Department of Veterinary Physiology

MJF College of Veterinary & Animal Sciences, Jaipur, Rajasthan- 303702

B.V.Sc. & A.H.

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Respiration during Exercise

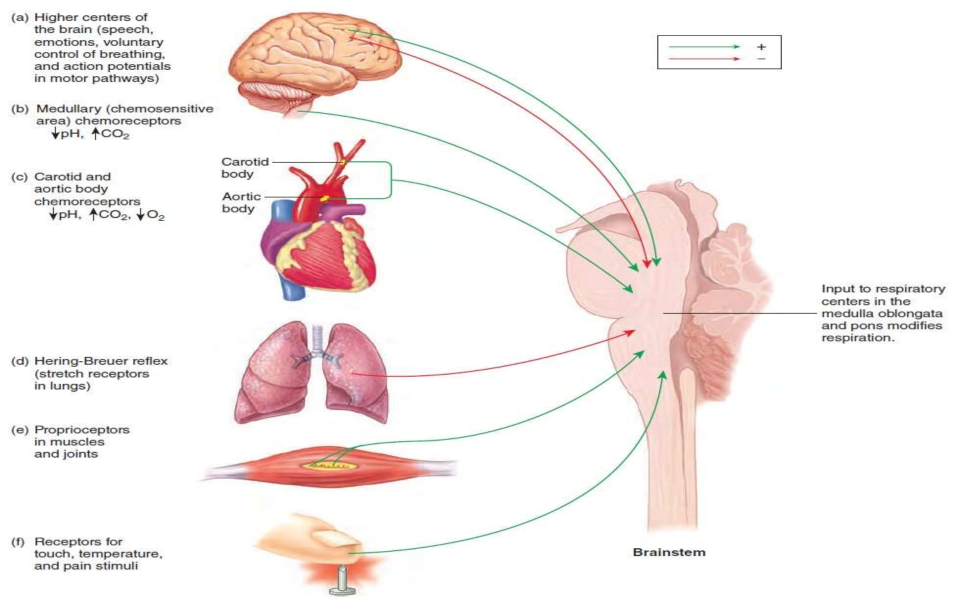

Figure 15.16 Nervous and Chemical Mechanisms of Breathing

Several regulatory mechanisms affect the rate and depth of breathing. A plus sign indicates that the mechanism increases breathing and a minus sign indicates that it results in a decrease in breathing.

Dr. Brijesh Kumar
Assistant Professor
Dept. of Veterinary Physiology

Dr. Sandeep Bissu
Assistant Professor
Dept. of Veterinary Physiology

Humoral Control and Respiration during Exercise

- **Humoral Control**
- **Respiration during Exercise**
  - Respiratory Changes
  - Cardiac Changes
  - Circulatory Changes

Non-respiratory functions of lungs

VENTILATION AND CARDIAC RESPONSE DURING EXERCISE
(Physiological Adjustment to Exercise)

- Exercise requires the coordination of most of the body's organ systems
  - Working muscle can increase its O_2 consumption by an enormous factor (up to 100 times for individual muscles)
  - Requires rapid O_2 delivery and fast removal of waste and heat.
- Any exercise for more than a few seconds duration
  - Requires aerobic respiration to provide enough energy
  - Anaerobic glycolysis gives only 2 ATPs/glucose while aerobic respiration gives 36 ATPs/glucose

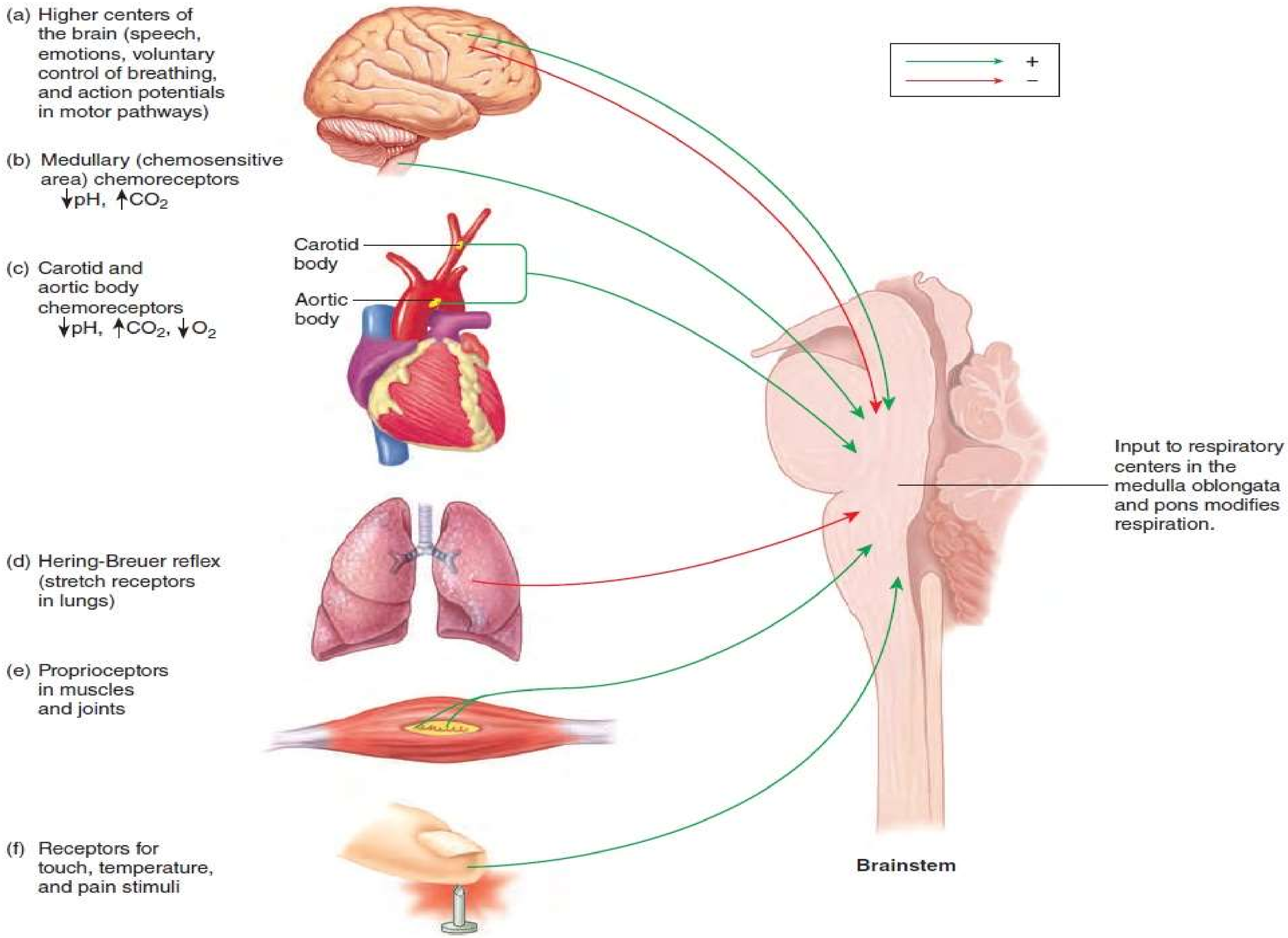

Figure 15.16 Nervous and Chemical Mechanisms of Breathing

Several regulatory mechanisms affect the rate and depth of breathing. A plus sign indicates that the mechanism increases breathing and a minus sign indicates that it results in a decrease in breathing.

- O_2 consumption goes up with intensity of exercise because aerobic metabolism must be used to generate ATP
- Glycogen is the main initial fuel source

- Sympathetic nervous system causes glycogen breakdown to glucose
- Liver releases glucose into the blood to supply muscles and brain

Respiratory changes during Exercise

- ***Tidal volume and respiratory frequency***
- In heavy exercise respiratory frequency in horses increases from about **15-45 breathes/min at rest to about 130-140 breathes/min**
- The tidal volume can increase from about **7 L/min to about 12-15 L/breath**
- These 2 factors together increase the pulmonary ventilation from about **210 L/min to over 1560 L/min**
- The stimuli for increased respiration in exercise are
  - Stimuli from motor cortex, from proprioceptors of joint and muscles
  - Elevated pulmonary blood flow with elevated venous CO_2

S.N.	Criteria	Normal Respiration	Respiration during Exercise
	O_2 Consumption	C	40C (80L/Min.)
	Minute ventilation	MV	23 MV
	cardiac output	CO 30L/Min.	5-8 CO 150-300L/Min.
	O_2 carrying capacity		60% increase
	Heart Beat	30/ Minute	240-250/Minute

Oxygen consumption

- O_2 consumption is augmented in horses by more than 40 fold between rest and exercise
- Maximal O_2 consumption can reach up to 80 L/min for a 440 kg horse
  - To provide this increase in O_2 consumption, minute ventilation, cardiac output and Hb level (by release of stored erythrocytes from spleen) increases
- 40-fold increase in O_2 consumption is provided by **23 fold increase** in minute ventilation and **5-8 fold increase in cardiac output.**
- This is due to the ability to augment O_2 consumption by 40 fold, cardiac output by 8 fold, O_2 extraction by 5 fold, 60% increase in O_2 carrying capacity.

Blood gases
acidosis

- During strenuous exercise horses develop metabolic
- $PaCO_2$ increases in horses (in many species, $PaCO_2$ falls due to higher respiratory frequency)
- Arterial PO_2 decreases (reason not known) in horses and human athletes
- Arterial pH declines
- Combined effect of low PO_2, pH and high temperature delivers more O_2 to tissues (decreased affinity of Hb to O_2)
- *Respiration is usually not the limiting factor in endurance exercise*
- In older horses and during prolonged intense exercise, bleeding from nose (*epistaxis*) may be observed which is called as ***exercise-induced pulmonary haemorrhage***.

Cardiac Changes during Exercise

- ***Stroke Volume and Heart Rate Go Up, Increasing Cardiac Output***
- In exercise the heart rate of horses rises from about 30 beats/min to 240–250 beats/min; in dogs it is raised from about 100 to 300 beats/min
- The stroke volume is increased in dogs and horses which are due to increased sympathetic nerve activity, increased venous return and increase in EDV.
- Myocardial contractility is increased
  - Due to increase in preload and afterload, increase in myocardial O_2 consumption
- Combined, these adjustments can increase cardiac output (CO) of horses from approximately **30 L/min to nearly 150-300 L/min (5-8 fold increase)**
- Cardiac output is controlled by the ANS and by hormones like epinephrine

- The increased CO in exercise will cause the **pressure to rise from 130/80 to 230/100 mmHg**
- **The cardiovascular system may be the limiting factor in endurance exercise**
- Blood flow increases in pulmonary circulation, coronary vessels and skeletal muscles and in skin but blood flow is decreased in nonworking muscles and splanchnic organs.

Circulatory Response to Exercise

- Skeletal muscle blood flow increases during exercise and this increase is caused by local metabolic control mechanisms.
- From initiation of exercise, metabolic products accumulate in the muscles and O_2 concentration decreases. Both factors produce vasodilatation of the skeletal muscle arterioles and this vasodilatation is a local response not dependent on nerves or hormones.
- Blood flow increase to the skeletal muscles which delivers more O_2 and removes the metabolic end products, thus maintaining balance between metabolic activity and blood flow.
- In exercise more blood is shifted to muscle and heart tissue; less blood goes to the viscera and tissues not needed at the moment:
- Flow to skin is initially reduced but is later increased to get rid of excess heat

Tissue	Rest L/min	Exercise L/min
Viscera	1.2	0.6
Muscle & Heart	1.0	26.0
Other	2.8	3.4
Total	5.0	30.0

- **However, there are three *compensatory neural mechanisms* -**
- **central command**
- **Exercise reflex and**
- **Arterial baroreceptor reflex available to the body to maintain sufficient arterial B.P. and skeletal muscle blood flow.**
- ***Non-neural Mechanisms*:** Two non–neural mechanisms help to increase cardiac output during exercise.
- ***Muscle Pump*:**
- ***Respiratory Pump*:**

NON–RESPIRATORY FUNCTIONS OF LUNGS

- **THERMAL REGULATION – PANTING**
- **Defense Function**
- **Metabolic Function**
- ***Metabolic acidosis***
- ***Metabolic alkalosis***
- ***Respiratory Acidosis***
- ***Respiratory Alkalosis***

Thank You!!!