EFFECT OF EXERCISE ON CARDIORESPIRATORY SYSTEM

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Anatomy and Physiology of the Heart

The heart is made up mainly of cardiac muscle. The heart is a funnel-shaped, hollow, muscular organ that is responsible for pumping blood to all parts of the body.

- The heart is located near the center of the thoracic cavity between the lungs and is contained in the pericardial sac.
- The pericardial sac supports the heart and contains some fluid for lubrication.

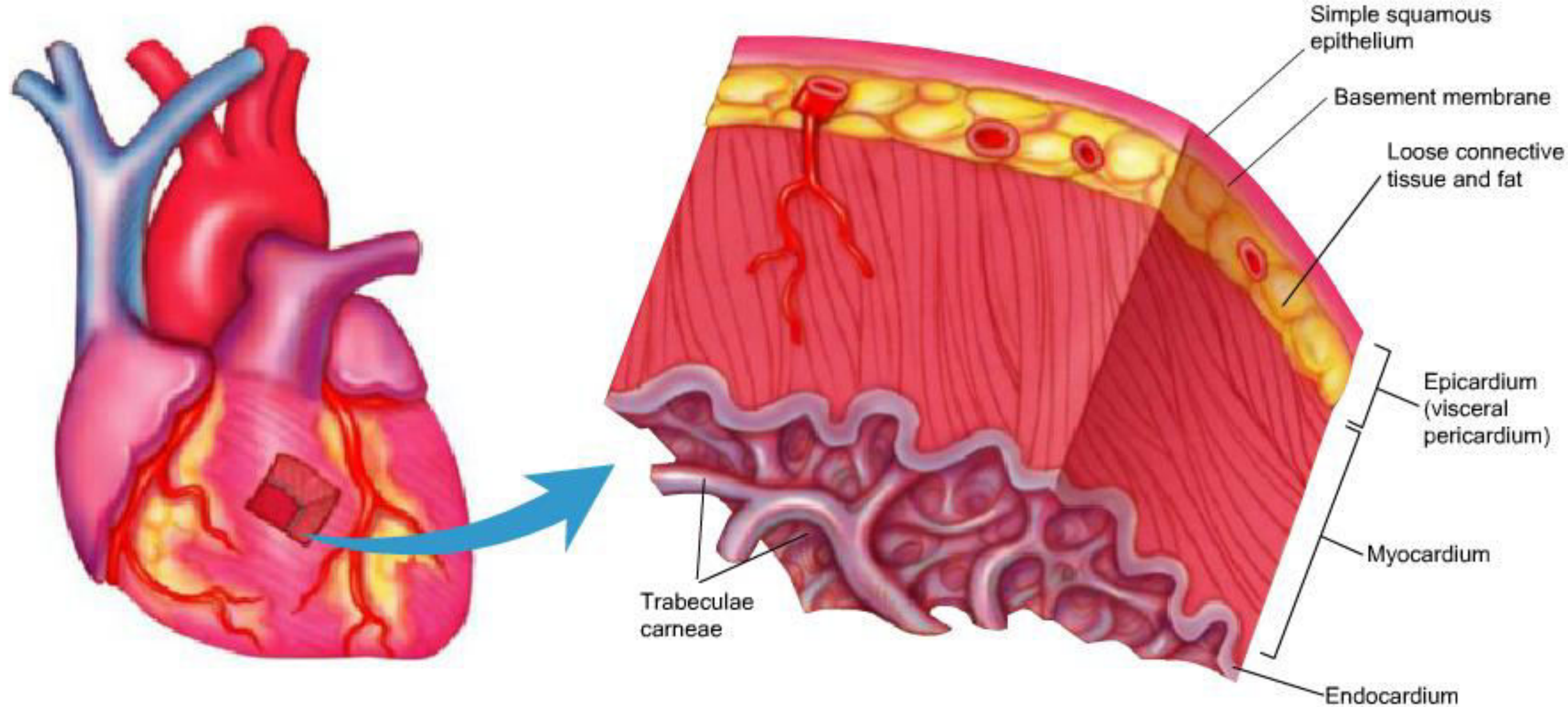


FIGURE 20.04
Heart Wall

The heart wall is made up of three layers.

- **Epicardium – outer layer of heart wall, which is also the inner layer of epicardial sac;**
- **Endocardium – inner layer that consists of endothelial cells, which line the heart, covers the heart valves, and lines the blood vessels.**
- **Myocardium – middle layer composed of cardiac muscle,** which contracts to pump blood.
- **The cardiac muscle is an involuntary, striated muscle with fibers that intertwine.**

- The heart is divided into **right and left hand side** by Septum. It is further divided into **four chambers.**
- Therefore, the heart is said to have

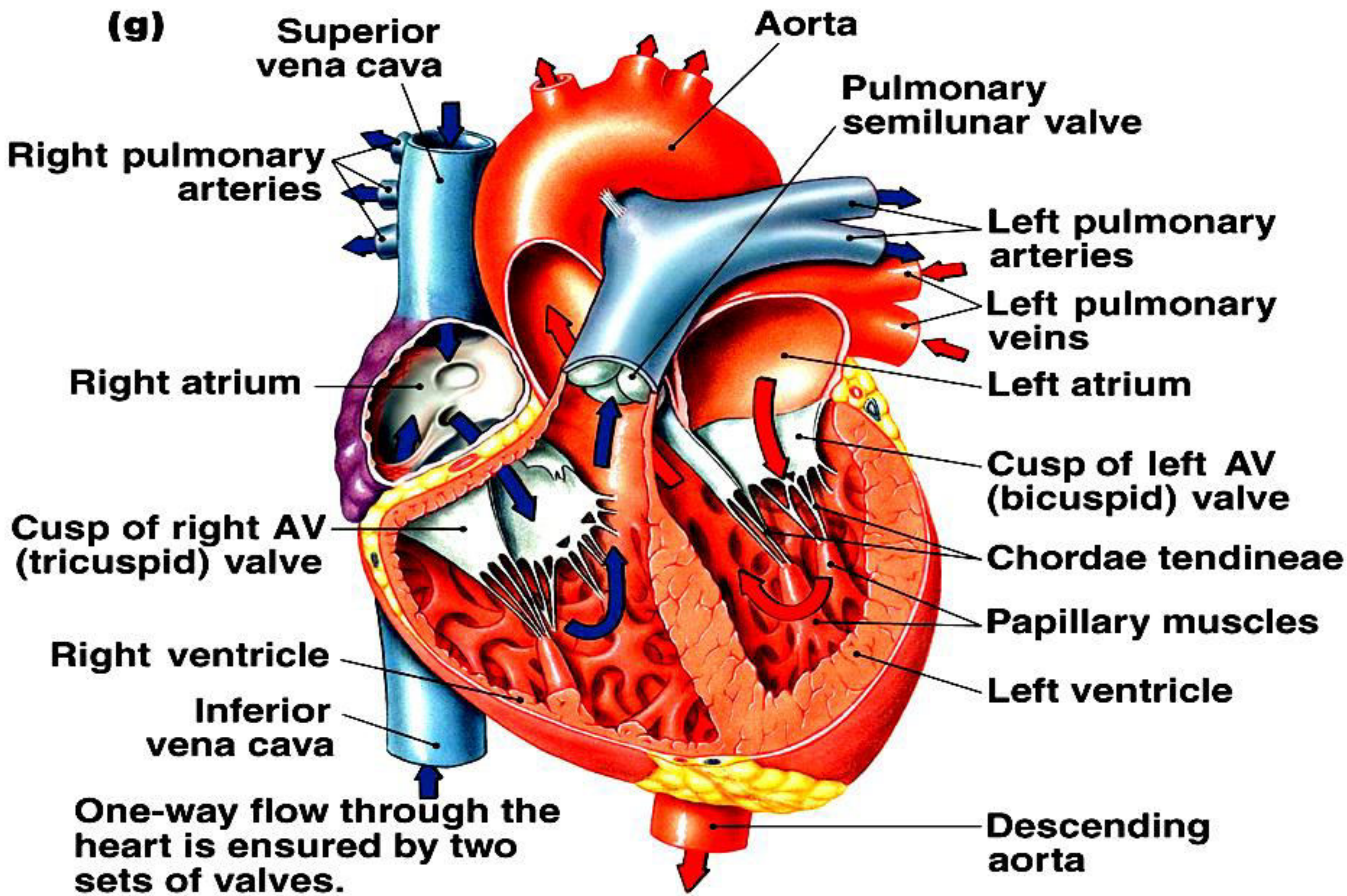
  Right atrium,

  Right ventricle,

  Left atrium, and

  Left ventricle.

Internal heart anatomy



- The **atrioventricular valves** (AV valve) separate the **atrium** and **ventricle** on each side of the heart.
- The AV valves have flaps of tissues, called cusps, which open and close to ensure that the blood flows only in one direction and does not backflow into the atriums.
- Two AV valves—between atria & ventricles, making a "**LUB**" sound when closing.
- Two SL valves—base of major arteries making a "**DUB**" sound when closing.

- The AV valve on the right side of the heart is called the **tricuspid valve** because it has three cusps.
- The AV valve on the left side of the heart is called the **bicuspid valve** (or mitral valve) because it has two cusps.
- The **pulmonary valve** and the **aortic valve** prevent blood from back-flowing into their respective ventricles.

- The pulmonary valve is located between the right ventricle and the pulmonary artery.
- The aortic valve is located between the left ventricle and the aortic artery.

Blood flow through the heart

The total circulation is divided into two main parts:

- Pulmonary circulation, and
- Systemic circulation.

Pulmonary circulation

- Pulmonary circulation is the part of the circulatory system that takes the blood from the heart to the lungs, where it is oxygenated, and returns it to the heart.
- The main parts of the pulmonary circulation system include the heart, pulmonary arteries, capillaries of the lungs, and pulmonary veins.

Flow of Blood in Pulmonary Circulation

- Blood that is low in oxygen returns to the heart through two large veins called the superior (or cranial) vena cava and the inferior (or caudal) vena cava.
- The un-oxygenated blood enters the right atrium of the heart.

- The blood then passes through the right atrioventricular (tricuspid) valve into the right ventricle.
- The right ventricle pumps the blood through the pulmonary valve into the pulmonary artery.
- The pulmonary artery quickly divides into two branches.
- Each branch of the pulmonary artery carries blood to a lung.
- In the lungs the pulmonary arteries branch into capillaries that surround the alveoli.

- Through diffusion, carbon dioxide moves from the blood into the alveoli and oxygen moves from the alveoli into the blood.
- The oxygenated blood then returns to the heart through the pulmonary vein into the left atrium.
- From the left atrium, the blood flows through the left atrioventricular (bicuspid) valve into the left ventricle.
- The thick-walled left ventricle pumps the blood through the aortic valve into the aorta.

- Un-oxygenated blood is dark or brownish red, while oxygenated blood is bright red.
- In the pulmonary system, un-oxygenated blood is carried by the pulmonary arteries and oxygenated blood is carried by pulmonary veins.
- In the systemic system, arteries carry oxygenated blood and veins carry un-oxygenated blood.

Systemic circulation

- The **systemic circulation** includes the flow of oxygenated blood from the heart to the tissues in all parts of the body and the return of un-oxygenated blood back to the heart.
- The **blood vessels**, including the **arteries**, **capillaries**, **and veins**, are the main parts of systemic circulation.
- Through systemic circulation, **oxygen and nutrients** are delivered to the body tissues via the arteries.
- Blood is filtered during systemic circulation by the **kidneys** (most of the waste) and **liver** (sugars).

Cardiac Cycle

- The heart's constant contracting and relaxing forces blood into the arteries. Each contraction is followed by limited relaxation. Cardiac muscle never completely relaxes:

- Contraction of the heart is called systole or "the period of work." Relaxation of the heart is called diastole or "the period of rest.

- This process is directed by the nervous system, nerve impulses initiating each sequence.

The Heartbeat:

A. Cardiac cycle — one complete heart beat where both atria contract simultaneously followed by both ventricles contracting simultaneously.

a. Systole — when ventricles contract and pump blood out of the heart.

b. Diastole—when ventricles relax and receive blood from atria.

The *heart sounds*, lub-dup, are due to the closing of the atrioventricular valves, followed by the closing of the semilunar valves.

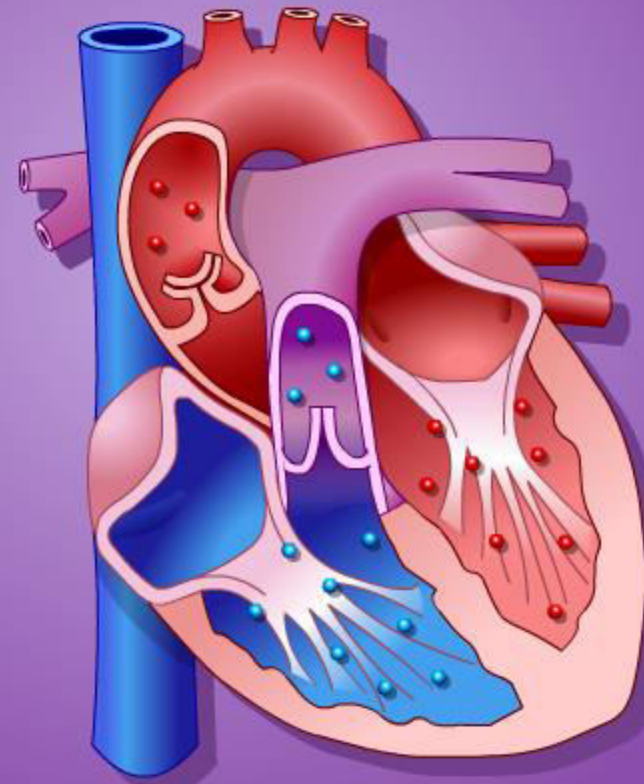
Intrinsic Control of Heartbeat

- The *SA* (*sinoatrial*) *node*, or *pacemaker*, initiates the heartbeat and causes the atria to contract on average every 0.85 seconds.
- The *AV* (*atrioventricular*) *node* conveys the stimulus and initiates contraction of the ventricles.
- The signal for the ventricles to contract travels from the AV node through the *atrioventricular bundle* to the smaller *Purkinje fibers*.

Extrinsic Control of Heartbeat

- A *cardiac control center* in the medulla oblongata speeds up or slows down the heart rate by way of the autonomic nervous system branches: *parasympathetic system* (slows heart rate) and the *sympathetic system* (increases heart rate).
- Hormones *epinephrine* and norepinephrine from the adrenal medulla also stimulate faster heart rate.

The Cardiac Cycle



Ventricular contraction causes the atrioventricular (AV) valves to close, which signals the beginning of ventricular systole. The semilunar valves were closed during the previous diastole and remain closed during this period.

The Heartbeat cont.

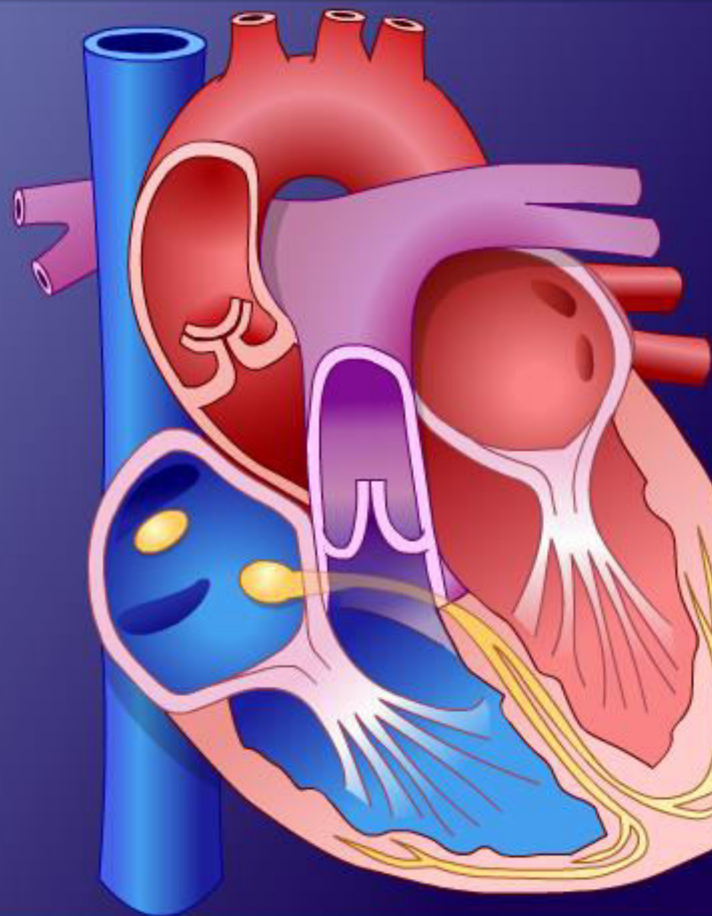
B. Intrinsic Conduction System:

* SA node (pacemaker)—initiates the heartbeat and causes the atria to contract.
* AV node—causes the ventricles to contract.

C. Extrinsic Control of Heartbeat—the autonomic nervous system and hormones can modify the rate of the heartbeat.

D. Electrocardiogram (ECG)—a recording of the electrical changes that occur in the myocardium during a cardiac cycle.

Conducting System of the Heart

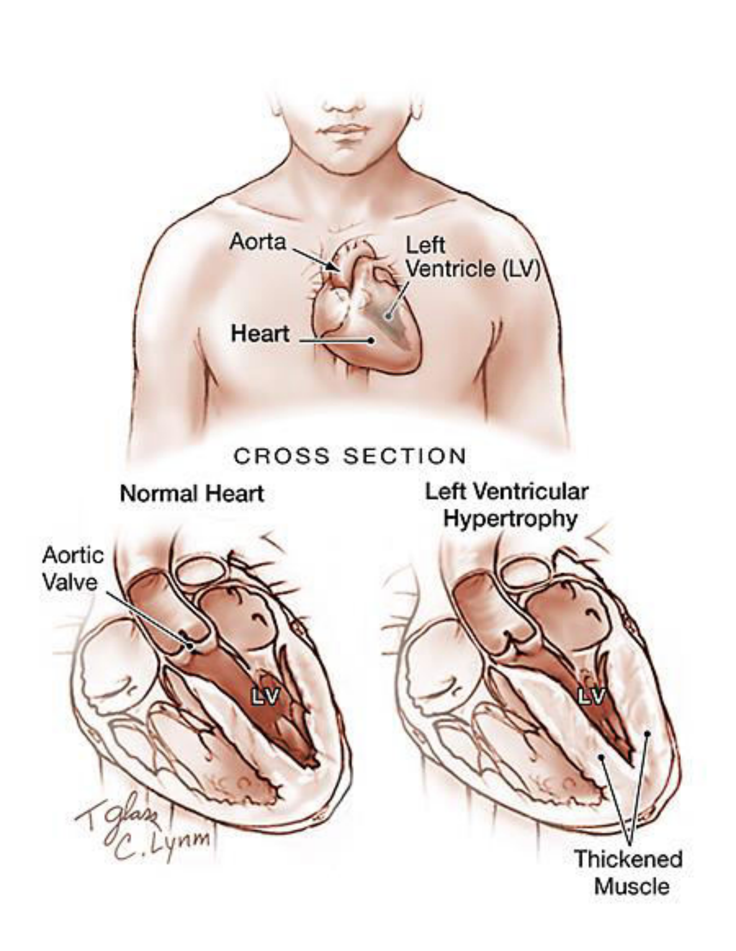


Action potentials originate in the sinoatrial (SA) node and travel across the wall of the atrium from the sinoatrial node to the atrioventricular (AV) node.

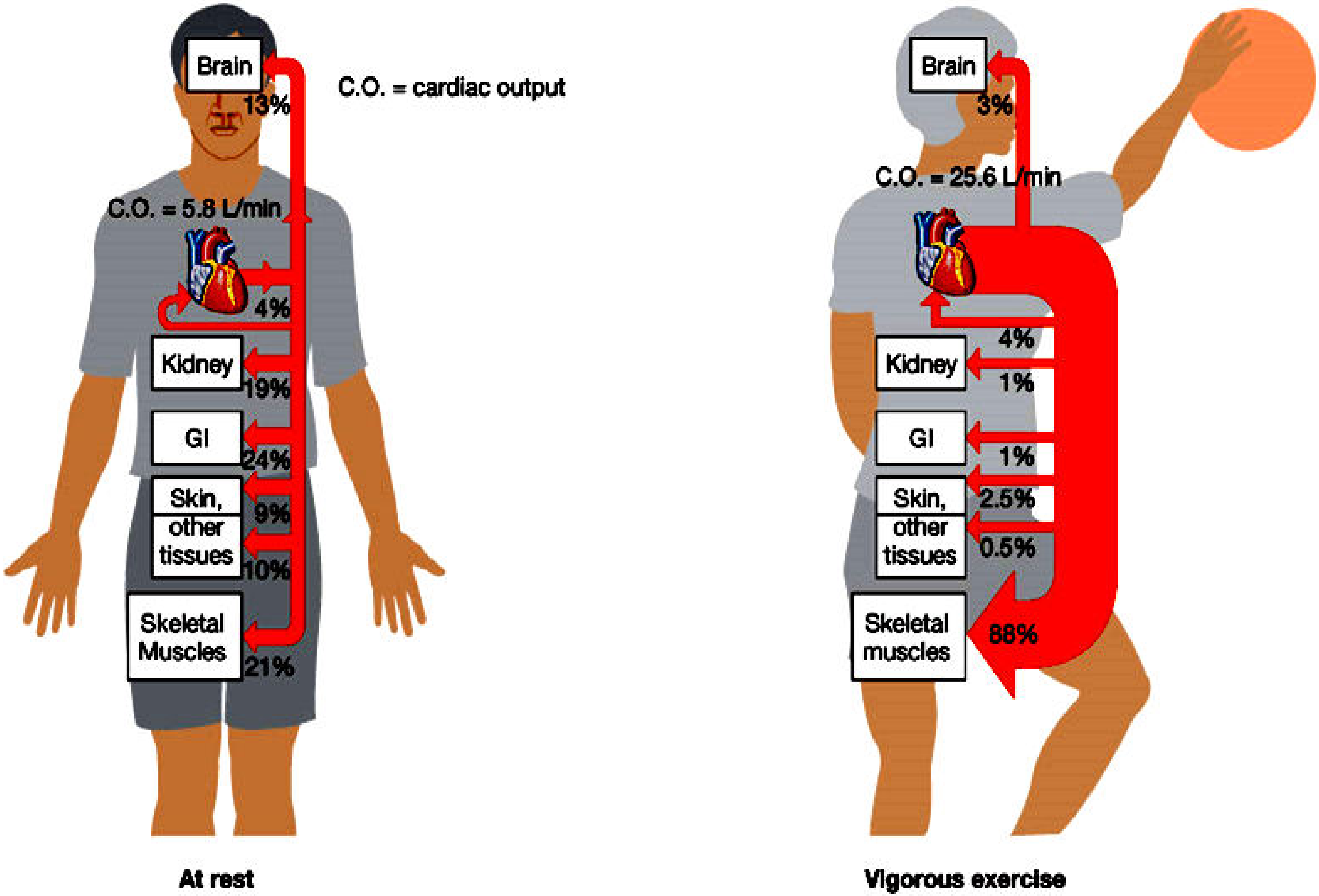
Cardio respiratory adaptations from aerobic training

- Chronic cardio (heart) and respiratory (lungs) changes are easier to remember if you understand that the changes are occurring to improve the ability to carry oxygen around the body to the working muscles

- These changes are important and decrease your chance of developing heart disease / problems.



Cardiovascular Response to Exercise



Chronic adaptations to Aerobic training

- Cardiac hypertrophy (increased ventricular volume)
- Increased capillarisation of the heart muscle
- Increased stroke volume
- Lower resting heart rate
- Lower heart rate during sub max workloads
- Improved heart rate recovery rates

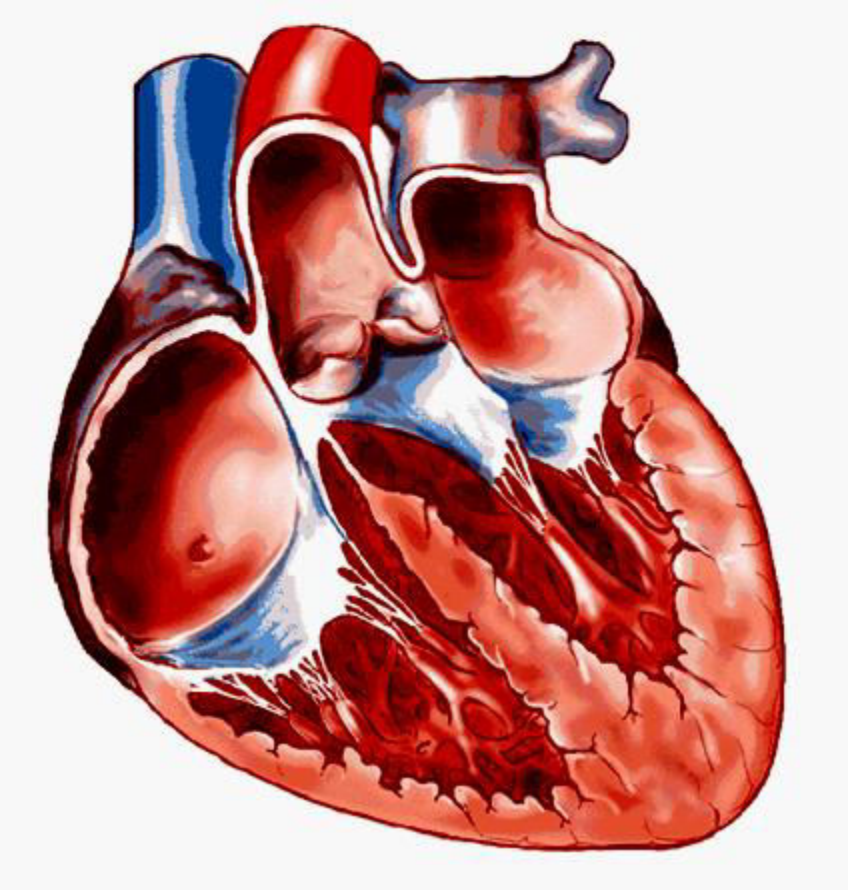
Chronic adaptations to Aerobic training

- Increased cardiac output at max. workloads
- Lower blood pressure
- Increased arterio-venous oxygen difference (a-VO2 diff)
- Increased blood volume and haemoglobin levels
- Increased capillarisation of skeletal muscle
- Changes to blood cholesterol, triglycerides, lipoprotein levels (L.D.L's and H.D.L's)
- Increased lung ventilation
- Increased max. oxygen uptake (VO2 max)
- Increased anaerobic threshold

CARDIOVASCULAR ADAPTATIONS TO AEROBIC TRAINING

CARDIAC HYPERTROPHY

Enlargement of the heart muscle itself. The heart chambers are enlarged, therefore increased ventricular volume – most important is LV size.



INCREASED CAPILLARISATION OF THE HEART MUSCLE

- Cardiac hypertrophy also leads to an increase in the capillary density and blood flow to the heart muscle itself.
- The increased supply of blood and O2 allows the heart to beat more strongly and efficiently during both EXERCISE and REST.
- Also decreases chance of heart attack.

INCREASED STROKE VOLUME

- Stroke volume is the amount of blood pumped per beat. Through aerobic training SV increases at REST, during SUB MAX. workloads and MAX. workloads.

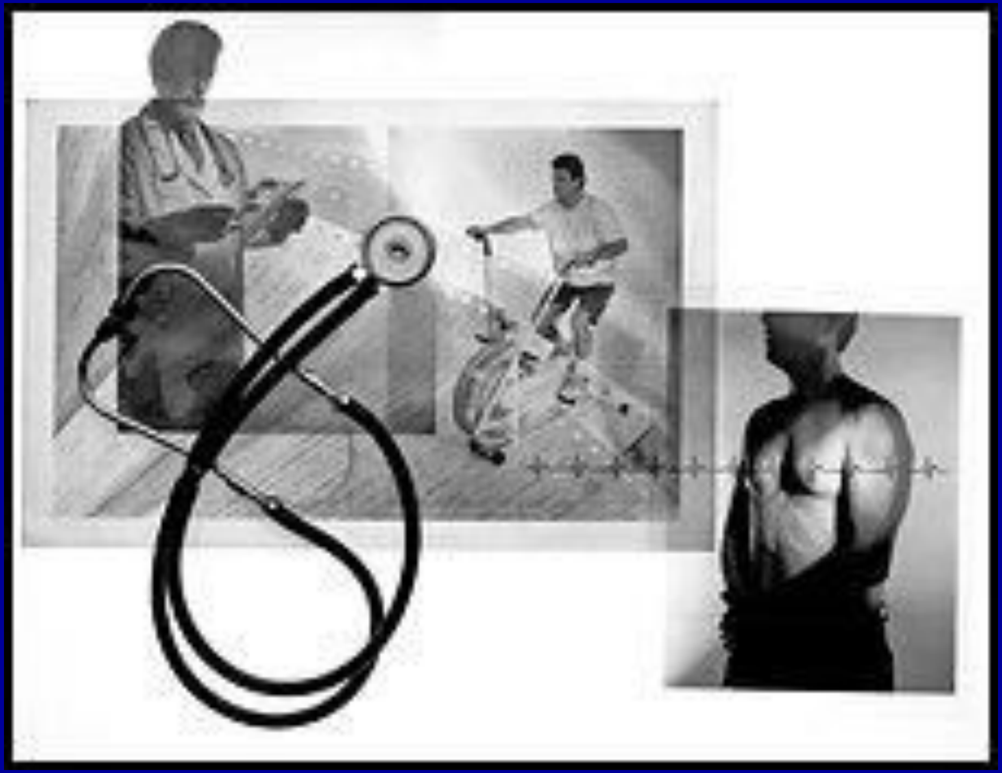
LOWER RESTING HEART RATE

- Resting heart rate is very useful in determining aerobic fitness. Generally the lower the resting heart rate the greater the aerobic fitness level.
- Because the athlete has greater stroke volume the heart does not need to beat as often to pump the same amount of blood around the body

CARDIOVASCULAR ADAPTATION

LOWER HEART RATE DURING SUB MAX WORKLOADS

- Compared to untrained individuals, athletes have lower heart rates during sub max. workloads. Mainly due to increased SV.
- The heart works more efficiently



CARDIOVASCULAR ADAPTATIONS

IMPROVED HEART RATE RECOVERY

- The heart rate of an athlete will return to normal (pre exercise levels) quicker than an untrained person.

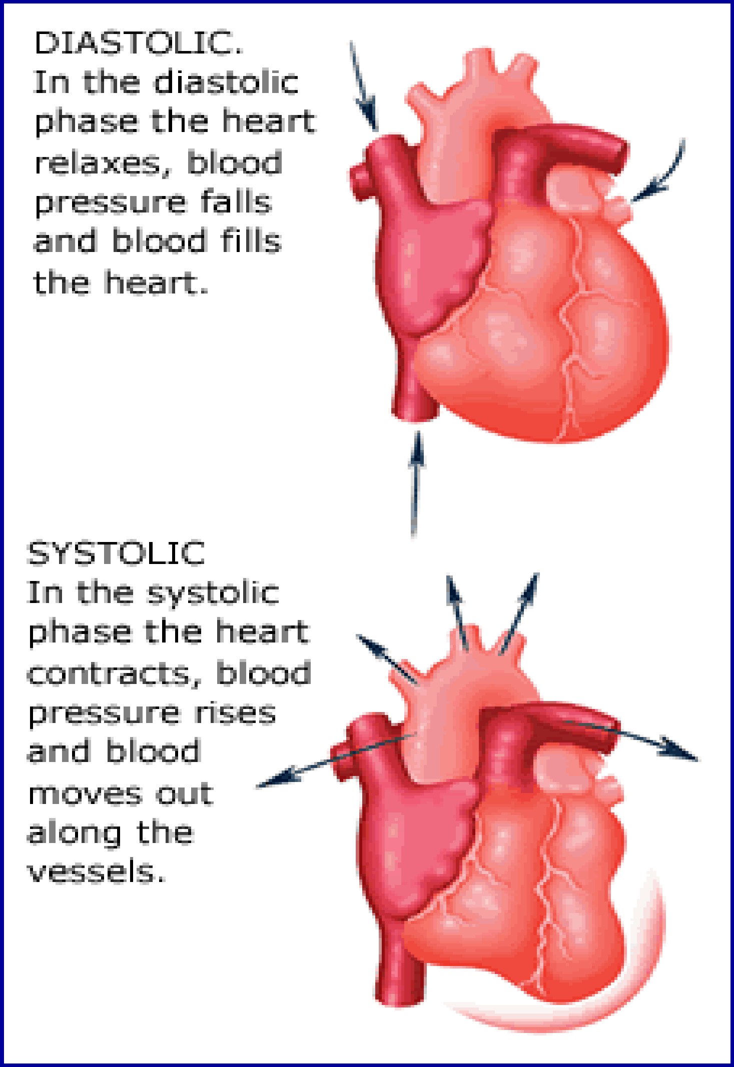
INCREASED CARDIAC OUTPUT AT MAXIMUM WORKLOADS

- Cardiac Output is the amount of blood pumped by the heart per minute
- Q remains unchanged at rest and even during sub max. work regardless of how hard you train.
- During max. exercise may increase up to 30 litres per minute for highly trained athletes

CARDIOVASCULAR ADAPTATIONS

LOWER BLOOD PRESSURE

- **Both systolic and diastolic blood pressure levels may decrease during REST and EXERCISE.**
- **This helps by reducing resistance to blood flow and reduces strain on the heart.**



INCREASED ARTERIO-VENOUS OXYGEN DIFFERENCE (a-VO2 diff)

- Due to increased myoglobin stores and an increase in size and number of mitochondria trained individuals are able to absorb more O2 from their blood.
- a-VO2 diff is increased during SUB MAX and MAX exercise. A bigger a-VO2 diff indicates greater uptake of o2 by the muscle

INCREASED BLOOD VOLUME AND HAEMOGLOBIN LEVELS

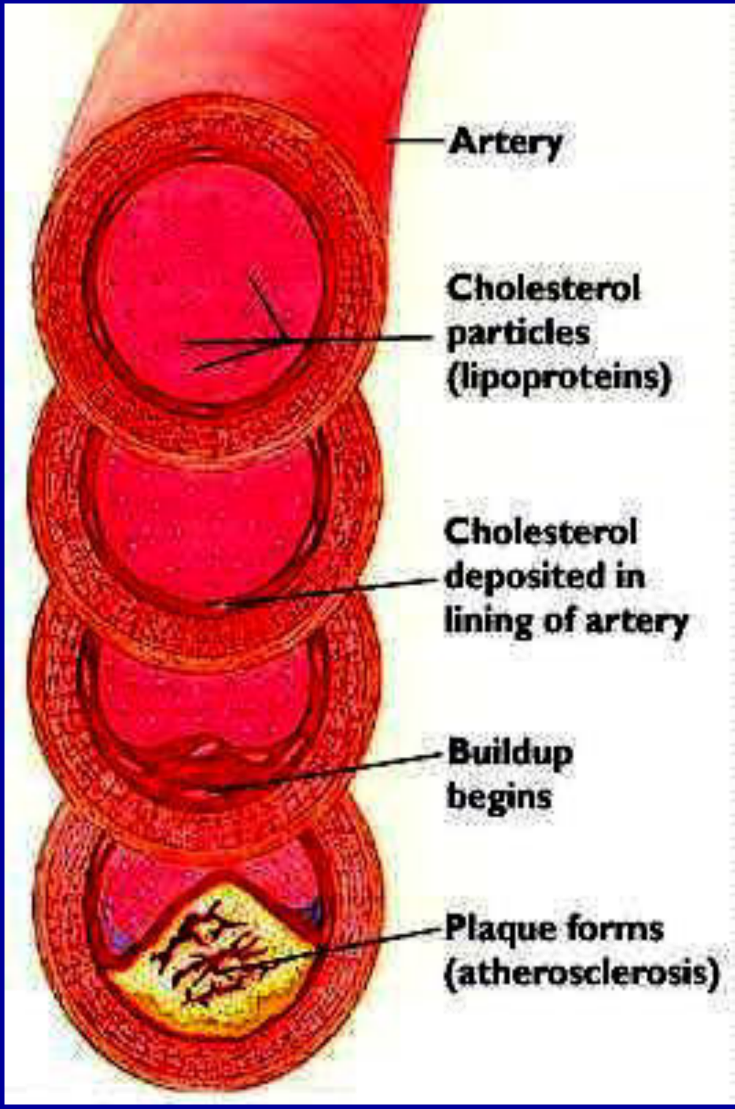
- Aerobic training may lead to total blood volume increasing up to 25%, as a result RBC's may increase in number and therefore haemoglobin content increases thus O2 carrying capacity increases also.

INCREASED CAPILLARISATION OF SKELETAL MUSCLE

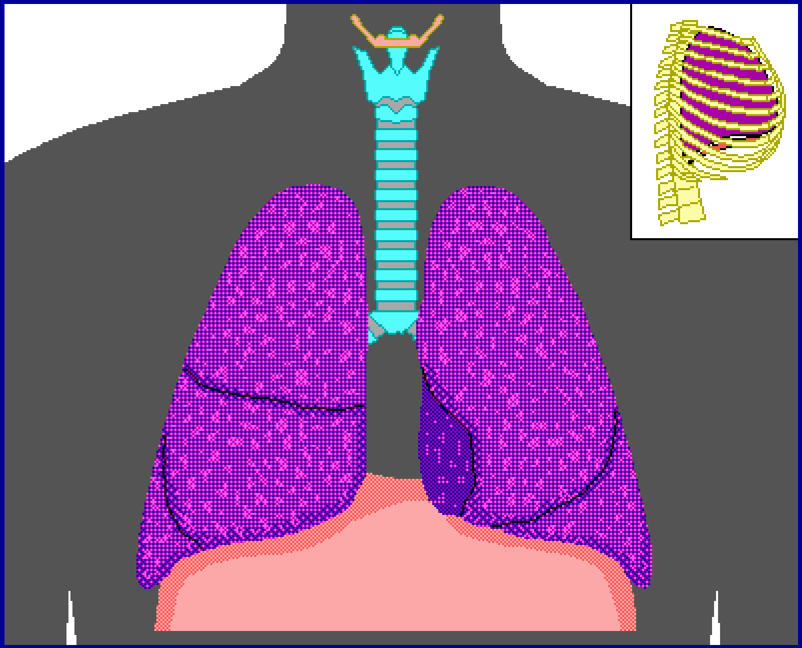
- Long term aerobic training leads to increased capillarisation of the muscle, therefore more blood supply therefore more O2 can be delivered to the muscle

CHANGES TO BLOOD CHOLESTEROL, TRIGLYCERIDES, LOW AND HIGH DENSITY LIPOPROTEIN LEVELS

- Regular aerobic training may result in a decrease in blood cholesterol levels, triglycerides and LDL's. These substances are important in fighting heart disease.
- Also HDL's are thought to increase – these are the good lipoproteins and protect us against heart disease.



RESPIRATORY ADAPTATIONS



- When talking about the respiratory system we are talking about the lungs, air passages and our breathing (ventilation).

RESPIRATORY ADAPTATIONS

- Just as there are cardiovascular adaptations to AEROBIC training there are also respiratory adaptations. These include:
- Increased lung ventilation
- Increased oxygen uptake
- Increased anaerobic or lactate threshold

RESPIRATORY ADAPTATIONS

INCREASED LUNG VENTILATION

- Aerobic training results in a more efficient and improved lung ventilation.
- At REST and during SUB MAX. work ventilation may be decreased due to improved oxygen extraction (pulmonary diffusion), however during MAX. work ventilation is increased because of increased tidal volume and respiratory frequency.

RESPIRATORY ADAPTATIONS

INCREASED MAXIMUM OXYGEN UPTAKE (VO2 MAX)

- VO2 max is improved as a result of aerobic training – it can be improved between 5 to 30 %. (LIU page 255)
- Improvements are a result of:

  -Increases in cardiac output

  -red blood cell numbers

  -a-VO2 diff

  - muscle capillarisation

  - greater oxygen extraction by muscles

RESPIRATORY ADAPTATIONS

INCREASED ANAEROBIC OR LACTATE THRESHOLD

- As a result of improved O2 delivery & utilisation a higher lactate threshold (the point where O2 supply cannot keep up with O2 demand) is developed.
- Much higher exercise intensities can therefore be reached and LA and H+ ion accumulation is delayed.
- The athlete can work harder for longer