Cardiovascular Physiology
Regulation of Heart Rate
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Part 11-12

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Regulation of Heart Rate

- **Cardiac output** depends on both **heart rate** and **stroke volume**

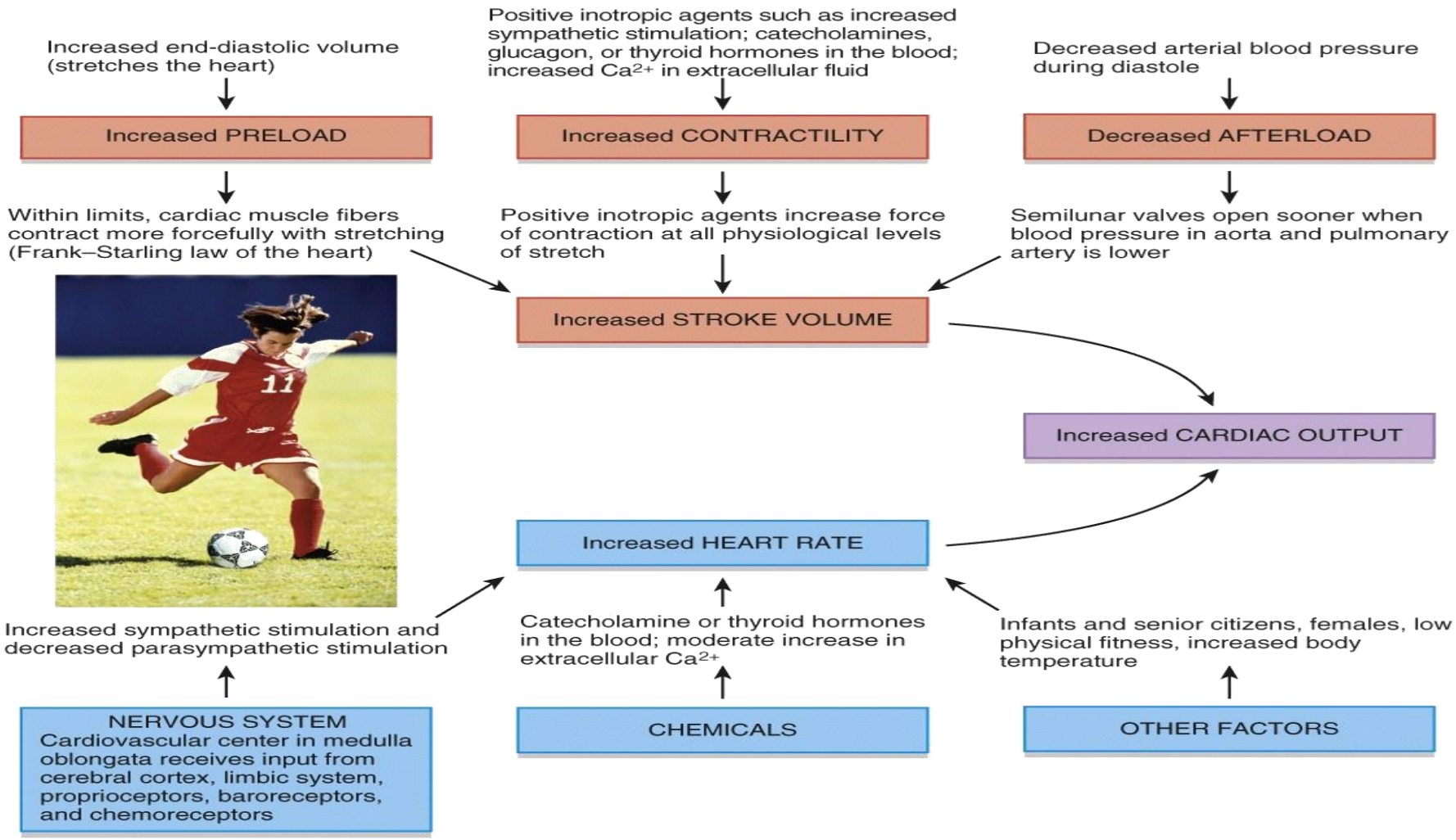
- Among the several factors that contribute to regulation of heart rate, the most important are:

1. The autonomic nervous system (**Autonomic Regulation**)

2. Hormones released by the adrenal medullae (epinephrine and norepinephrine) (**Chemical Regulation**)

- Adjustments in heart rate are important in the short-term control of cardiac output and blood pressure

Cardiac Output



Autonomic Regulation of Heart Rate

- Nervous system regulation of the heart originates in the **cardiovascular center in the medulla oblongata**.

- This region of the brain stem receives input from a variety of sensory receptors and from higher brain centers, such as the limbic system and cerebral cortex.

- The cardiovascular center then directs appropriate output by **increasing or decreasing** the frequency of nerve impulses in both the **sympathetic and parasympathetic** branches of the ANS.

Autonomic Regulation of Heart Rate

- Even before physical activity begins, an increase in heart rate occurs because the **limbic system** sends nerve impulses to the cardiovascular center in the medulla.

- As physical activity begins, **proprioceptors** that are monitoring the position of limbs and muscles send nerve impulses at an increased frequency to the cardiovascular center.

- Other sensory receptors that provide input to the cardiovascular center include **chemoreceptors**, which monitor chemical changes in the blood, and **baroreceptors** (located in the arch of the aorta and in the carotid arteries), which monitor the stretching of major arteries and veins caused by the pressure of the blood flowing through them.

Sympathetic Regulation of Heart Rate

- Sympathetic neurons extend from the **medulla oblongata** into the **spinal cord**. From the thoracic region of the spinal cord, sympathetic cardiac accelerator nerves extend out to the SA node, AV node, and most portions of the myocardium.

- Impulses in the cardiac accelerator nerves trigger the release of **norepinephrine**, which binds to **beta-1 receptors** on cardiac muscle fibers.

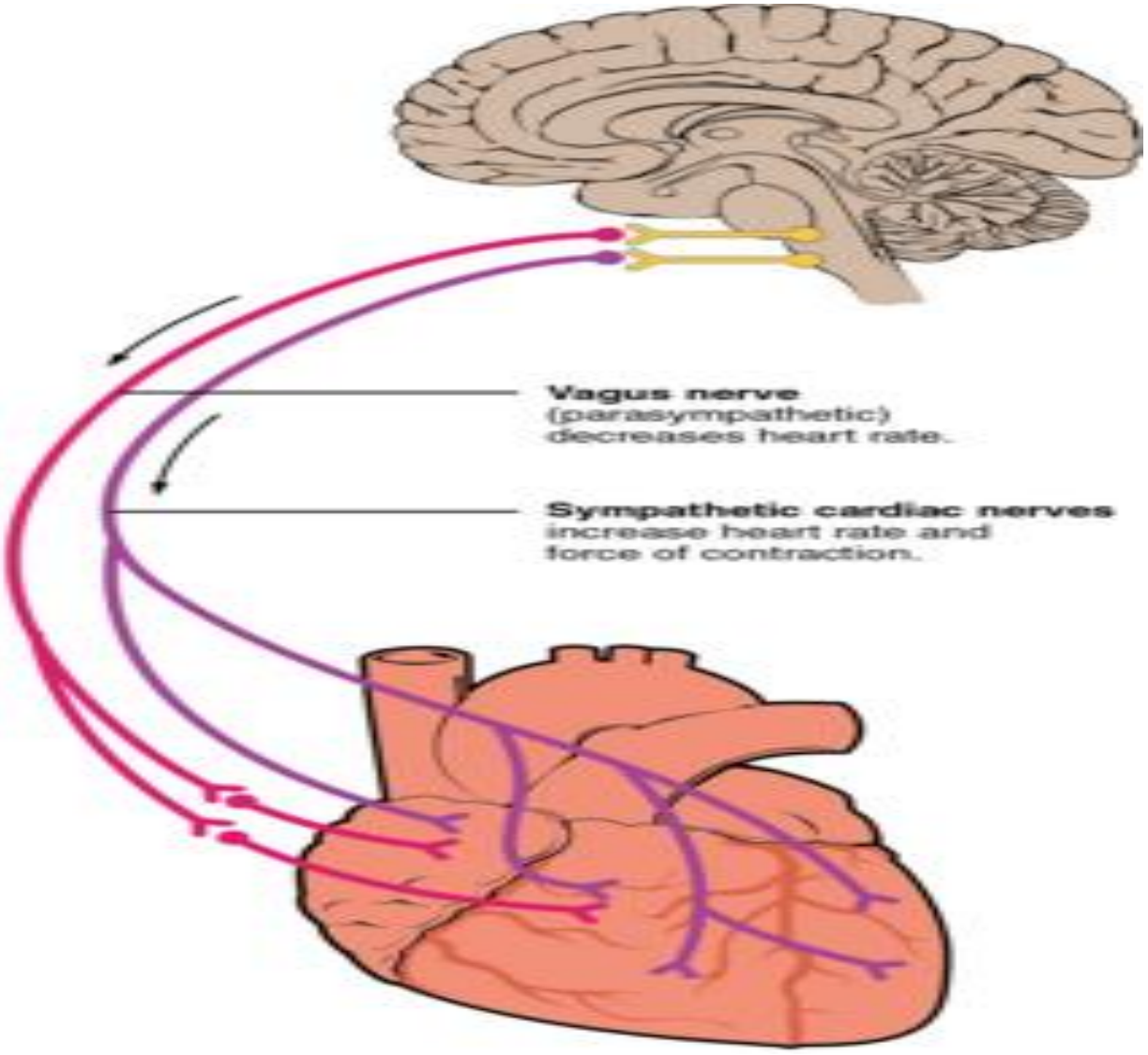
Autonomic Regulation of Heart Rate

- This interaction has two separate effects:

(1) In SA (and AV) node fibers, norepinephrine speeds the rate of spontaneous depolarization so that these pacemakers fire impulses more rapidly and heart rate increases

(2) In contractile fibers throughout the atria and ventricles, norepinephrine enhances Ca2 entry through the voltage-gated slow Ca2 channels, thereby increasing contractility. As a result, a greater volume of blood is ejected during systole. With a moderate increase in heart rate, stroke volume does not decline because the increased contractility offsets the decreased preload.

Autonomic Regulation of Heart Rate



Autonomic Regulation of Heart Rate

- With **maximal sympathetic stimulation**, however, heart rate may reach 200 beats/ min in a 20-year-old person. At such a high heart rate, **stroke volume is lower** than at rest due to the very short filling time.

- The maximal heart rate declines with age; as a rule, subtracting your age from 220 provides a good estimate of your maximal heart rate in beats per minute.

Parasympathetic Regulation of Heart Rate

- Parasympathetic nerve impulses reach the heart via the **right and left vagus (X) nerves**. Vagal axons terminate in the SA node, AV node, and atrial myocardium.

- They release acetylcholine, which decreases heart rate by slowing the rate of spontaneous depolarization in autorhythmic fibers. As only a few vagal fibers innervate ventricular muscle, changes in parasympathetic activity have little effect on contractility of the ventricles.

Autonomic Regulation of Heart Rate

- A continually shifting balance exists between sympathetic and parasympathetic stimulation of the heart. At rest, parasympathetic stimulation predominates. The resting heart rate about 75 beats/min is usually lower than the autorhythmic rate of the SA node (about 100 beats/min).

- With maximal stimulation by the parasympathetic division, the heart can slow to 20 or 30 beats/min, or can even stop momentarily.

Chemical Regulation of Heart Rate

- Certain chemicals influence both the basic physiology of cardiac muscle and the heart rate. For example, hypoxia (lowered oxygen level), acidosis (low pH), and alkalosis (high pH) all depress cardiac activity.

- Several hormones and cations have major effects on the heart.

1. Hormones

1. Hormones. Epinephrine and norepinephrine (from the adrenal medullae) enhance the heart's pumping effectiveness.

- These hormones affect cardiac muscle fibers in much the same way as does norepinephrine released by cardiac accelerator nerves: they increase both heart rate and contractility.
- Exercise, stress, and excitement cause the adrenal medullae to release more hormones.
- Thyroid hormones also enhance cardiac contractility and increase heart rate. One sign of hyperthyroidism (excessive thyroid hormone) is tachycardia, an elevated resting heart rate.

2. Cations

- 2. Cations. Given that differences between intracellular and extracellular concentrations of several cations (for example, Na and K) are crucial for the production of action potentials in all nerve and muscle fibers, it is not surprising that ionic imbalances can quickly compromise the pumping effectiveness of the heart.

- In particular, the relative concentrations of three cations: K, Ca2, and Na have a large effect on cardiac function.

- Elevated blood levels of K or Na decrease heart rate and contractility.

2. Cations

- Excess Na blocks Ca2 inflow during cardiac action potentials, thereby decreasing the force of contraction, whereas excess K blocks generation of action potentials.

- A moderate increase in interstitial (and thus intracellular) Ca2 level speeds heart rate and strengthens the heartbeat.

Other Factors in Heart Rate Regulation

- Age, gender, physical fitness, and body temperature also influence resting heart rate.
- A newborn baby is likely to have a resting heart rate over 120 beats/min; the rate then gradually declines throughout life.
- Adult females often have slightly higher resting heart rates than adult males, although regular exercise tends to bring resting heart rate down in both sexes.
- A physically fit person may even exhibit bradycardia, a resting heart rate under 50 beats/min. This is a beneficial effect of endurance-type training because a slowly beating heart is more energy efficient than one that beats more rapidly.

Other Factors in Heart Rate Regulation

- Strenuous exercise, causes the SA node to discharge impulses more quickly, thereby increasing heart rate. Decreased body temperature decreases heart rate and strength of contraction.

- During surgical repair of certain heart abnormalities, it is helpful to slow a patient's heart rate by hypothermia, in which the person's body is deliberately cooled to a low core temperature.

- Hypothermia slows metabolism, which reduces the oxygen needs of the tissues, allowing the heart and brain to withstand short periods of interrupted or reduced blood flow during a medical or surgical procedure.


Thank You