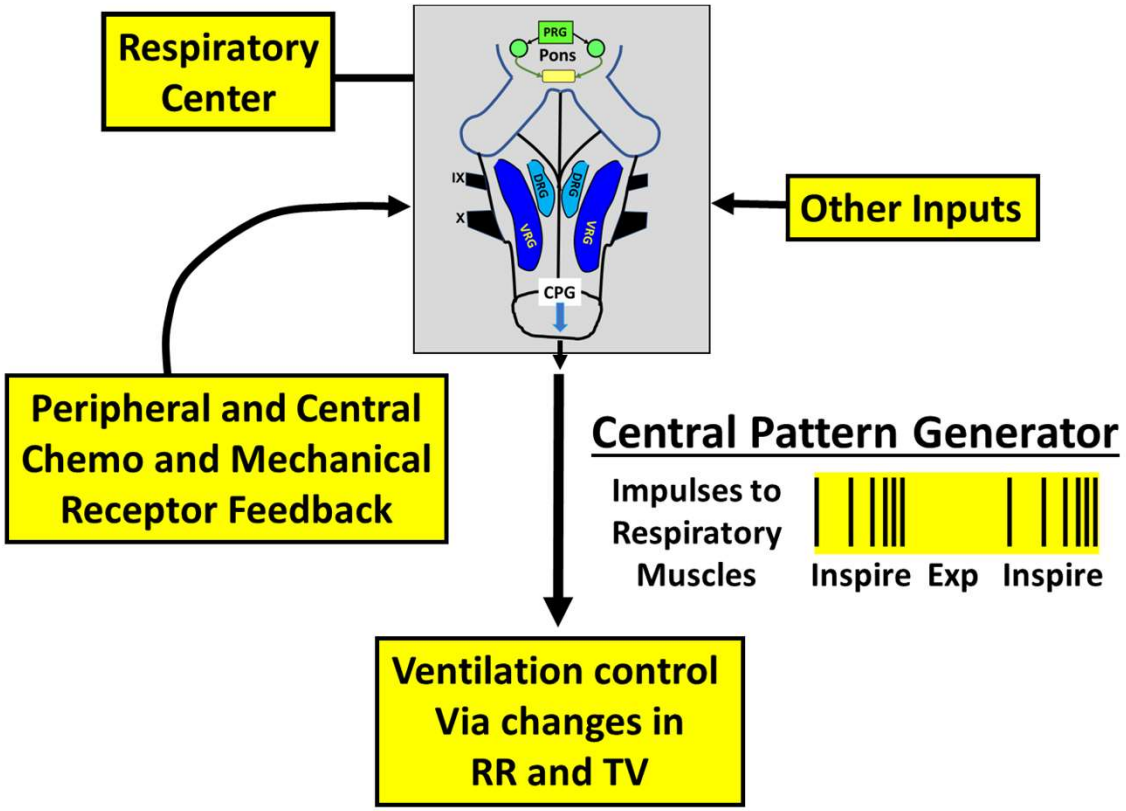
Lecture 43
Respiratory Controls and Reflexes



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Brainstem Respiratory Related Neurons (RRN)

Brain Stem
- **Pons**
- **Medulla**

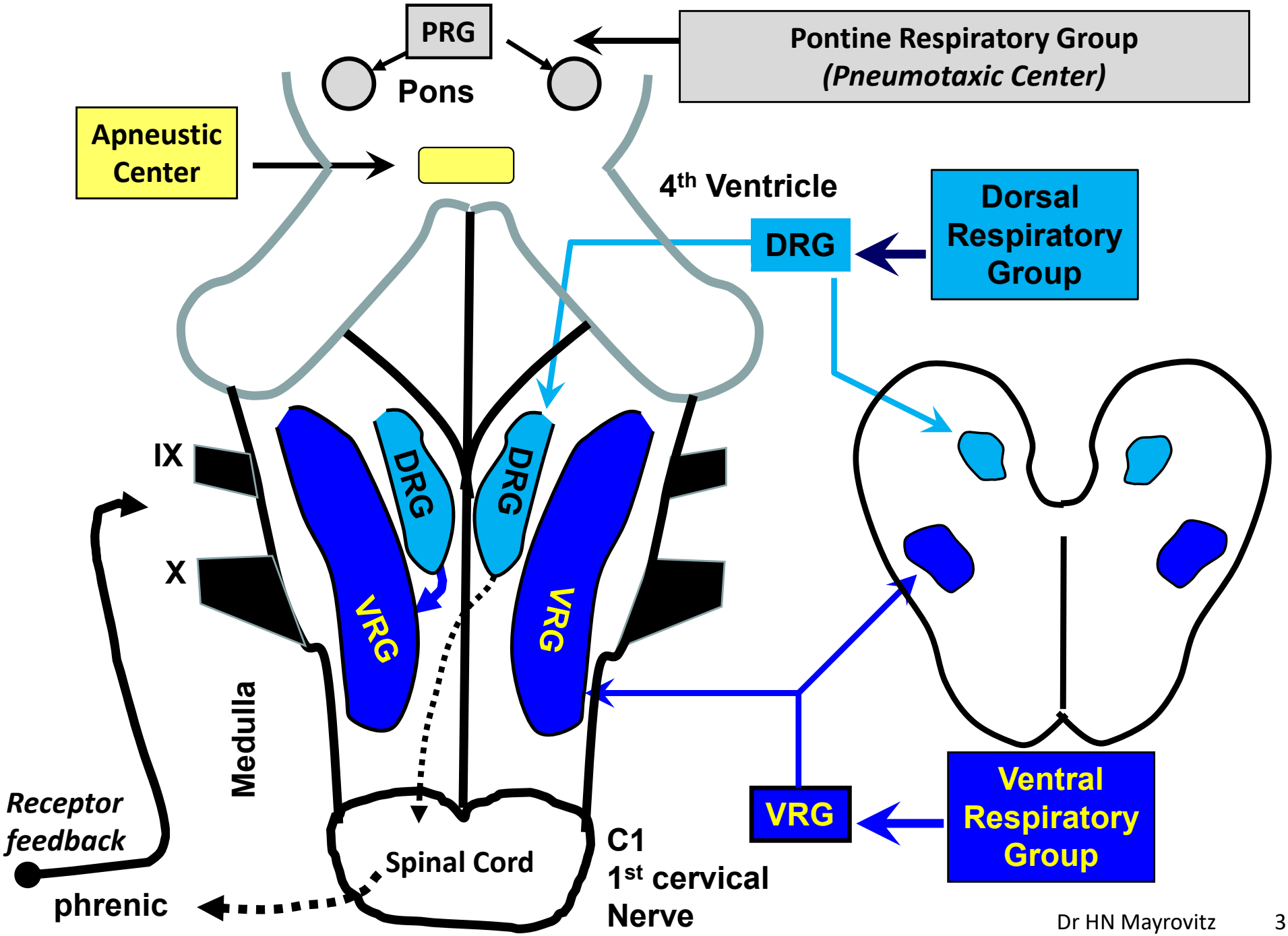
Respiratory Related Neurons (RRN)
- **Inspiratory → peak activity during inspiration**
- **Expiratory → peak activity during expiration**

Interneurons → Local networks
Premotor neurons → innervate motor neurons
Motor neurons → innervate respiratory muscles

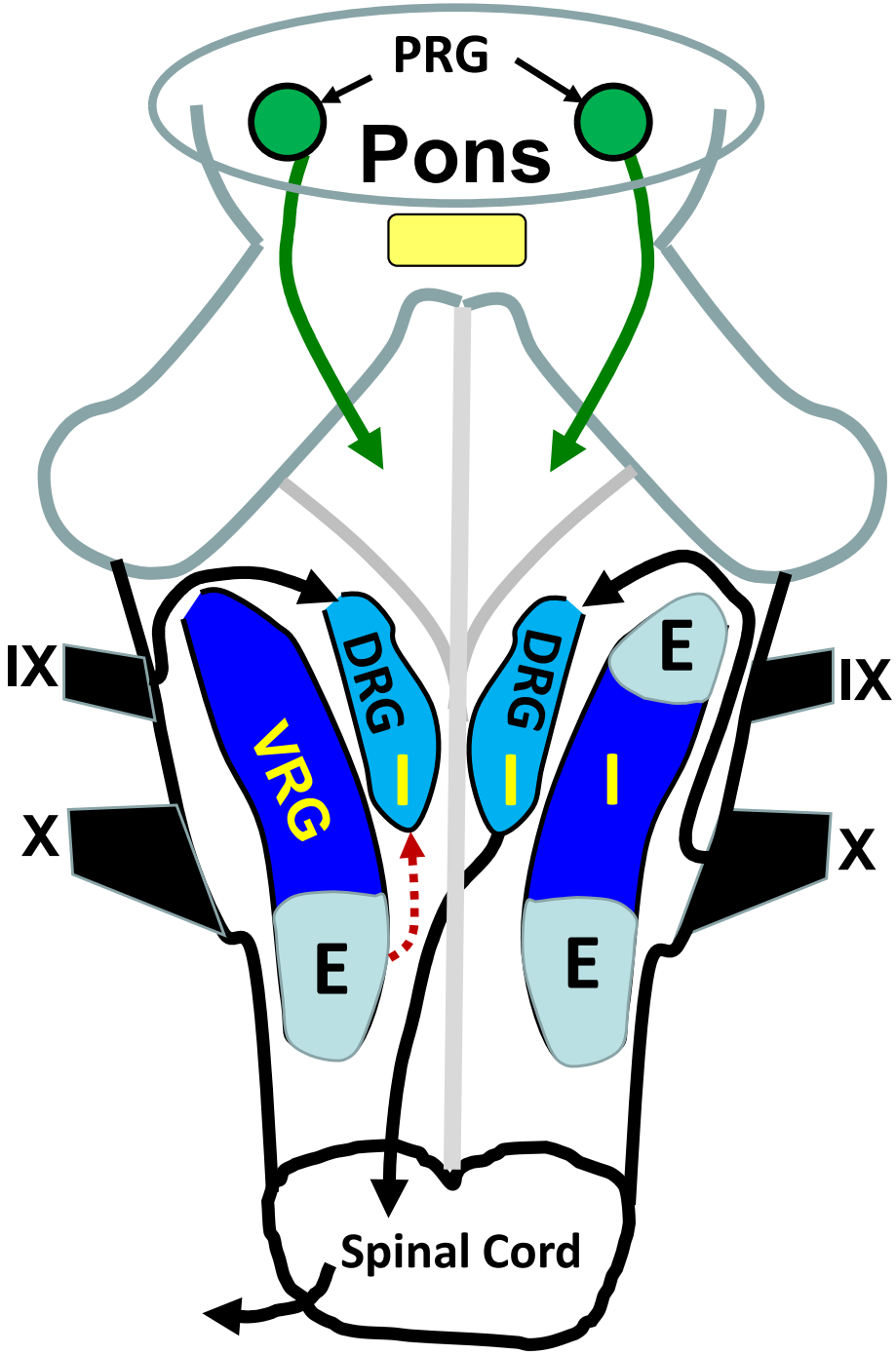
Medullary Cell Groups
- **Dorsal Respiratory Group (DRG) → Inspiration → phrenic n. → diaphragm**
- **Ventral Respiratory Group (VRG) → Forced expiration and Inspiration**

Pontine Cell Groups (PRG)
- **Pneumotaxic Center → upper pons**
- **Apneustic Center → widely distributed cell groups in lower pons**

Respiratory Cell Groups



Pontine Respiratory Group (PRG)



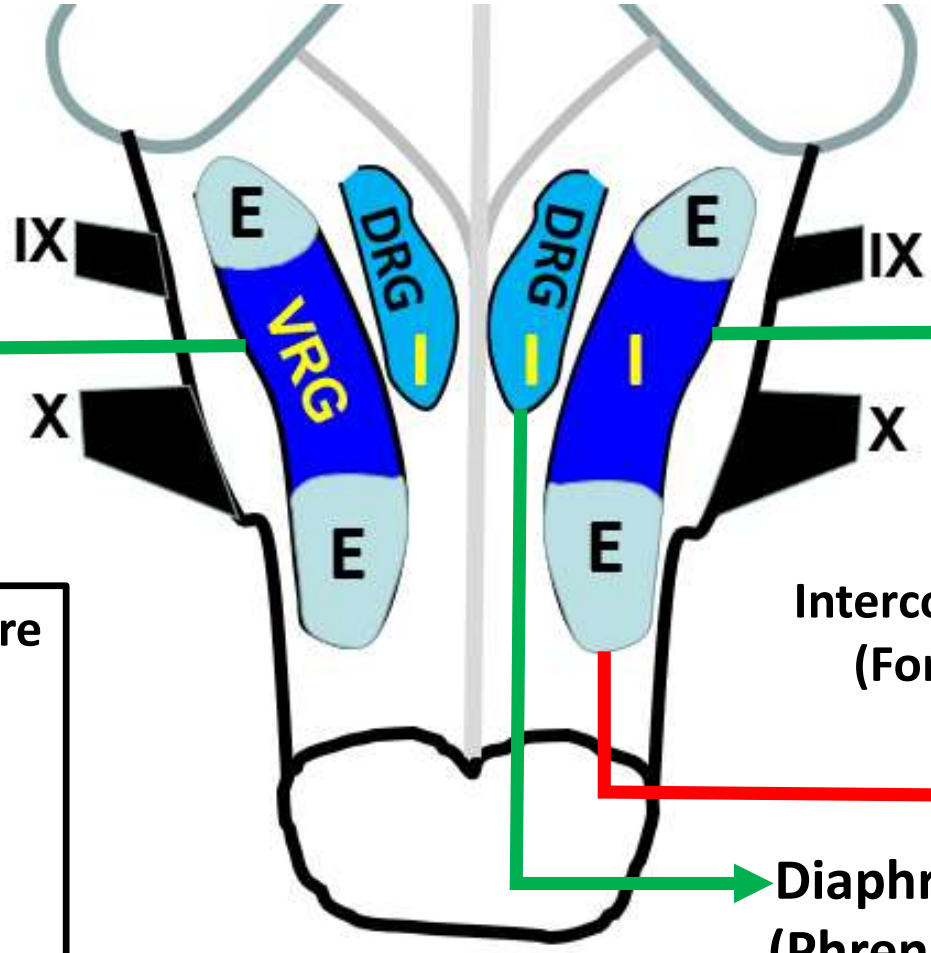
Pontine Respiratory Group
(Pneumotaxic Center)

- In upper pons
- Some neurons active during inspiration and expiration
- Important role in switching off limiting inspiration duration
- If damage leads to apneusis: prolonged inspiratory spasms with short intervals of expiration
- Also fine-tunes breathing based on afferent receptor feedback

Medullary Cell Groups: Motor Outputs

I=Active during inspiration
E=Active during expirations

Inspiration
Expiration

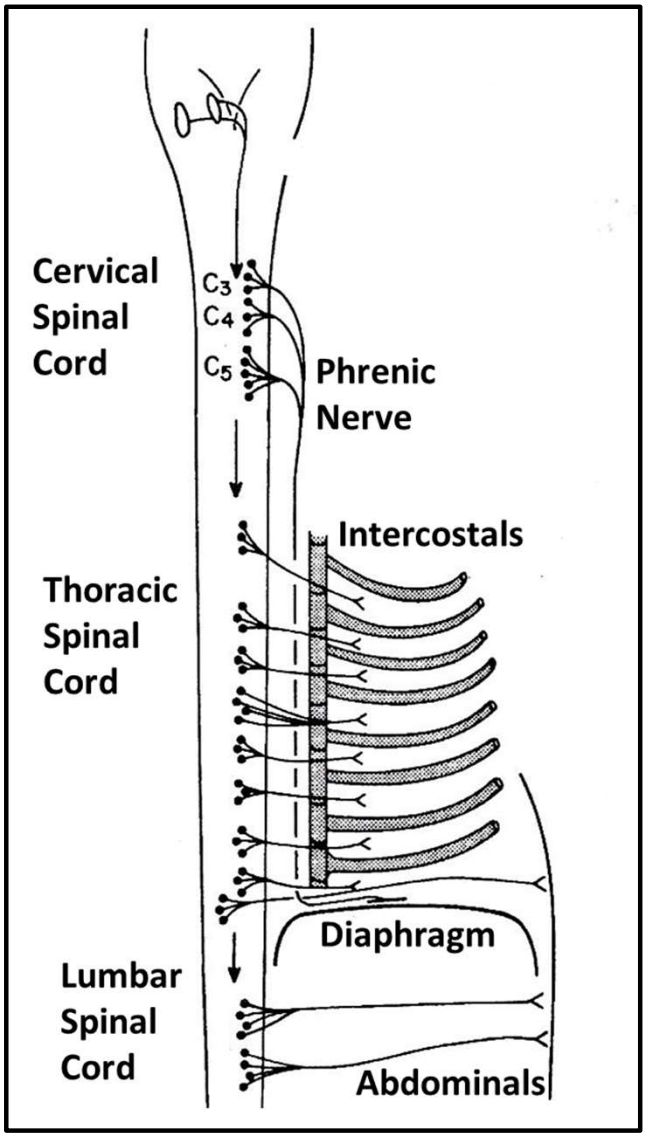


- Nostrils flare
- Laryngeal opening dilates
- Pharynx
- Other

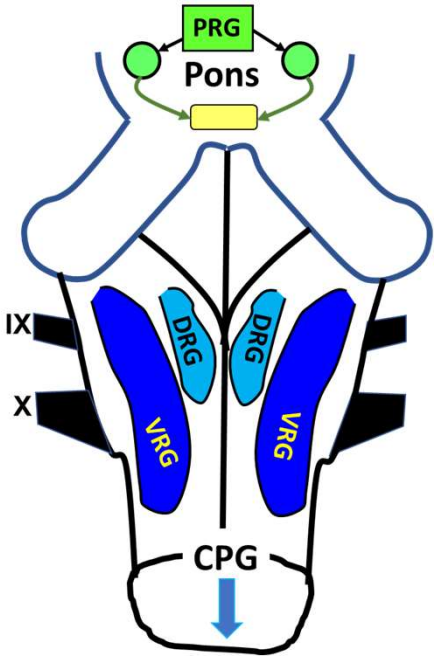
Intercostal m.
(Forced)

Diaphragm
(Phrenic n.)

Intercostal m.
Abdominal m.
(Forced)



Respiratory Center Actions: Summary



Pneumotaxic Center (PRG)

Inhibits apneustic output
Switches off Inspiration

Apneustic Center

Pons

Maintenance of signal
Prolongs inspiration

Receptor Feedback Via IX & X

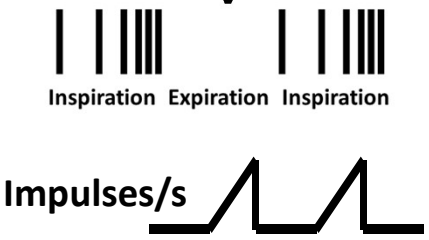
Inspiratory Center DRG

NTS

Expiratory Center VRG

Medulla

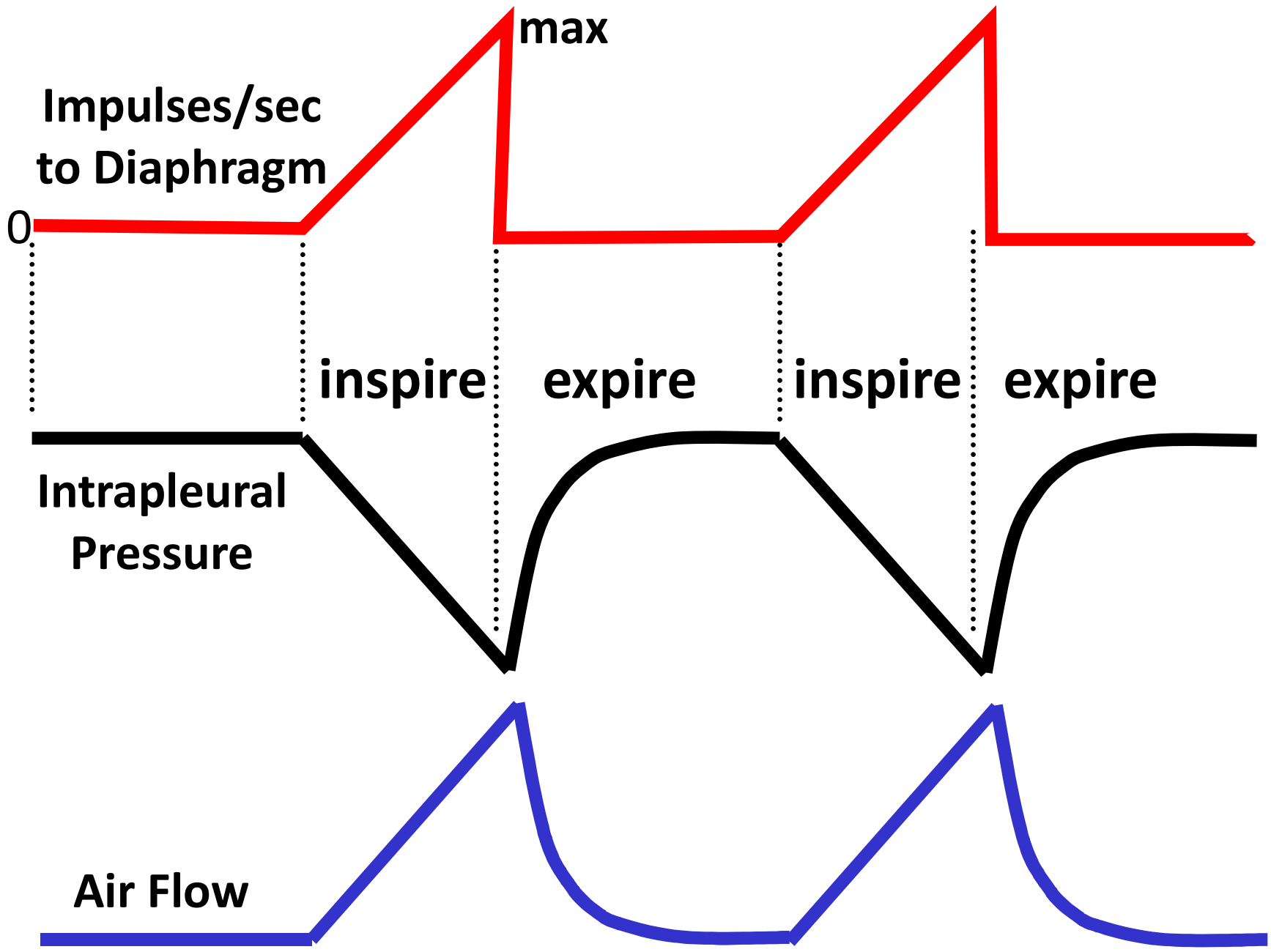
To inspiratory muscles



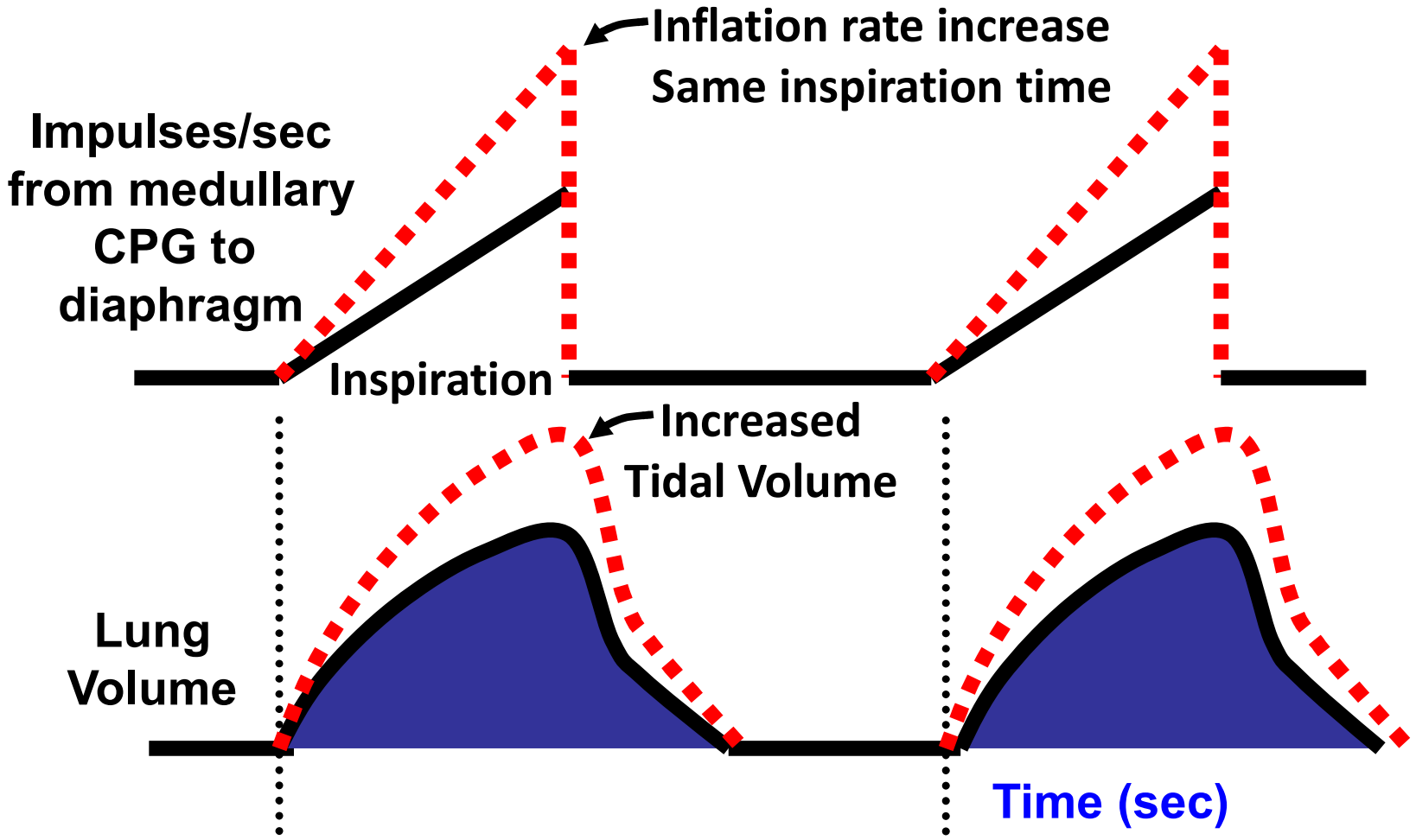
Basic rhythm is generated in medulla
(Central Pattern Generator)
CPG → Cause is unknown

NTS = Nucleus Tractus Solatarius
CPG = central pattern generator
VRG = ventral respiratory group
DRG = dorsal respiratory group
PRG = pontine respiratory group

Central Pattern Generator Drive inspiration

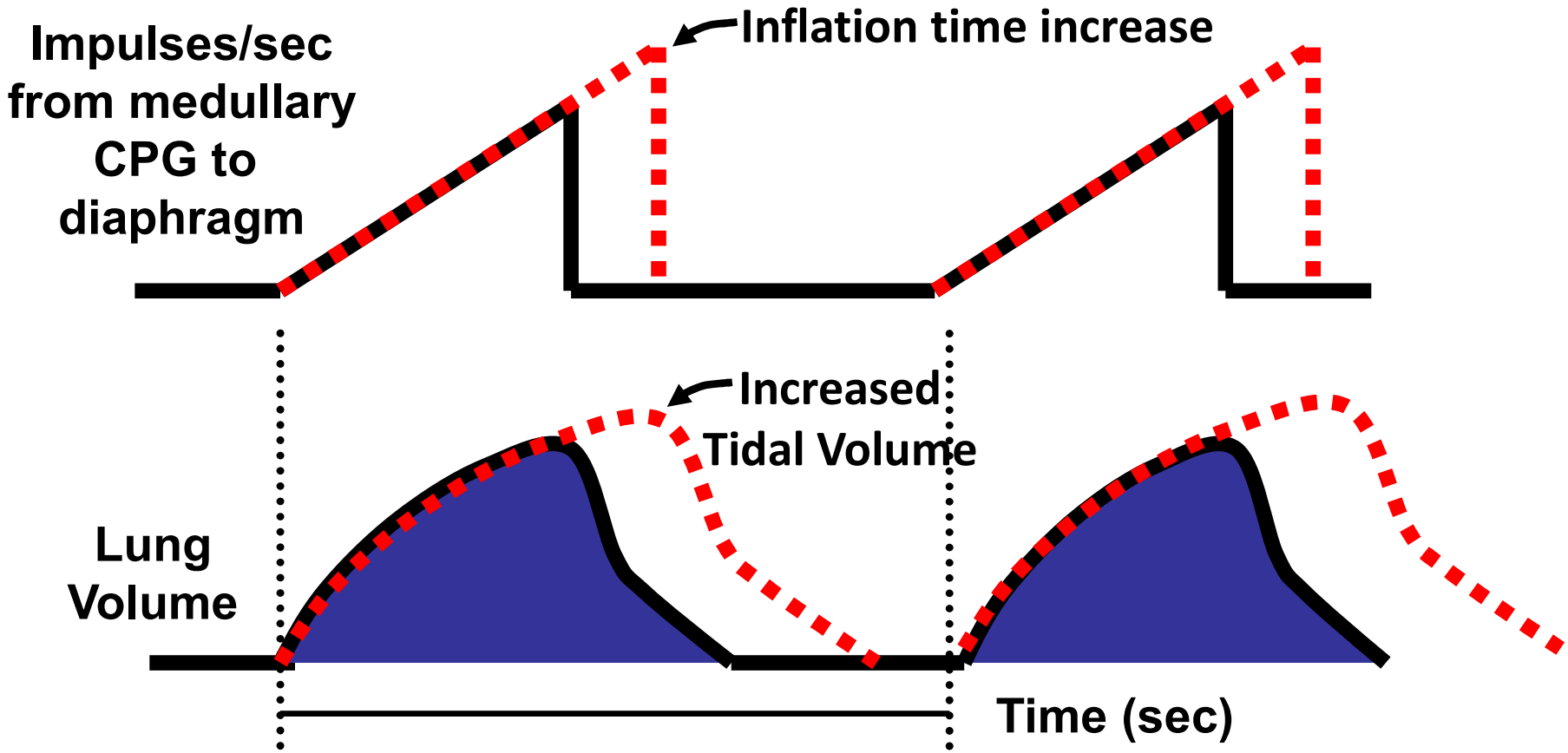


Impulse Intensity Modulates Ventilation



- *Afferent feedback from mechano- and chemo receptors*
- *Actions of pneumotaxic center neural outflow to medullary centers*
- *Inputs from higher centers*

Impulse Intensity Modulates Ventilation



Duration lengthened if impulses from PRG to DRG are delayed so ……..

Inspiration time lengthened → TV increased.

OPPOSITE if PRG impulses occur sooner or with greater intensity

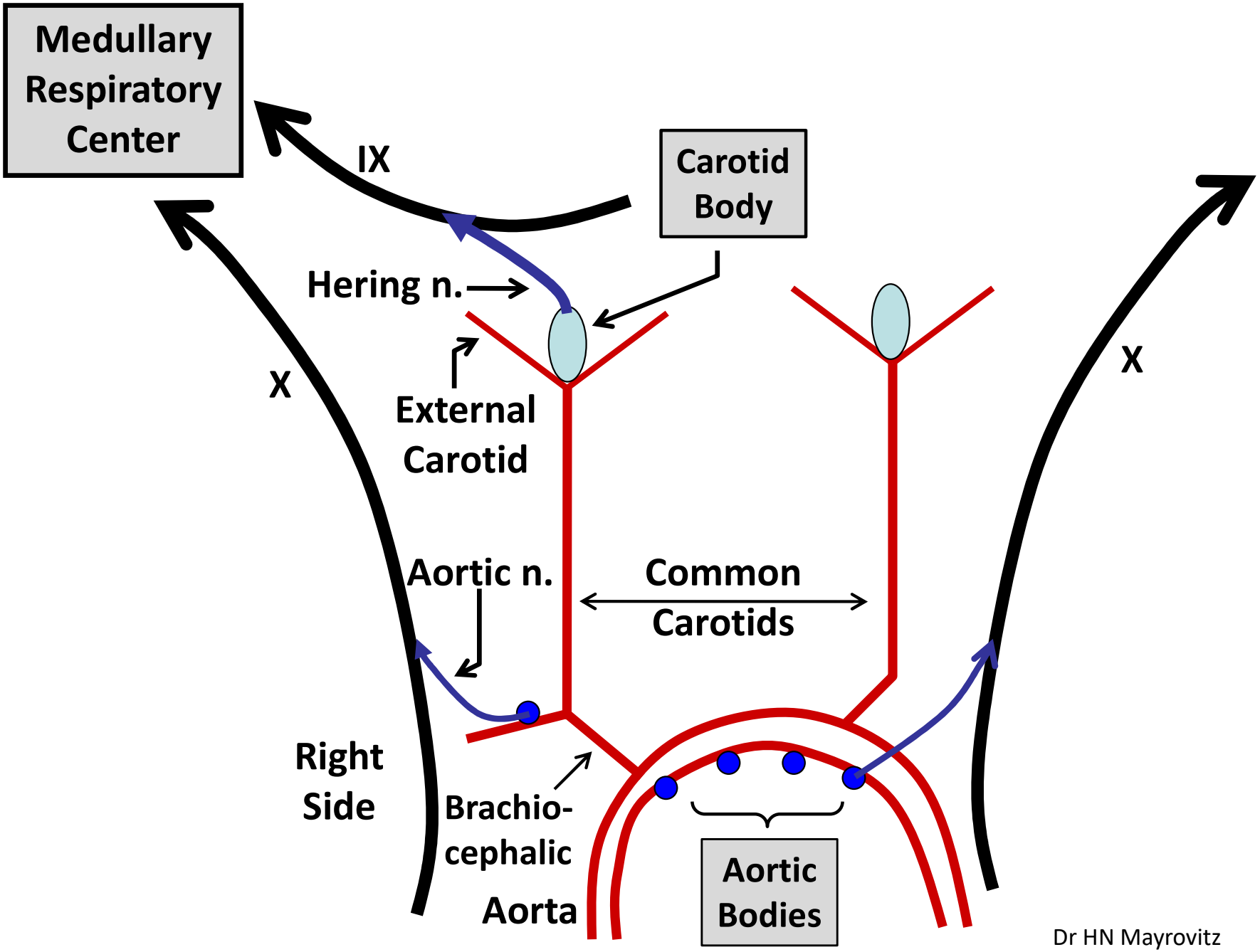
Chemical Control

Peripheral Chemoreceptors

- Carotid Bodies
- Aortic Bodies

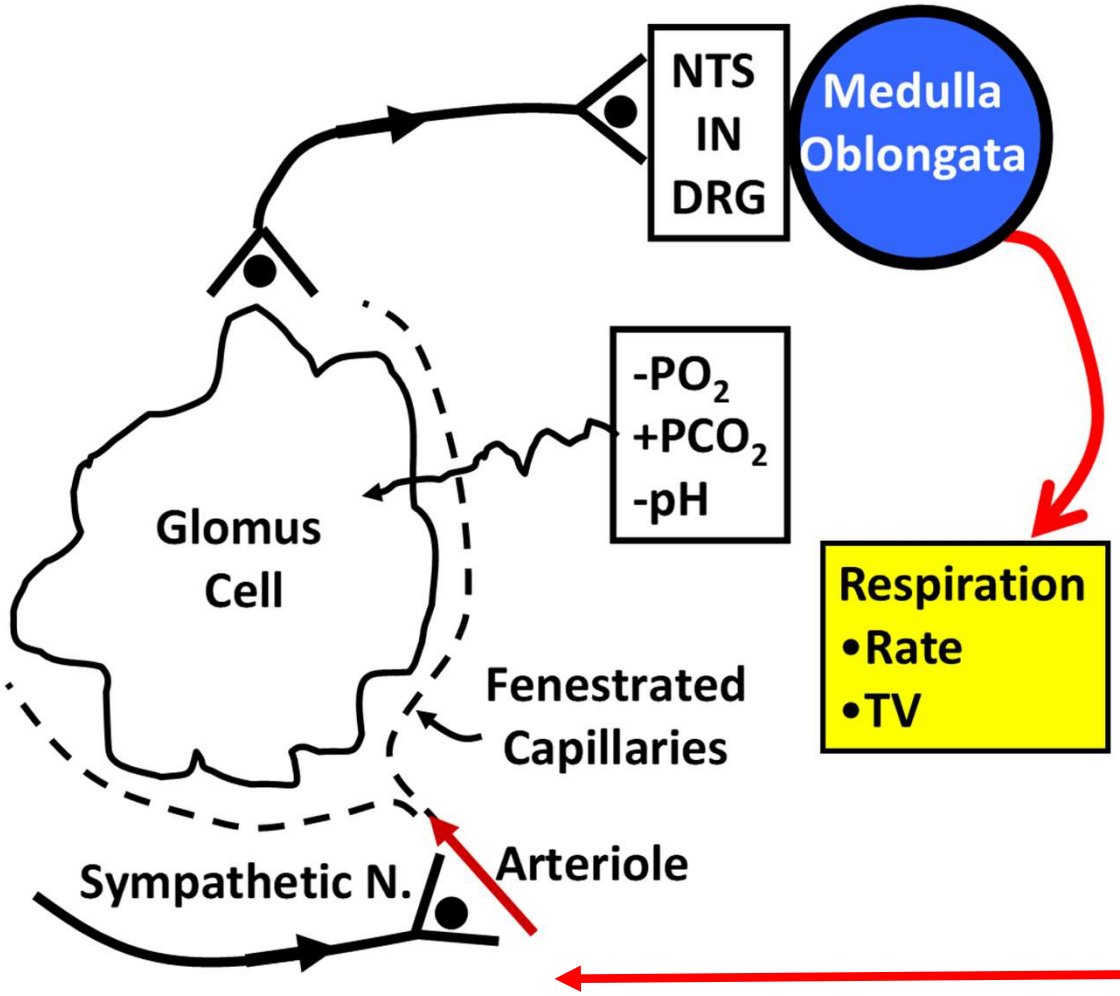
Central Chemoreceptors

Peripheral Chemoreceptor (PCR): Pathways



Carotid Body Function: Overview

NTS and DRG:
Nucleus Tractus Solitarius
Dorsal Respiratory Group



- Carotid body: very high blood flow/g
- Advantage to sample blood chemistry
- Glomus cells in carotid body monitors blood PO_2, PCO_2 and pH
- For indicated directional changes, afferent nerve traffic to the respiratory center is increased
- Results is increased efferent nerve traffic from dorsal respiratory cell groups (DRG) causing increased respiration rate and tidal volume
- Certain activities may be modulated by sympathetic nerve vascular control of arterioles feeding the glomus cells

Peripheral Chemoreceptors (PCR): Summary

- Located bilaterally in carotid and aortic bodies
- Respond to Hypoxia, Hypercapnia and Acidosis
- Afferent pathways for:

  Carotid body → Hering's nerve

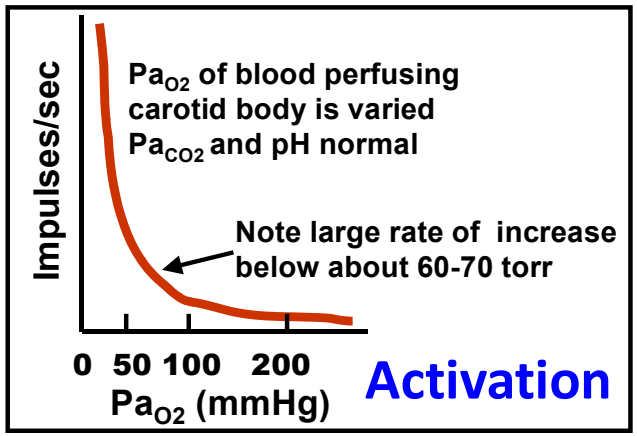
  Aortic body → vagus nerve
- Large afferent impulse traffic at normal blood gases
- Increased afferent activity caused by

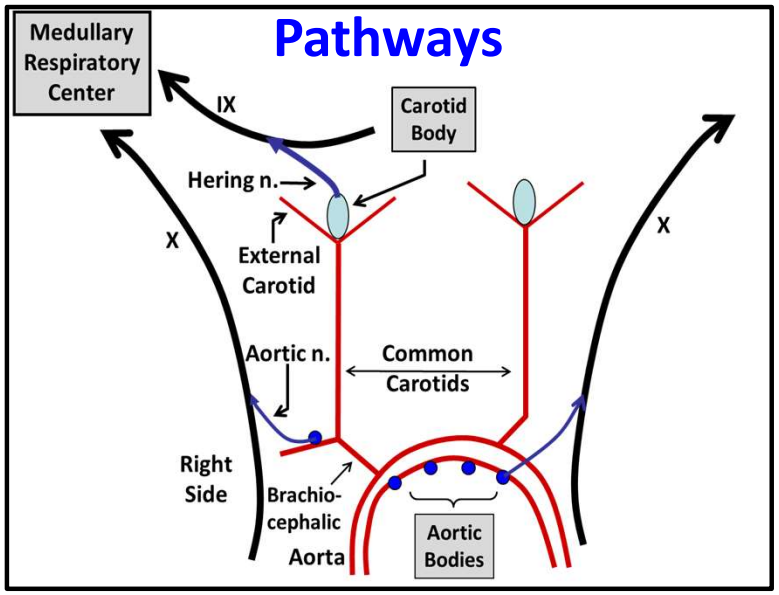
  (1) decreased arterial Pa_{O2}

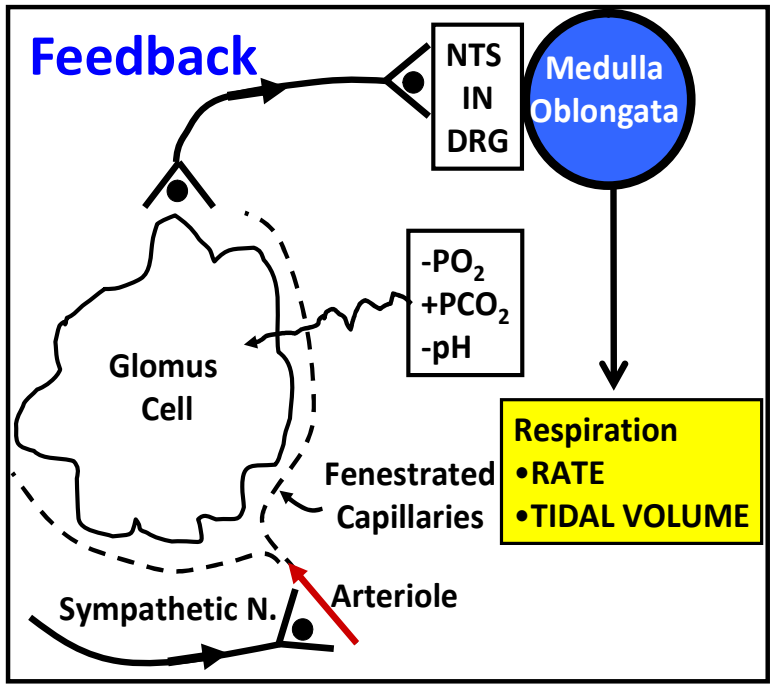
  (2) increased Pa_{CO2}

  (3) decreased arterial pH
- Feedback to respiratory center → increased V'
- Response to hypoxemia depends on Pa_{CO2} & pH

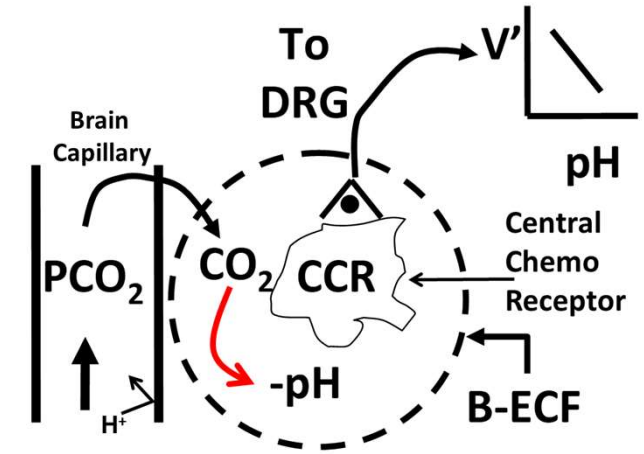
  More Pa_{CO2} or lower pH → greater $\Delta V'$ for same ΔPa_{O2}



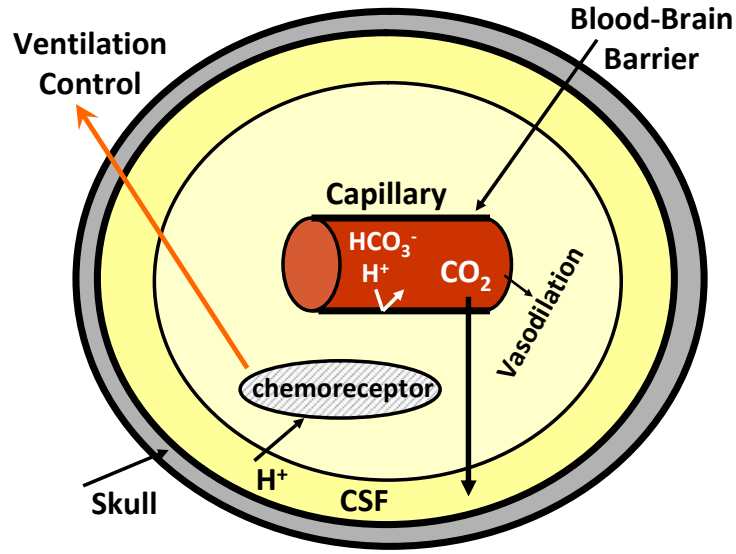




Central Chemoreceptors: Summary



B-ECF = Brain Extracellular Fluid



- CCR in brain parenchyma bathed in brain extracellular fluid/CSF
- If blood gases and pH near normal CCR are the main control of ventilation
- CCR are sensitive to arterial hypercapnia (and associated fall in pH)
- CCR actually sense pH (H^+) around receptor neurons bathed in CSF
- pH changes may occur due to:
  1) increased cerebral blood CO_2 diffusing across the blood-brain barrier resulting in a rapid (60 sec) decrease in the pH of CSF
  2) decreased pH of brain or CSF not due to changes in Pa_{CO2} (delayed)
- CCR do not respond to hypoxia
- CCR and PCR both affect ventilation response to increased CO_2 levels

Bypass

Feedback Aspects of Respiratory Control

Respiratory Mechanoreceptors

Receptors Located in

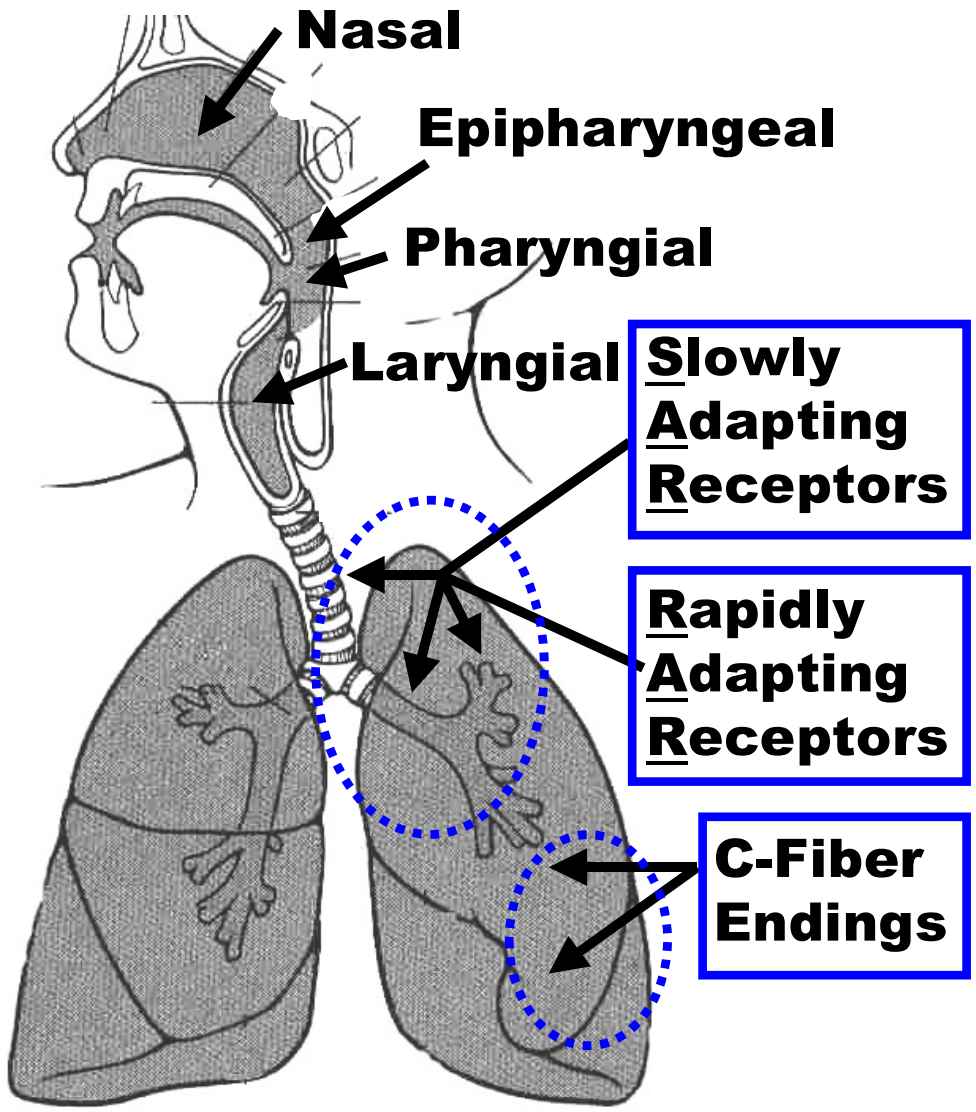
- Upper respiratory
- Tracheo-bronchial tree
- Lung parenchyma

Broadly three types

- Slowly Adapting (SAR)
  Among ASM cells
- Rapidly Adapting (RAR)
  Among airway epithelial cells
- C-fiber endings (J-receptors)
  near blood vessels/capillaries

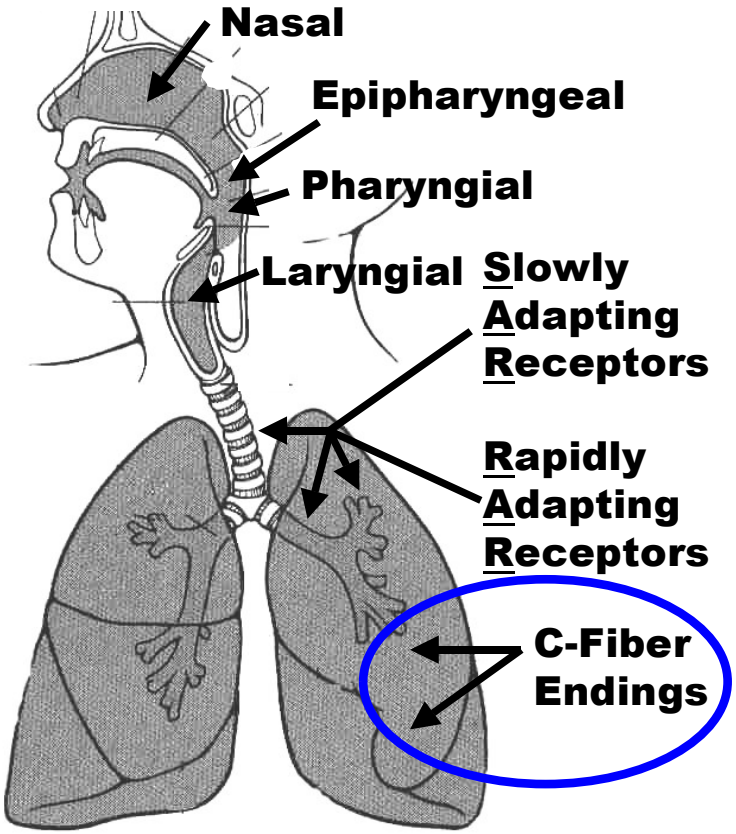
Vagal Afferents

- Connect to respiratory cntr
- Initiate many reflexes



C-Fiber Receptors (Juxtacapillary or J Receptors)

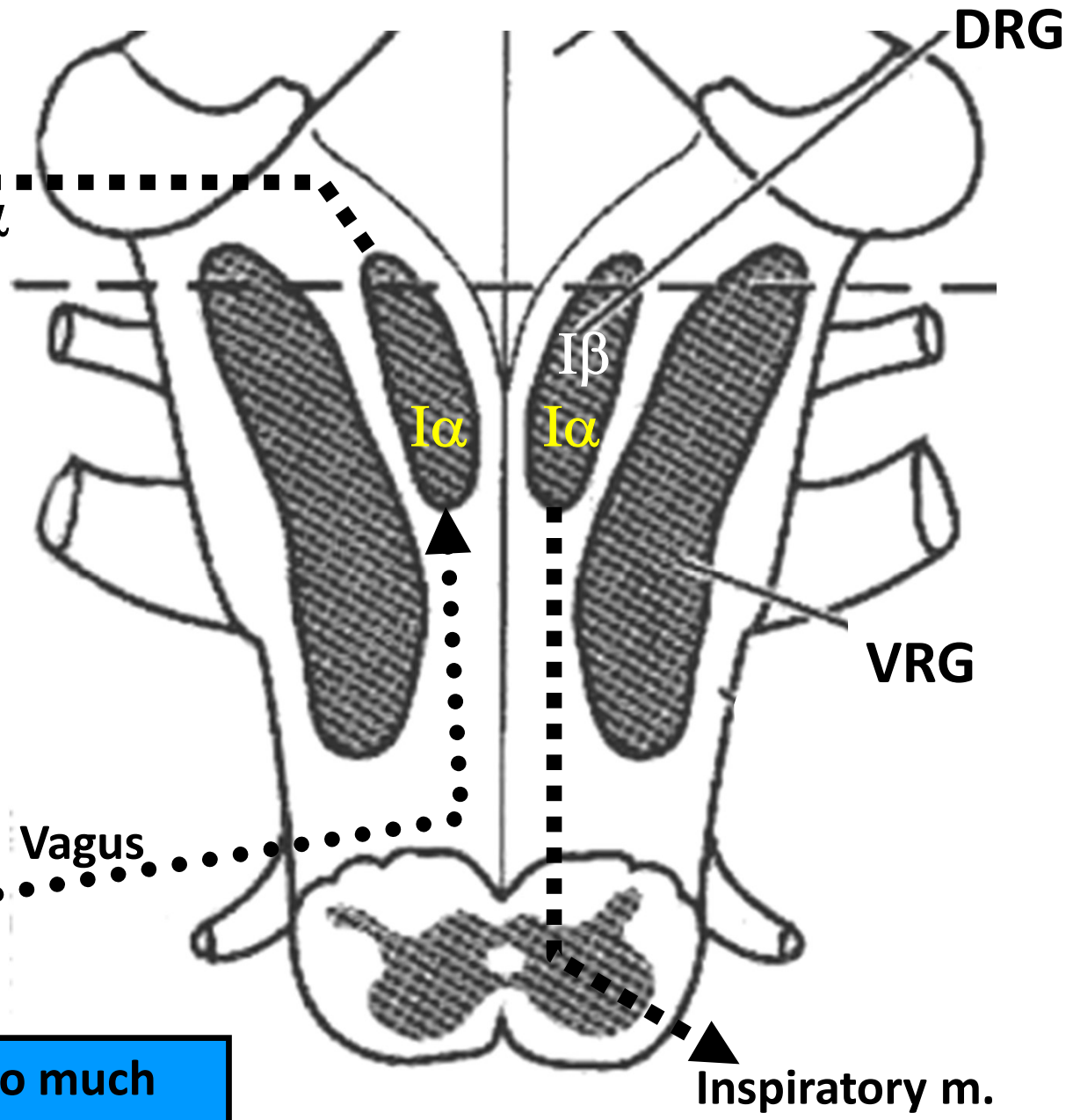
- Network of small unmyelinated axons (C-fibers) innervate receptors in alveoli near or in the walls of pulmonary capillaries
- Sensitive to distension and/or distortion caused by increases in capillary or interstitial volume
- Increased distention leads to increased ventilation (*pulmonary congestion* by LV failure)
- Decreased distention leads to decreased ventilation (e.g. pulmonary *embolism* that obstructs flow proximal to capillaries)



Summary: Hering-Breuer INFLATION Reflex

Hering-Breuer Operative in

- ***Infants***
- ***Adults if TV > 0.8-1.0 liters***



Impulses to inspiratory muscles are decreased

- **Reduces inspiration duration**
- **Reduces TV**
- **Prevents overdistention**

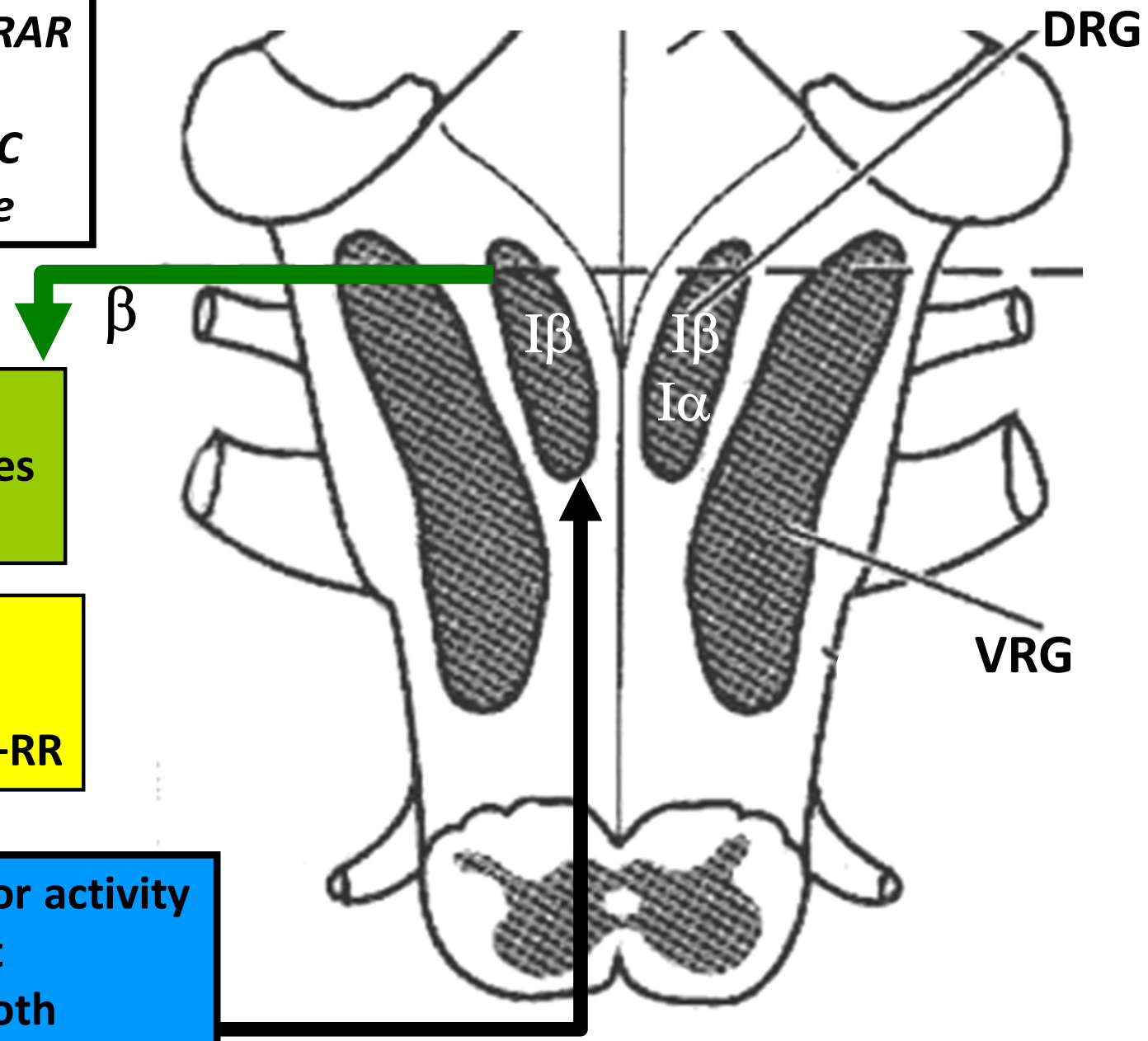
Inhibitory impulses to DRG via Vagus

Stretch Receptors Among ASM cells

Too much lung Inflation

Summary: Hering-Breuer DEFLATION Reflex

- *Pneumothorax → RAR*
- *Trigger for sighs*
- *Maintain Infant FRC low chest wall force*

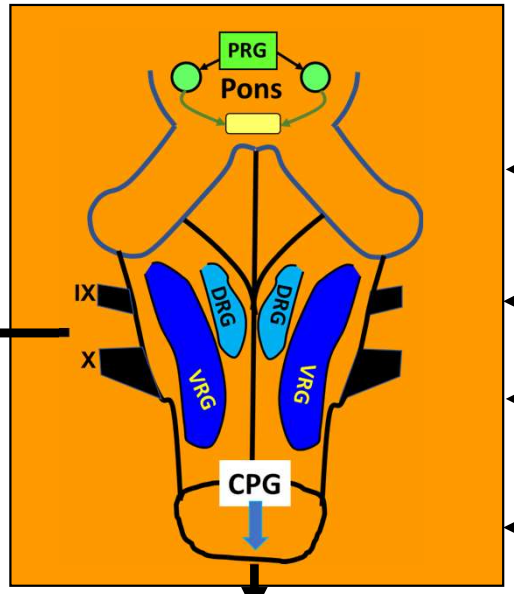


Impulses to inspiratory muscles are increased

Hyperpnea
- **Tachypnea +RR**
- **Hyperpnea +TV & +RR**

Less stretch receptor activity causes a reflex that promotes either/both increased TV and RR

Overall Respiratory Control Summary



Upper Airway Muscles
pharynx
larynx
flare nostrils
open mouth

Reticular Formation

Limbic

Emotions (Forebrain)

$+CO_2$, -pH

$-O_2$, $+CO_2$, -pH

Airway Smooth Muscle

Spinal Respiratory Motoneurons

Phrenic (diaphragm)
Spinal n. (intercostals, abdomen)

Skeletal Muscle Receptors

Respiratory Muscles

Ventilation: TV/RR

Receptors: lung & airways chest wall & diaphragm

Neocortex (Voluntary)

Blood Gases

Peripheral Chemoreceptors

CSF [H^+]

Central Chemoreceptors

Summary of Some Major Roles of Individual Centers

DRG are mainly involved with inspiration. Nerve impulses from DRG stimulate respiratory muscles and set the basic pattern generation for rhythmic breathing

VRG are mainly involved with expiration but have some neurons that are involved with forced inspiration and forced expiration Nerve connections to the DRG help determine when inspiration ends by inhibiting DRG output

Apneustic Center: Not really a center but groups of widely distributed respiratory neurons. Neural output to DRG Maintains Inspiration. When inhibited from PRG a main role is to contribute to the *turn-off of inspiration* and to limit depth of inspiration. I.e. inspiration "turn-off" switch

PRG: Modulates activity of Apneustic Center in response to various feed back signals from mechoreceptors and chemoreceptors. However, on-off breathing continues without it.

High Altitude: Respiratory Adaptation

Decreased Atmospheric Pressure → Hypoxemia

Peripheral Chemoreceptors drive increased ventilation

- Increases Pa_{O2} but Decreases Pa_{CO2}
- Decreased CO_2 effects Central Chemoreceptors (+pH)
- CCR response acts to counter hypoxia induced hyperpnea
- CSF and arterial pH tend to normalize over days
- Renal excretion of $HCO3^-$
- Early acute Mountain Sickness possible

Physiological Adaptations to High Altitude

- Polycythemia - Increases O_2 carrying capacity
- P_{50} Shift to Right - Better O_2 unloading
- Increased Capillary Density

End Respiratory Physiology
Lecture 43