

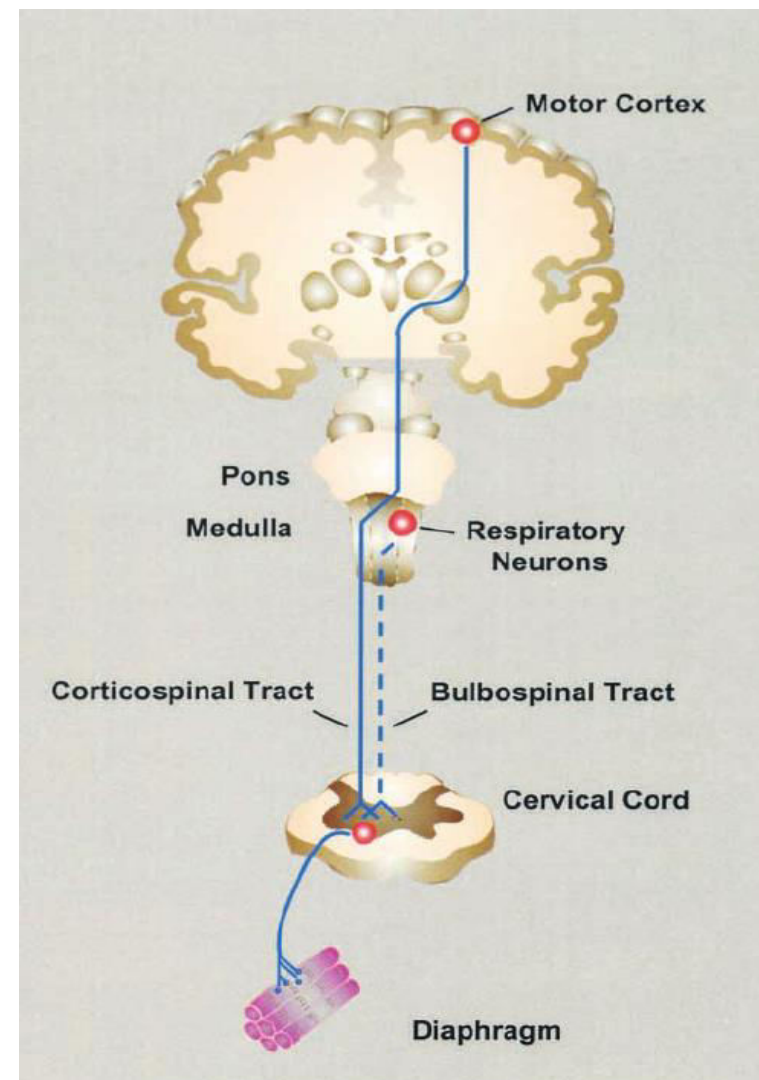
# Lecture 10

## Neural control of respiration

- ⊙ **Voluntary control**
- ⊙ **Automatic control**
- ⊙ **Reflex control**

# 1) Voluntary control

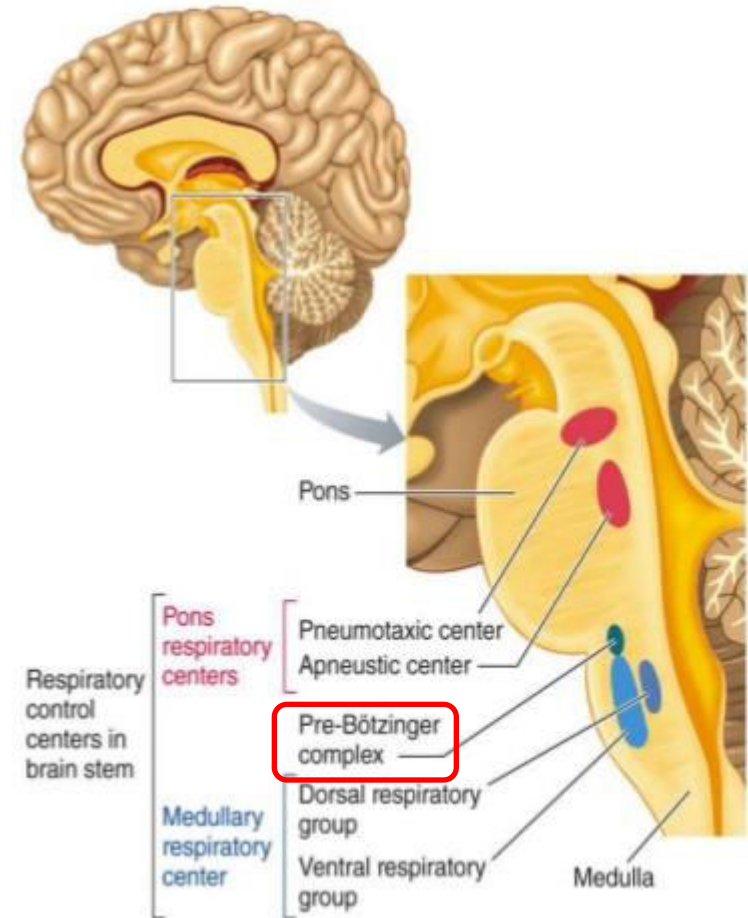
- ⊙ Respiratory muscles are voluntary muscles (skeletal muscles)
- ⊙ Center: in the motor cortex
  - Corticospinal tract
- ⊙ Function:
  - Modulation of respiration (talking, singing)
  - Voluntary hyperventilation
  - Voluntary apnea
- ⊙ Damage to respiratory centers → loss of automatic control and voluntary control alone will be present
  - This condition is called Ondine's curse (suffer from respiratory arrest during sleep)



## 2) Involuntary (automatic) control Medullary centers

### 1) Pre-Botzinger complex

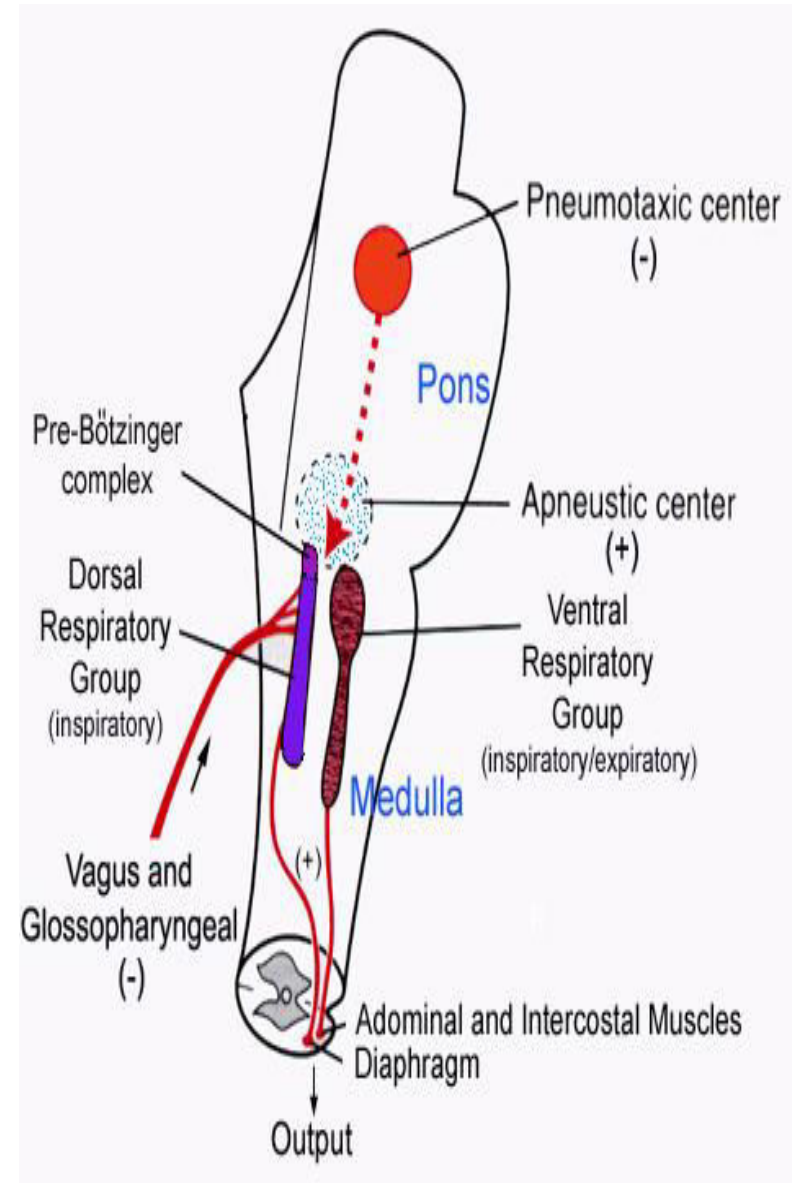
- ⊙ Located on both sides of medulla, between nucleus ambiguus and lateral reticular nucleus
- ⊙ Discharge rhythmically → responsible for the rhythmicity of respiration.
  - Pacemaker



# Medullary centers

## 2) Dorsal respiratory group (DRG)

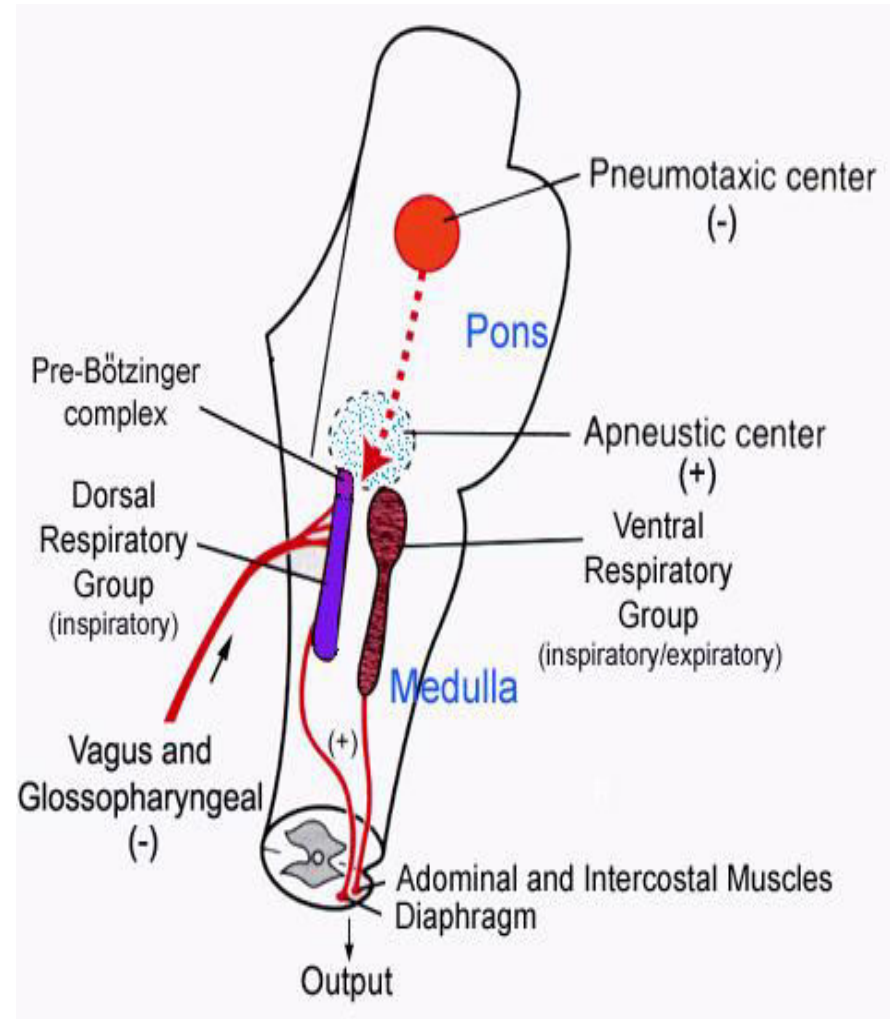
- ⊙ Location: dorsomedial part of medulla
- ⊙ Nucleus of tractus solitarius
- ⊙ Made up of I (inspiratory) neurons controlled by pre-Botzinger complex
- ⊙ Output ⇒ phrenic motor neuron ⇒ phrenic nerve ⇒ diaphragm
- ⊙ Input from IX & X cranial nerves (lung, chemoreceptors, and baroreceptors)



# Medullary centers

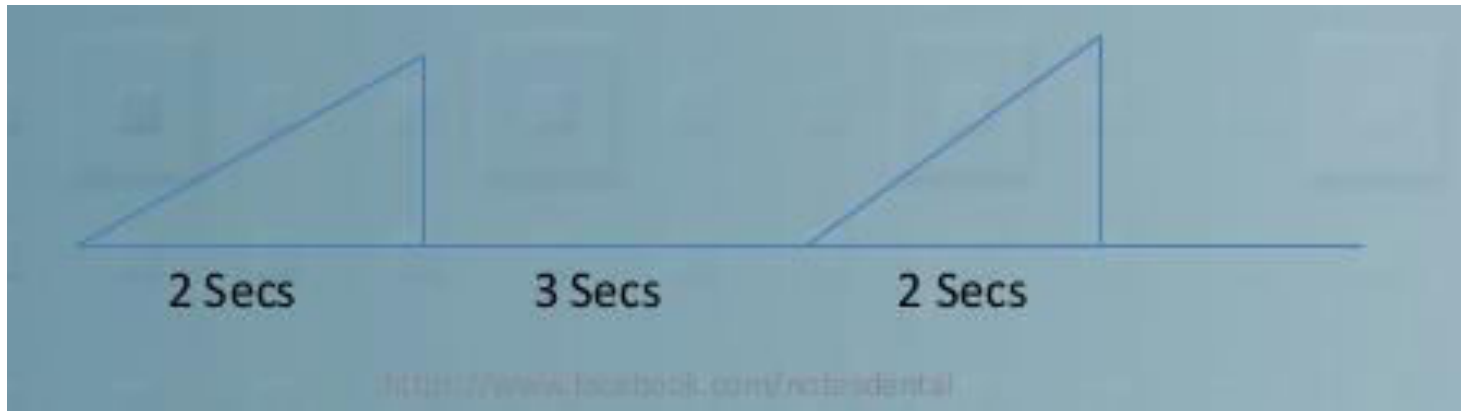
## 3) Ventral respiratory group (VRG)

- ⊙ Location: ventrolateral part of medulla.
- ⊙ Nucleus ambiguus and retroambiguus.
- ⊙ E and I neurons
- ⊙ Output to spinal motor neurons that innervate expiratory muscles (forced expiration) & accessory inspiratory muscles.
- ⊙ Inactive during quiet breathing



# Inspiratory Ramp Signal (IRS)

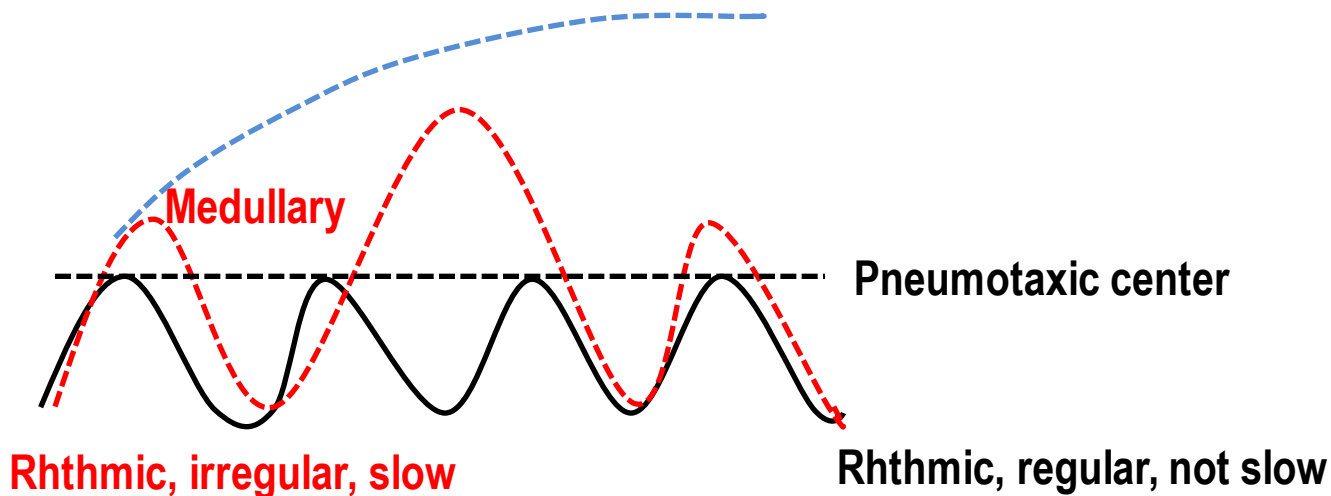
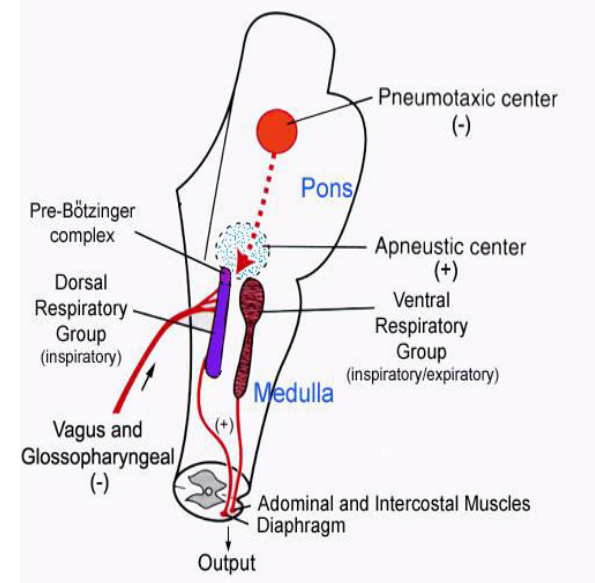
- ⊙ Nervous signals that are transmitted to the respiratory muscles begins weakly and increases steadily in a ramp manner for about 2 seconds.
- ⊙ Stops abruptly for approximately the next 3 seconds → relaxation of the diaphragm → elastic recoil of lungs and chest wall causes expiration
- ⊙ And again the new cycle begins.



# Pontine centers

## 1) Pneumotaxic center

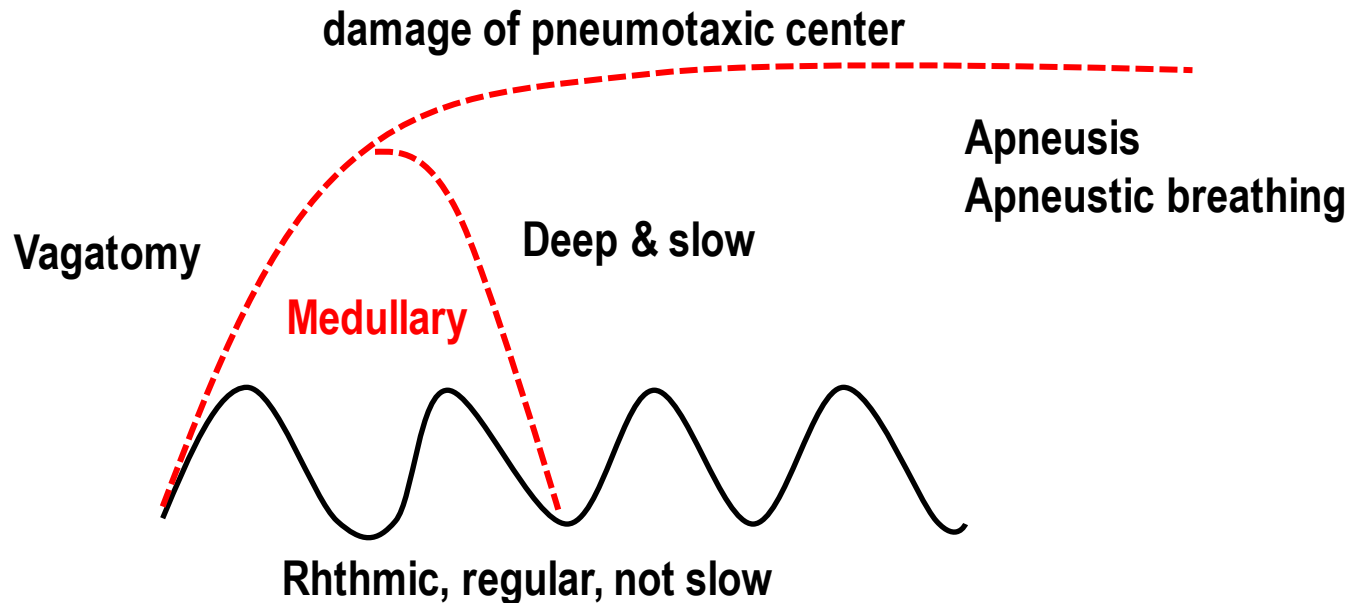
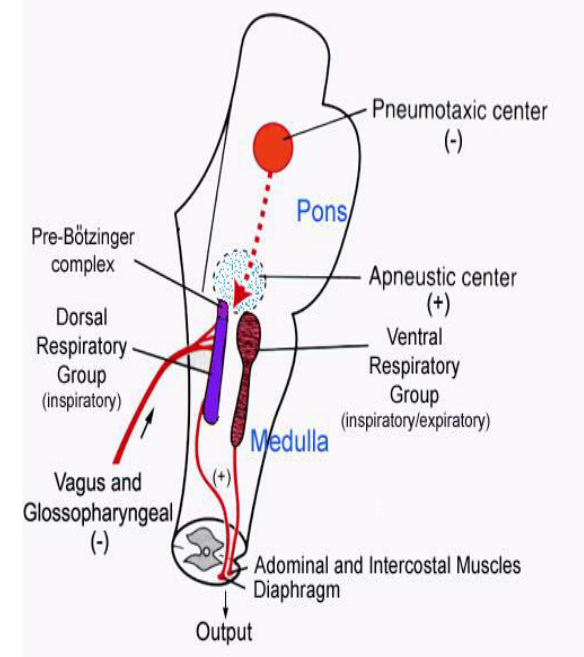
- Location: upper pons
- Function: inhibition (off switch)
  - Inhibits I neurons (DRG)
  - Make respiration regular and faster (Duration of IRS  $\downarrow \rightarrow \uparrow$ RR &  $\downarrow$  filling volume)
  - Damage to pneumotaxic center  $\rightarrow$  respiration is slow &  $\uparrow$  TV
  - If vagi are also simultaneously cut  $\rightarrow$  apneusis



# Pontine centers

## 2) Apneustic center

- ⊙ Location: lower pons
- ⊙ Function: stimulation (on switch)
  - Stimulates DRG
  - Stimulates pneumotaxic center → inhibits DRG and apneustic center



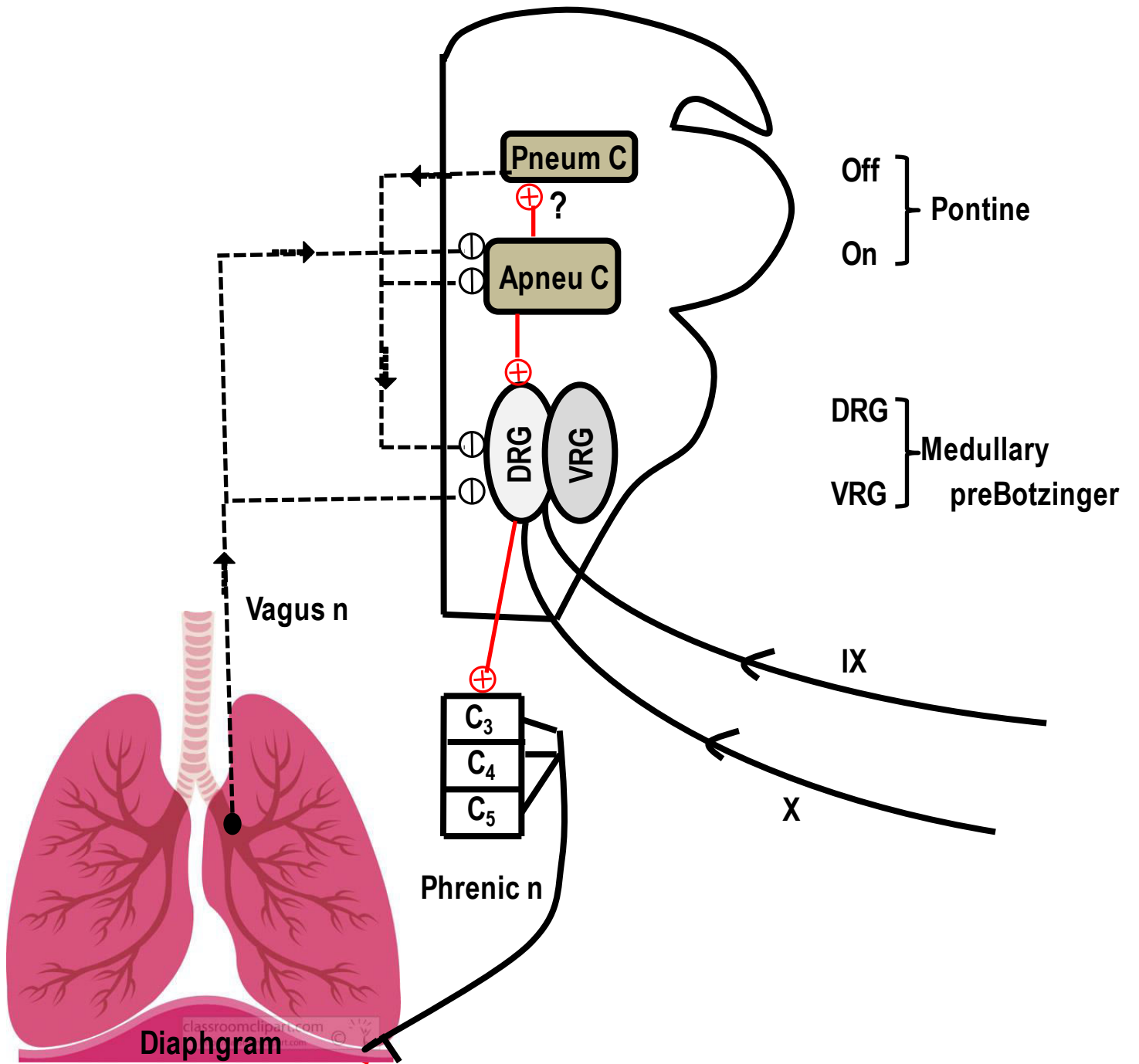


## ⊙ **Inspiration is limited by (3 off switch)**

- Pneumotaxic center
- Hering Breuer reflex (inflation reflex) stretch receptors in smooth muscle of bronchi
- Muscle spindle in intercostal muscles

## ⊙ **Mechanism of normal breathing**

- ① Apneustic center send excitatory impulses to DRG
- ② DRG send excitatory impulses to inspiratory muscles (diaphragm)  
→ inspiration
- ③ Switch off inhibitory impulses to apneustic from
  - Pneumotaxic center
  - Vagus
  - Muscle spindle in intercostal muscles
- ④ Expiration followed passively
- ⑤ Apneustic center recovered from inhibition and cycle repeated.



**1) Upper pons**

No effect on automatic respiration

**2) Mid pons**

Deep & slow

**5) Upper medulla**

Rhythmic, irregular, slow

**6) Lower medulla (Hanging)**

Respiratory failure

**3) Vagotomy**

Deep & slow  
(infants and animals)

**7) Lower cervical (fall on head)**

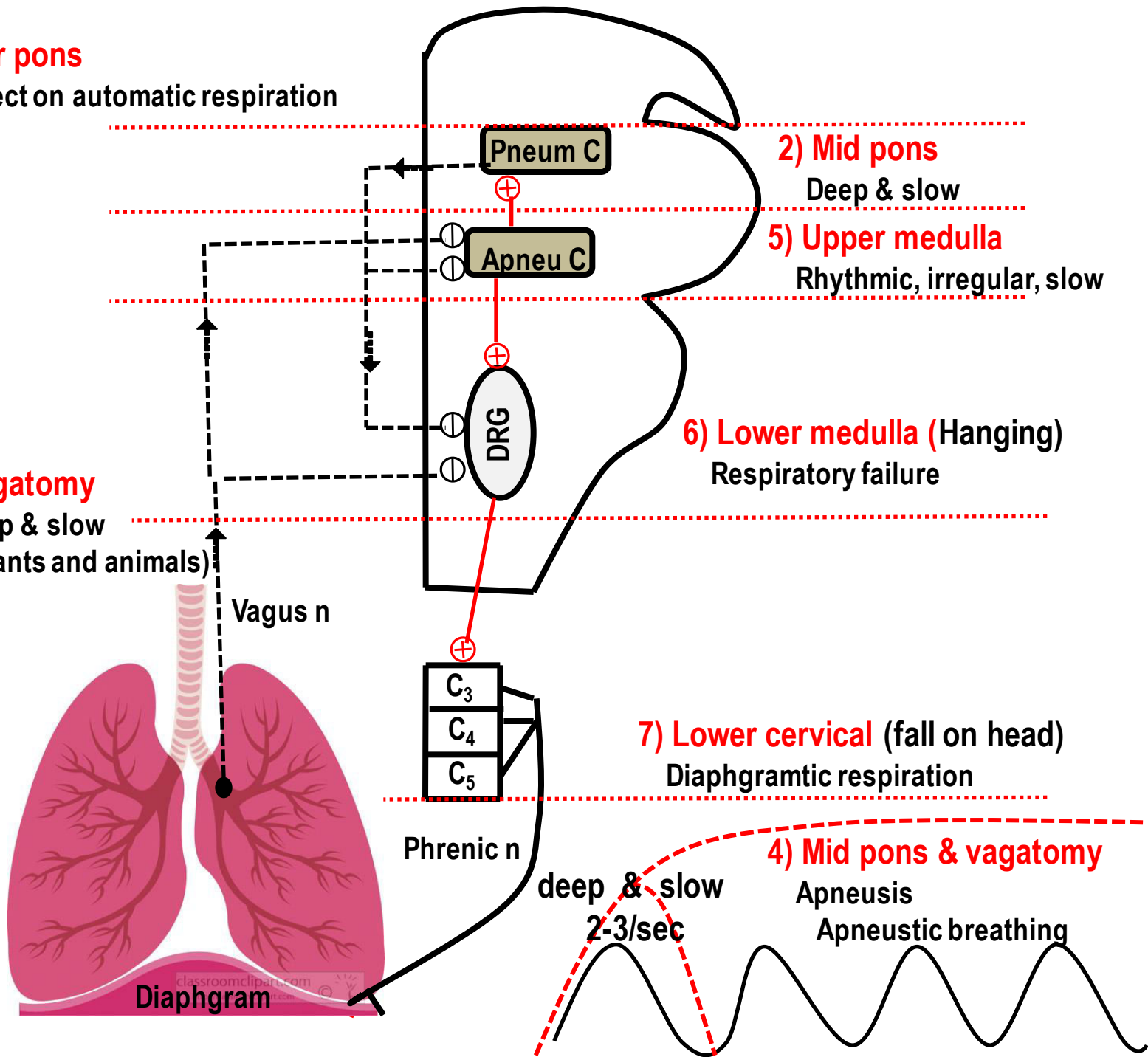
Diaphragmatic respiration

**4) Mid pons & vagotomy**

deep & slow  
2-3/sec

Apneusis

Apneustic breathing



### **3) Reflex control**

- 1) Respiratory system**
- 2) CVS**
- 3) Chest wall receptors (intercostal muscles)**
- 4) Proprioceptors (skeletal muscles)**
- 5) Viscera**
- 6) Higher center**

# 1) Receptors in respiratory system (upper airways)

<b>Site</b>	<b>Nerve</b>	<b>Stimulus</b>	<b>Response</b>
<b>Nose</b>	V	<ul style="list-style-type: none"><li>▪ Mechanical (dust, mucus, food)</li><li>▪ Chemical (smoke)</li></ul>	Sneezing (forced inspiration followed by forced expiration with open glottis)
<b>Pharynx</b>	IX	Food during swallowing	Apnea
<b>Chest</b>	X	Irritant	Coughing (Cough: forced inspiration followed by forced expiration against closed glottis which open suddenly)

# 1) Receptors in respiratory system (lower airways)

	Lung stretch receptors	Lung irritant receptors	J receptors (juxta-pulmonary capillary)
<b>Site</b>	Bronchi and bronchioles SM	Bronchi and bronchioles mucosa	Juxta-pulmonary capillary
<b>Nerve</b>	X	X	X
<b>Stimulus</b>	Lung inflation	Mechanical and chemical irritant	↑ pulmonary pressure (lung congestion)
<b>Response</b>	Hering Breuer reflex	Cough and bronchospasm	Tachypnea and dyspnea

## 2) Receptors in CVS

	<b>Arterial baroreceptors High pressure receptors</b>	<b>Atrial baroreceptors Low pressure receptors</b>
<b>Site</b>	Aortic arch and carotid sinus	Right atrium
<b>Nerve</b>	IX & X	X
<b>Stimulus</b>	↑ Blood pressure ↑ Pulse pressure	↑ Central venous pressure (venous return)
<b>Response</b>	Inhibitory (adrenaline apnea)	Excitatory

## 3) Receptors in chest wall muscle

<b>Site</b>	Muscle spindle of intercostal muscles
<b>Nerve</b>	Intercostal nerves
<b>Stimulus</b>	Inspiration
<b>Response</b>	Determine TV

4) Proprioceptors (skeletal muscle)	
<b>Site</b>	Muscles, tendons and joints
<b>Nerve</b>	Somatic nerves
<b>Stimulus</b>	Movement (exercise)
<b>Response</b>	↑ Ventilation

5) Viscera		
	Swallowing	Hiccup
<b>Site</b>	Pharynx	Phrenic nerve
<b>Nerve</b>	IX	X
<b>Stimulus</b>	Mechanical (food)	Irritation of phrenic nerve by gastric distension
<b>Response</b>	Apnea	Spasmodic contraction of inspiratory muscles with closed glottis (apnea or breathing in closed space → ↑PCO <sub>2</sub> → improvement from hiccup)



## 6) Higher centers

- ⊙ Limbic system (pain and emotion)
- ⊙ Hypothalamus
  - Parasympathetic (pain) → inhibition
  - Sympathetic (emotion) → stimulation
  - Thermostat (fever) → stimulation

