CONTROL OF BREATHING

Objectives

1. Distinguish between the automatic and conscious/voluntary control of breathing. Identify the key structures involved in generation of the resting quiet breathing rhythm of inspiration followed by expiration.

2. Specify the key sources of sensory input to the rhythm generator that modify its output to the respiratory muscles.

3. Identify the location of the central & peripheral chemoreceptors and describe their effect (if any) on ventilation in response to changes in arterial PCO₂, PO₂, and pH.

4. Describe how a decrease in plasma pH regulates ventilation & partial pressures of oxygen and carbon dioxide in the blood. Provide examples of metabolic acids that have this effect in exercise and in diabetes.

5. Based on what you know about the chemical control of ventilation, explain the danger of hyperventilation prior to diving under water.
Breathing is:

**initiated** in the medulla by aggregates of neurons

**modified** by higher structure of CNS & input from central & peripheral chemoreceptors & mechanoceptors in the lungs & chest wall

Compare the control of the rhythmic activity of the heart & generation of cardiac output to rhythmic activity of the chest wall & breathing
AUTOMATIC BREATHING IS INITIATED IN THE MEDULLA

**DRG**
- mainly inspiratory neurons (active during inspiration) driving the inspiratory muscles
- receives input from peripheral chemoreceptors & mechanoreceptors

**VRG**
- mainly expiratory neurons, silent during quiet breathing & active during active expiration driving the expiratory muscles

Rhythm refining role of areas in the **Pons**- Thomas Lumsden
1920 ablation experiments in anesthetized cats--
**pneumotaxic centre**: stop inspiration & prolonged expiration
**apneustic centre**: prolonged & deep inspiration
BULBOSPINAL INSPIRATORY NEURONS INITIATE INSPIRATION VIA SPINAL NERVES TO THE INSPIRATORY MUSCLES

THE PHRENIC NERVES SUPPLY MOTOR INPUT TO THE DIAPHRAGM

• The hrenic nerve is formed by rootlets exiting the cervical spine C3, C4, C5. Two bilateral phrenic nerves supply the hemi-diaphragms. "C3, 4, 5 keep the diaphragm alive"

• Intercostal nerves exiting thoracic & lumbar spine provide input to nerves supplying the intercostal & abdominal muscles

• Cranial nerve supply the motor output to the upper airway dilator muscles
MANY INPUTS TO THE MEDULLA CONTRIBUTE TO THE RHYTHM OF BREATHING
FEED BACK & FEED FORWARD INPUT
TO THE MEDULLARY RESPIRATORY CENTRE

cerebral motor cortex

corticospinal tract
c

to pons

to higher brain regions

MEDULLA

ventrolateral tract

spinal cord

respiratory muscles

movement of chest wall & lungs

ventilation

alveolar-capillary membrane

gas exchange

arterial blood  PCO₂, PO₂, pH

automatic/metabolic control

mechanoreceptors

chemoreceptor
THE HERING BREUER REFLEX
AN EARLY HISTORIC (1868) EXAMPLE OF THE MANY MECHANORECEPTOR INPUTS REGULATING THE RHYTHM OF BREATHING

• a reflex triggered to prevent over inflation of the lungs.

• stretch receptors in the smooth muscle of the airways respond to stretching of the lung during inflation, allowing expiration to occur- reflex is mediated by the vagus X CN.

• early physiologists believed the reflex played a major role in establishing the rate and depth (rhythm) of breathing in humans- -true for most mammals, not the case for adult humans at rest.

• the reflex may determine breathing rate and depth in newborns & in adult human when tidal volume > 1 L, as during exercising
MECHANOSENSOR FEEDBACK TO THE MEDULLARY RESPIRATORY CENTRE

cerebral motor cortex

corticospinal tract

pons

higher brain regions

MEDULLA

ventrolateral tract → automatic/metabolic control

spinal cord

respiratory muscles

movement of chest wall & lungs

ventilation

alveolar-capillary membrane

gas exchange

arterial blood \( \text{PCO}_2, \text{PO}_2, \text{pH} \)

chemoreceptor

mechanoreceptors

MECHANORECEPTOR FEEDBACK TO THE MEDULLARY RESPIRATORY CENTRE
CHEMORECEPTOR FEEDBACK
TO THE MEDULLARY RESPIRATORY CENTRE

- cerebral motor cortex
- pons
- higher brain regions
- ventrolateral tract
- automatic/metabolic control
- spinal cord
- respiratory muscles
- movement of chest wall & lungs
- ventilation
- alveolar-capillary membrane
- gas exchange
- arterial blood $\text{PCO}_2$, $\text{PO}_2$, pH
- chemoreceptor
- mechanoreceptors
- corticospinal tract
- pons
- higher brain regions
- ventrolateral tract
- automatic/metabolic control
- spinal cord
- respiratory muscles
- movement of chest wall & lungs
- ventilation
- alveolar-capillary membrane
- gas exchange
- arterial blood $\text{PCO}_2$, $\text{PO}_2$, pH
- chemoreceptor
- mechanoreceptors
- corticospinal tract
TWO TYPES OF CHEMORECEPTORS PROVIDE FEEDBACK TO THE RESPIRATORY NEURONS IN THE MEDULLA

CENTRAL CHEMORECEPTORS

- few mm below the ventral surface of the medulla
- stimulated by small changes (few mmHg) in arterial PCO$_2$ via the associated changes in [H+] in the brain ECF
- arterial PCO$_2$ primary regulator of breathing normal range=35-45 mmHg

- What would happen to arterial PCO$_2$ if you
  1. held your breath
  2. hyperventilated
TWO TYPES OF CHEMORECEPTORS PROVIDE FEEDBACK TO
THE RESPIRATORY NEURONS IN THE MEDULLA

PERIPHERAL CHEMORECEPTORS

• Carotid & Aortic Bodies
• minuscule structures “tasting” blood [own blood supply is ↑ ]
• sense mainly arterial PO₂ as well arterial PCO₂ & pH
• separate entities from baroreceptors (stretch receptors)
• CB sensory information carried via glossopharyngial nerves [IX CN]
• AB sensory information carried via vagus nerves [Xth CN]
PERIPHERAL CHEMORECEPTORS

• mainly sense a ↓ in arterial PO2 levels < 60 mmHg with exposure to high altitude or in disease states

• the ventilatory response to ↓ PO2 is hyperventilation which in turn results in a ↓ PCO2 and an ↑ PO2
Metabolic acids stimulate peripheral chemoreceptors & increase ventilation

- lactic acid produced by muscles during intense exercise
- diabetic ketoacidosis [Kussmaul breathing]
CONGENITAL CENTRAL HYPOVENTILATION SYNDROME
“ONDINE’S CURSE”– FORGETTING TO BREATH
A Rare Disorder In Children (400 Cases Known World Wide)

- Breathing is adequate when awake (conscious/voluntary breathing is working)
- Breathing is inadequate/absent during sleep (automatic breathing is not working)
- Treatment: Mechanical Ventilation or Diaphragm Pacing
- some patients with CCHS have low or absent ventilatory response to elevated CO2, low O2 and metabolic acidosis.