Regulation of breathing

- The motor neurons that stimulate the respiratory muscles are controlled by two major descending pathways: one that controls voluntary breathing and another that controls involuntary breathing.

- The unconscious rhythmic control of breathing is influenced by sensory feedback from receptors sensitive to the P_{CO_2}, pH, and P_{O_2} of arterial blood.

- Inspiration and expiration are produced by the contraction and relaxation of skeletal muscles in response to activity in somatic motor neurons in the spinal cord. The activity of these motor neurons is controlled, in turn, by descending tracts from neurons in the respiratory control centers in the medulla oblongata and from neurons in the cerebral cortex.

- Normal respiratory movement are involuntary. They are carried out autonomically (i.e. without concious control) through the rhythmical discharge of nerve impulses from controlling centers in the medulla oblongata and pons. Respiratory neurons in the brainstem are of two types:

  I neurons discharge during inspiration;

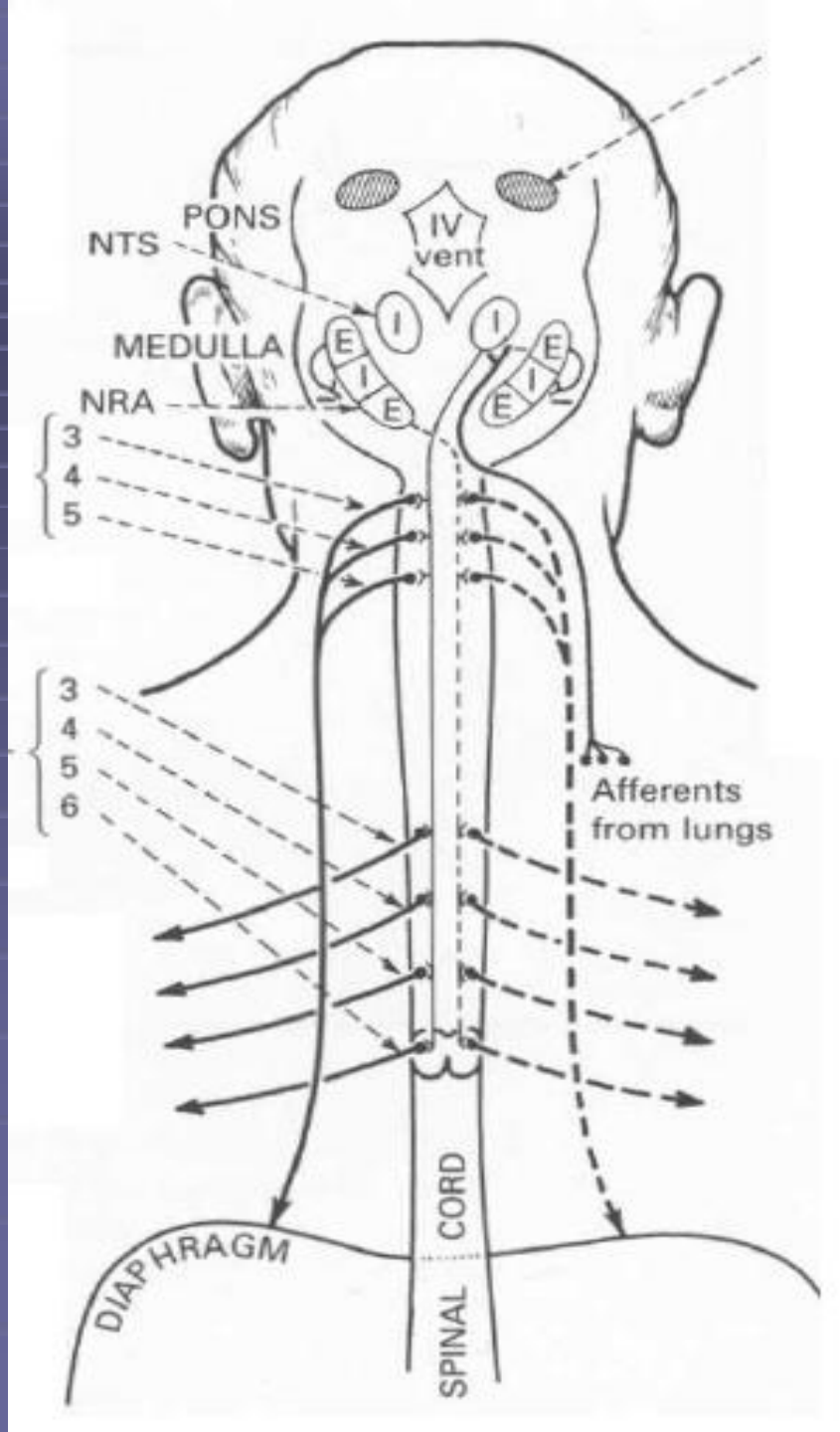
  E neurons discharge during expiration.

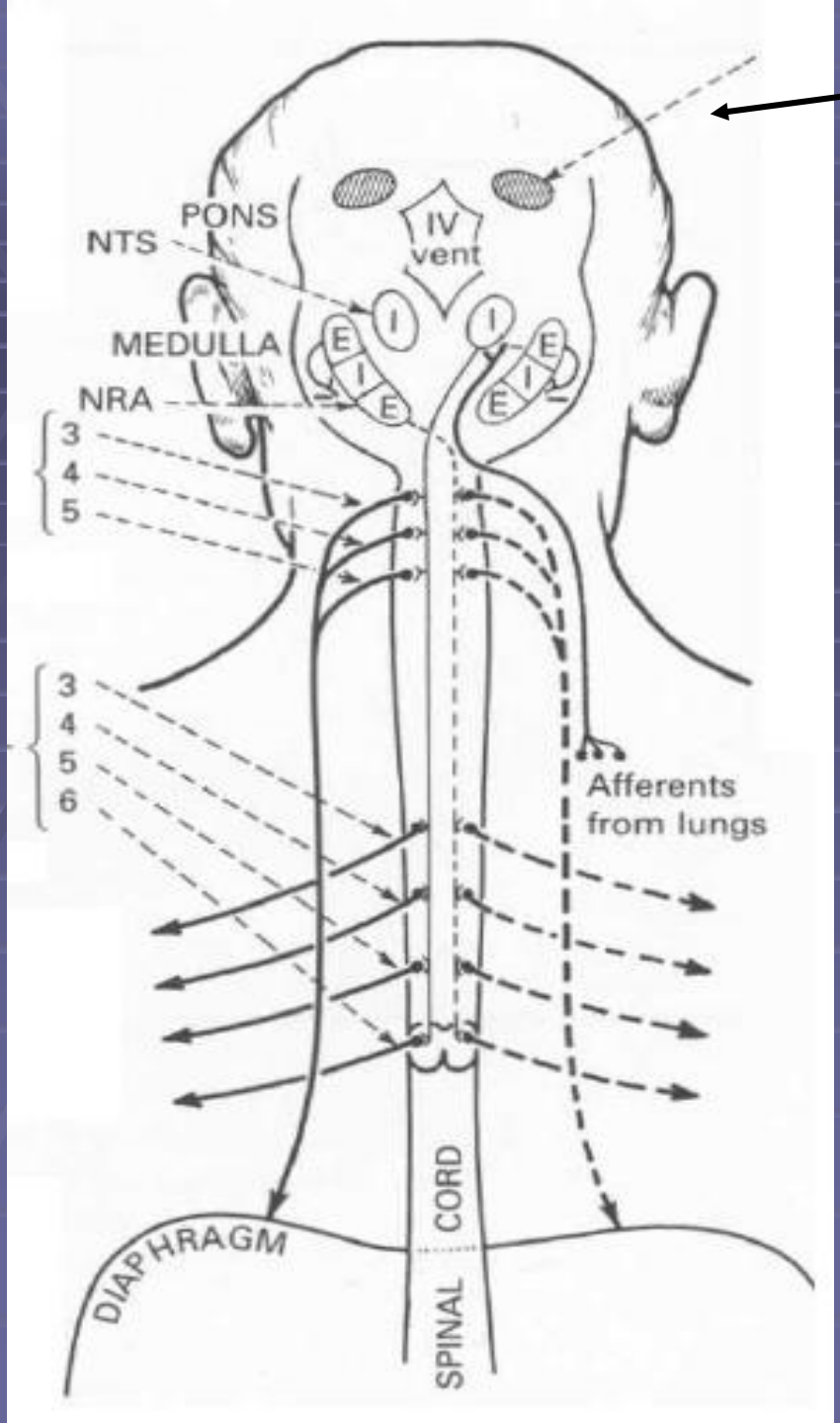
I neurons send out streams of impulses which travel down to the ANTERIOR HORN CELLS of the SPINAL CORD on the opposite site and are relayed from CERVICAL SEGMENTS

by the PHRENIC NERVES to the DIAPHRAGM and from THORACIC SEGMENTS

by the INTERCOSTAL NERVES to the INTERCOSTAL MUSCLES These nerve impulses cause the muscle of inspiration to contract

In the nucleus retroambiguus (NRA) **E neurons** in the upper end Inhibit the **I neurons** during expiration





PNEUMOTAXIC CENTER (PTC)
(nucleus parabrachialis)
Normal function unknown but may have a role in switching between inspiration and expiration

MEDULLARY GROUPS
The dorsal group in the nucleus of the tractus solitarius (NTS) contain I neuron.
The ventral group in the nucleus NRA contain both E and I neurons.
Afferent impulses in the vagus from lung stretch receptors inhibit I neuron discharge

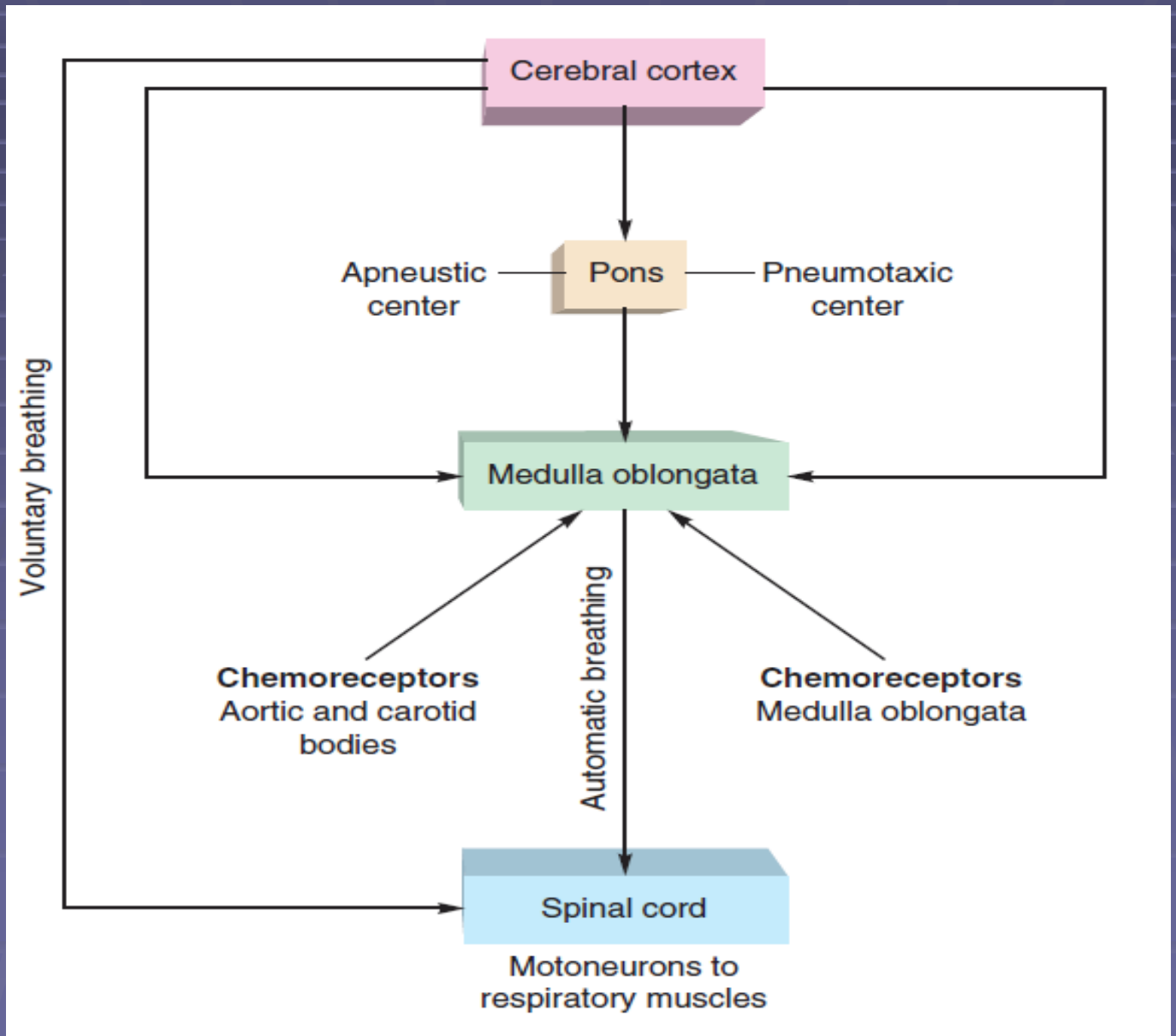
Inspiratory neurons inhibited
↓
The muscles of inspiration relax
↓
Expiration follows passively in quiet respiration

Expiratory (E) neurons are excited in *force* expiration

- Despite intensive research, the mechanism responsible for rhythmic respiratory discharge remains unsettled.

- The main components are in the medulla where there may be a group of pacemaker neurons situated.

The regulation of ventilation by the central nervous system.



Chemical regulation of respiration

- The activity of the respiratory centers is regulated by the O_2, CO_2 and H^+ content of the blood. Carbon dioxide and H^+ are most important. CO_2 dissolves in cerebrospinal fluid (CSF) which bathes receptors sensitive to H^+ on the ventral aspect of the medulla. Stimulation of these receptors is responsible for about 70% of the increase in the rate and depth of respiration in response to increased CO_2. Carotid and aortic bodies are responsible for the other 30% of the response to raised to CO_2. They also increase ventilation in response to a rise in H+ or a large drop in PaO_2 (to below 60 mmHg).

Increase in CO_2 increases H^+ concentration in CSF

($CO_2 + H_2O$ in CSF $\rightarrow H_2CO_3 \rightarrow HCO_3^- + H^+$)

→

Stimulates H^+ receptors

↓

Stimulates RESPIRATORY CENTERS

←

Increases rate and depth of breathing

Fall in blood CO_2 slightly depresses shallow breathing

- Arterial PaO_2, normally 100 mmHg, has to fall to 60 mmHg to stimulate chemoreceptors.
- Severe lack of O_2 depresses respiratory center.
- CHEMO-REFLEXES:

  in addition to the effect of CO_2 and O_2 on center, rise in H^+ of blood stimulates carotid and aortic bodies.

Lack of O2
e.g. as at low atm. pressure (high amplitude)

→

Stimulates CHEMORECEPTORS ('Oxygen-lack' receptors) in carotid body and aortic body

→

Reflexly stimulates respiration

Note: - These reflexes are usually powerful enough to override the direct depressant action of lack of O2 on respiratory centers themselves.

- The chemical and nervous means of regulating the activity of respiratory centers act together to adjust rate and depth of breathing to keep the P_aCO_2 close to 40 mmHg. This automatically sets the P_aO_2 to an appropriate value depending on the partial pressure of O_2.

- For example, exercise causes increased requirement for O_2 and the production of more CO_2. ventilation is increased to get rid of the extra CO_2 and keep the alveolar $PaCO_2$ at 40 mmHg. More oxygen is used by the tissues. The alveolar PO_2 and PCO_2 both remain constant.

Voluntary and reflex factor in the regulation of respiration

- Although fundamentally automatic and regulated by chemical factors in the blood there is a separate voluntary system for the regulation of ventilation. It originates in the cerebral cortex and sends impulses to the nerves of the respiratory muscles via the corticospinal tracts. In addition, ingoing impulses from many parts of the body modify the activity of the respiratory centers and consequently alter the outgoing impulses to the respiratory muscles to coordinate rhythm, rate or depth of breathing with other activities of the body.

SENSORY STIMULI	REFLEX alteration in respiratory movement
Pungent odors irritating nerve ending in nasal mucosa	Short inspirations, forced expirations with GLOTTIS open in sneezing.
Bolus of food contacting pharynx	Inhibition of respiration during swallowing.
Irritant contracting larynx, trachea	Short inspiration; series of forced expirations with GLOTTIS closed: GLOTTIS opens suddenly; blast of air carries out irritant material in coughing.
Painful, hot, cold stimuli to nerve ending in skin	Sharp inspiration after sudden pain or cold; increasing rate and depth of breathing with heat.

Stretch-proprioceptors
In INTERCOSTAL muscles.
DIAPHRAGM
ADOMINAL muscles

Spasmodic
Contraction of
Diaphragm
with GLOTTIS
Closed in
hiccoughing.

$\downarrow O_2$
as at high altitude
CHEMORECEPTORS
in CAROTID BODY
and AORTIC BODY

Decrease in blood pressure
BARORECEPTORS
In CAROTID sinus and
AORTIC arch

Respiration
stimulated.

- Proprioreceptors stimulated during muscle movements send impulses to respiratory center rate and depth of breathing.

(NB: This occurs with active or passive movements of limbs.)

In normal breathing respiratory rate and rhythm are thought to be influenced rhythmically by the **Hering-Breuer reflex.**