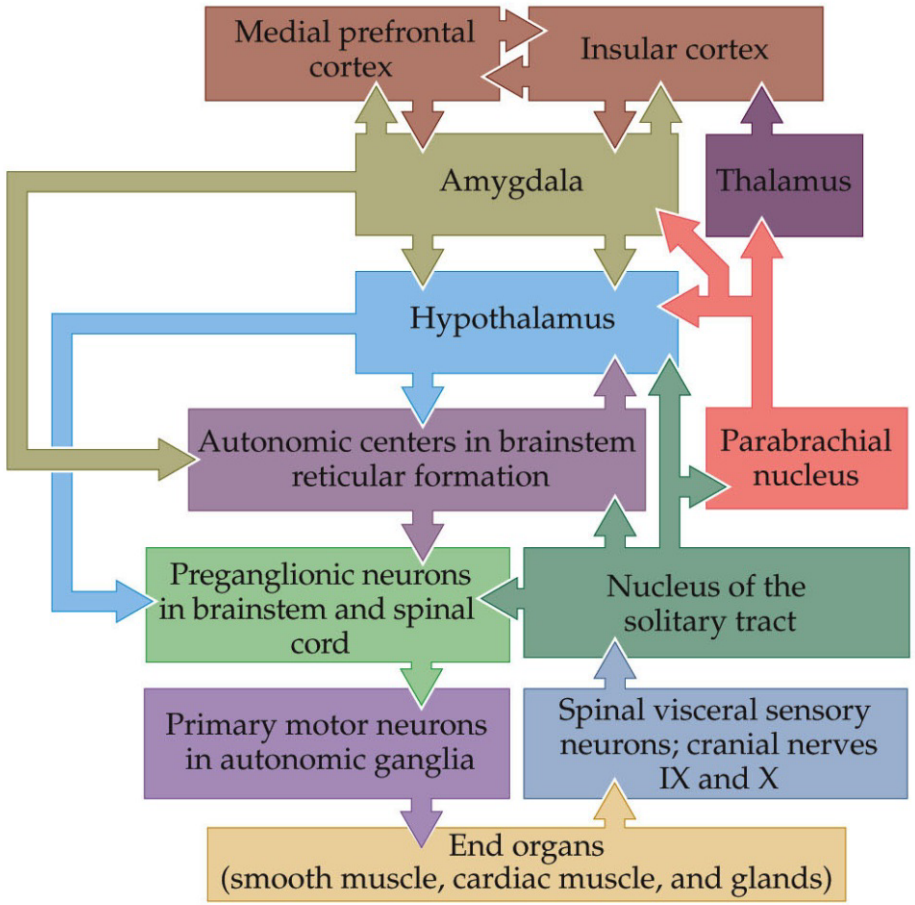
NEUROSCIENCE, Fourth Edition, Figure 15.15 (Part 3)

What brainstem and forebrain regions of the CNS control the preganglionic ANS neurons?

Why does your heart rate increase when you see a bear (or a scary movie)?

Hierarchy of Autonomic Control

- Afferent Fibers
  - Mechanical, Chemical, Thermal and Pain receptors to solitary nucleus
  - Solitary nucleus to visceral motor nuclei and reticular nuclei
    - Produce Autonomic reflexes
- Hypothalamus
  - Controls Reticular Nuclei
  - Hypothalamospinal/bulbar tract
    - And by control of pituitary gland hormones
  - Maintains Homeostasis
    - Balance of Parasympathetic and Sympathetic
- Limbic System
  - Cingulate Cortex (a.k.a "medial prefrontal cortex"), Insula, Amygdala
  - Controls Hypothalamus
  - See a Bear, Think "IT'S A BEAR!" ... and Heart Rate Increases
    - Similar effect during scary movies

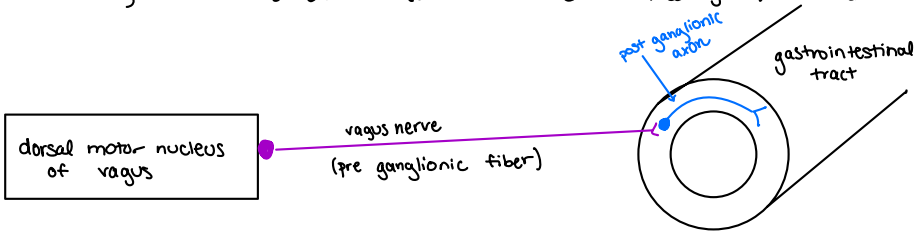


***NEUROSCIENCE, Fourth Edition,* Figure 21.7**

reflex

Vagus Nerve - Visceral Motor (part of enteric nervous system)

- Nucleus - dorsal motor nucleus of vagus (in medulla)
- motor ganglia — thoracic and abdominal parasympathetic activation
- Auerbach's plexus (myenteric) - organization of neurons in gut that controls motor aspects of gut function such as peristalsis
- Meissner's plexus (submucous) — located beneath mucus membrane of the gut, involved in chemical monitoring / gland secretion



Oculomotor Nerve

① cell bodies originate in edinger westphal nucleus

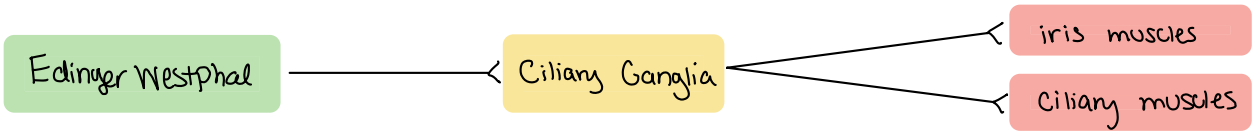
② projects to ciliary motor ganglia (found on top of eye)

③ post ganglionic fibers project to:

a) iris muscles ⟶ contraction constricts pupils

b) Ciliary muscles ⟶ contraction makes lens more convex resulting in a closer focus

· Damage – results in dilated pupils and trouble with near focus



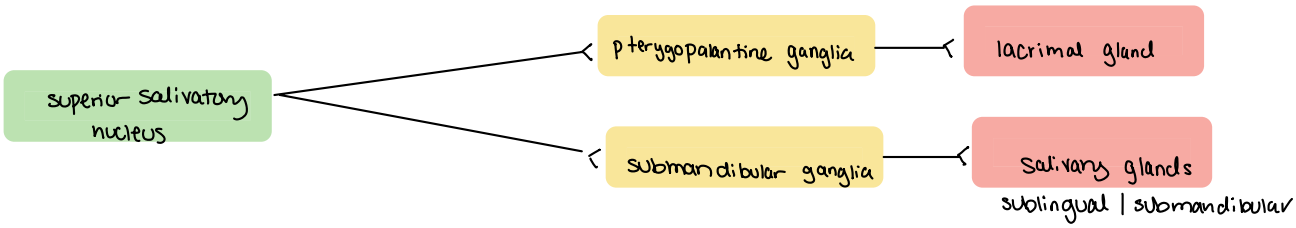
Facial Nerve

① fibers originate in superior salivatory nucleus

② preganglionic fibers project to:

a) pterygopalatine ganglia ⟶ which projects to lacrimal glands (tear production)

b) submandibular ganglia ⟶ projects to sublingual (under tongue) and submandibular glands (involved in saliva production)

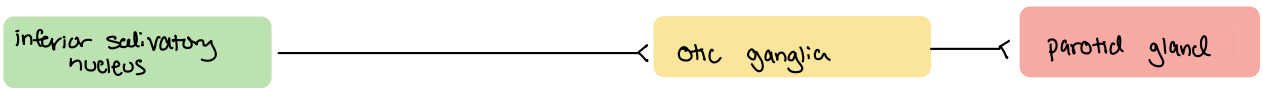


Glossopharyngeal Nerve

① cell bodies located in inferior salivatory nucleus

② preganglionic fibers project to otic motor ganglia

③ post-ganglionic fibers project to parotid gland (salivation)



Visceral Motor System

- LMNs of visceral motor system are located outside the CNS
  - Sympathetic → located in autonomic ganglia near the spinal cord
  - Parasympathetic → located in neural plexus (network of intersecting nerves) in or near target organ
- Synapses between visceral motor neurons are less differentiated w/ more branches and lots of synaptic terminal
  → neurotransmitters released by visceral motor terminals diffuse hundreds of um before binding to postsynaptic receptors

Sympathetic Nervous System

- preganglionic neurons located in intermediolateral cell column in the lateral horn of the thoracic / upper lumbar regions
  - upper / middle thoracic → sympathetic control of head + thorax
  - lower thoracic / upper lumbar → sympathetic control of abdominal / pelvic organs
- preganglionic neurons project to paravertebral + sympathetic chain ganglia
- neurons in chain or paravertebral ganglia directly innervate smooth muscles, cardiac muscles, and glands

- preganglionic cells release acetylcholine, which binds to nicotinic receptors on cell bodies in the ganglia
- post ganglionic fibers release norepinephrine which binds to muscarinic receptors in muscles / glands

Parasympathetic Nervous System

- preganglionic cells are located in sacral part of the spinal cord and in brainstem nuclei

brainstem
- edinger-westphal nucleus → oculomotor nerve, ciliary ganglia, pupil constriction, and eye focusing (in midbrain)
- superior salivatory nucleus (pons)
- inferior salivatory nucleus (medulla)
- nucleus ambiguous → provides source of cardio inhibitory innervation to cardiac ganglia via the vagus nerve
- dorsal motor nucleus of the vagus

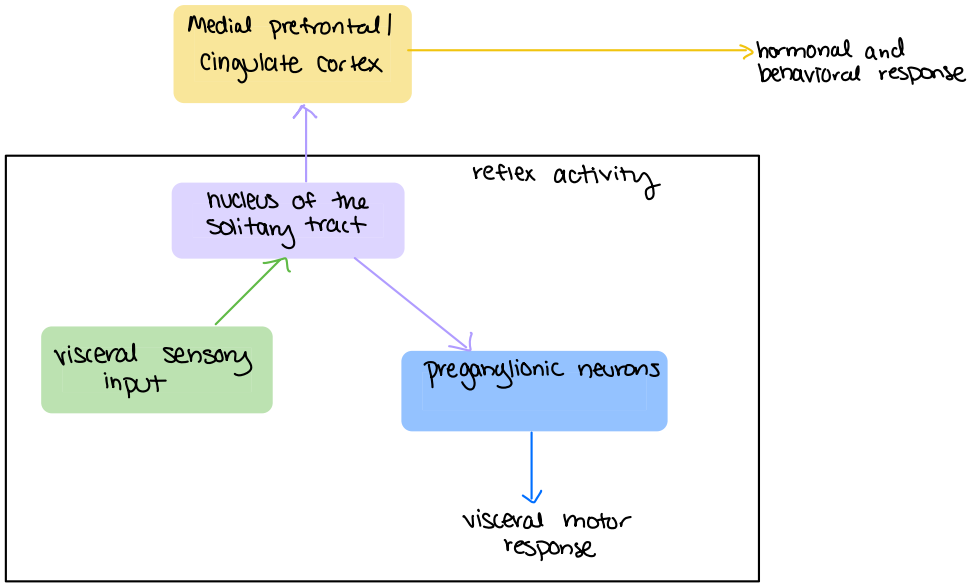
- sacral preganglionic neurons

Visceral Sensory Information

General Visceral Afferents:

- sensory receptors in visceral organs (pressure, chemical (pH), temperature, pain)
- arrive via spinal + cranial nerves w/ cell bodies in visceral sensory ganglia
  - visceral sensory ganglia in spinal cord are cells in dorsal root ganglia coming from the viscera
  - cranial nerves have visceral sensory ganglia, primarily from vagus + glossopharyngeal nerves
- synapse in nucleus of the solitary tract ⟶ spinal fibers travel through dorsal columns or ALF to solitary tract

Visceral Motor Reflexes



Cardiac Visceral Control

- Two types of receptors regulate cardiovascular function
  - baroreceptors (type of mechanoreceptor) ⟶ detect pressure in arteries/heart
  - chemoreceptors (located in carotid body) ⟶ detect levels of oxygen + CO_2

To slow heartrate (lowers blood pressure) ⟶ parasympathetic system

- receptors detect increase in blood pressure
- sensory afferents travel via vagus + glossopharyngeal nerves and synapse in nucleus of solitary tract
- projects from nucleus of solitary tract to dorsal motor nucleus of vagus
- from motor nucleus of vagus, neurons project via vagus nerve and synapse in cardiac plexus (visceral motor ganglia)
- neurons in cardiac plexus then release neurotransmiters to slow the heart

To increase heart rate (raise blood pressure) ⟶ sympathetic activation

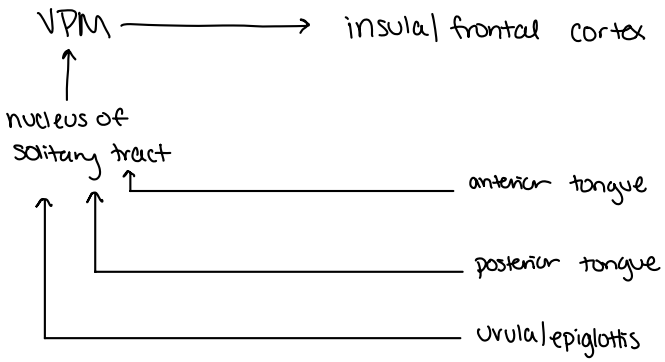
- integrated circuits in solitary nucleus project down to spinal cord (lateral horn)
- which activates sympathetic system

Special Visceral Afferents (SVA) – Taste

Cranial Nerves transmit sensory information from taste buds

- Facial Nerve – taste from anterior 2/3 of tongue
- Glossopharyngeal Nerve – posterior 1/3
- Vagus Nerve – epiglottis and uvula

- Cranial nerves synapse in solitary nucleus
- solitary nucleus to VPM of thalamus
- thalamus to insula and frontal cortex



Hierarchy of Autonomic Control

Hypothalamus

- controls reticular nuclei
- integrates higher order stimuli to better control autonomic nervous system
- helps maintain homeostasis → balance of parasympathetic and sympathetic
- hypothalamus projects to lateral horn → hypothalamospinal tract and brainstem → hypothalamobulbar tract
- solitary nucleus projects to hypothalamus

Limbic System

- cingulate cortex (medial prefrontal cortex), insula, amygdala
- controls hypothalamus