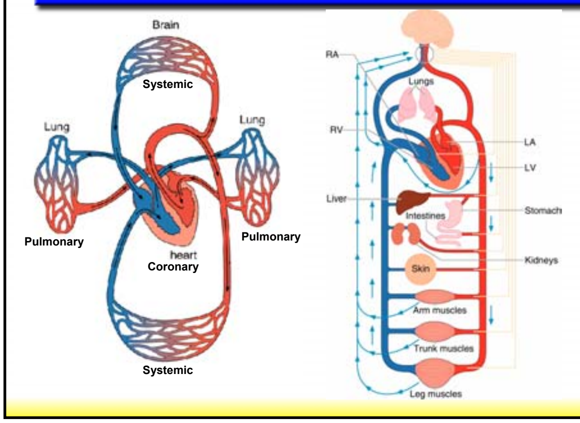
CARDIOVASCULAR CONTROL DURING EXERCISE & CARDIORESPIRATORY ADAPTATIONS TO TRAINING

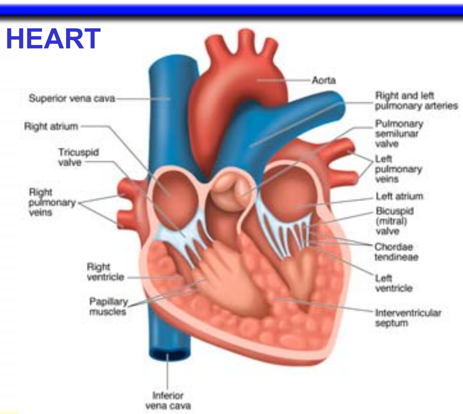
THE CARDIOVASCULAR SYSTEM



Normal Heart

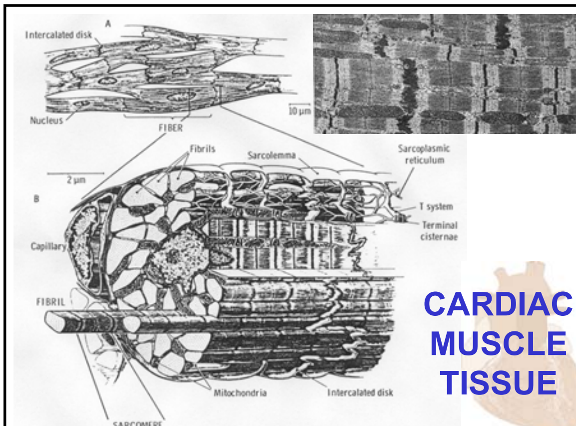
This is the external appearance of a normal heart.The epicardial surface is smooth and glistening.The amount of epicardial fat is usual.The left anterior descending coronary artery extends down from the aortic root to the apex.

THE HEART



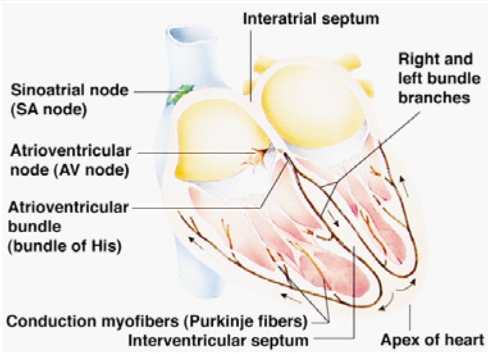
Myocardium—The Cardiac Muscle

- Thickness varies directly with stress placed on chamber walls.
- Left ventricle is the most powerful of chambers and thus, the largest.
- With vigorous exercise, the left ventricle size increases.
- Due to intercalated disks—impulses travel quickly in cardiac muscle and allow it to act as one large muscle fiber; all fibers contract together.

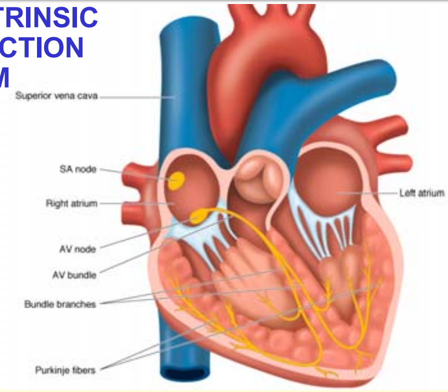


CARDIAC MUSCLE TISSUE

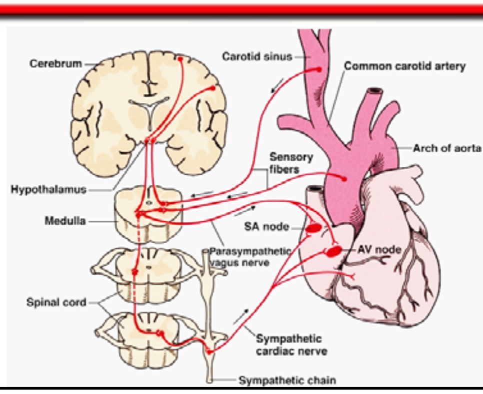
THE INTRINSIC CONDUCTION SYSTEM



THE INTRINSIC CONDUCTION SYSTEM



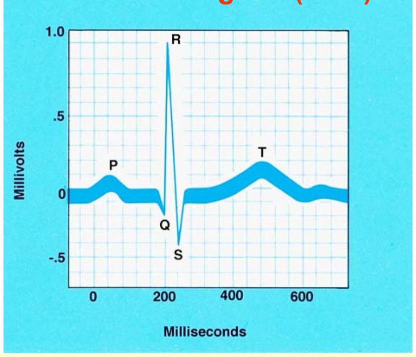
Extrinsic Control of the Heart



Extrinsic Control of the Heart

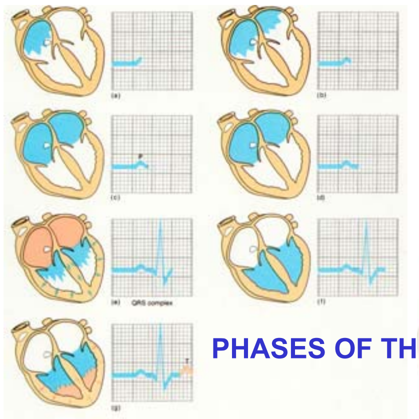
- PNS acts through the vagus nerve to decrease heart rate and force of contraction.
- SNS is stimulated by stress to increase heart rate and force of contraction.
- Epinephrine and norepinephrine—released due to sympathetic stimulation—increase heart rate.

Electrocardiogram (EKG)



Electrocardiogram (EKG)

- Records the heart's electrical activity and monitors cardiac changes
- The P wave—atrial depolarization
- The QRS complex—ventricular depolarization and atrial repolarization
- The T wave—ventricular repolarization



PHASES OF THE EKG

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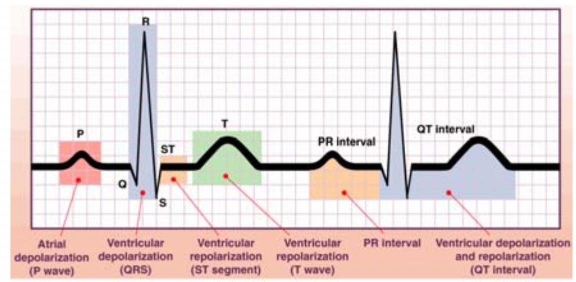
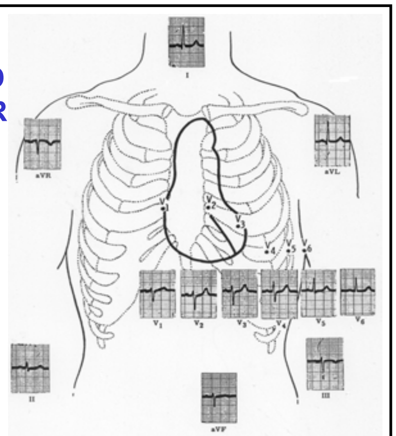
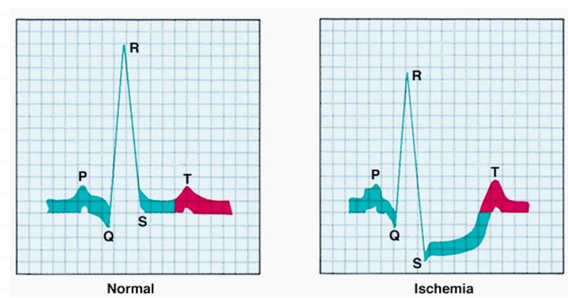


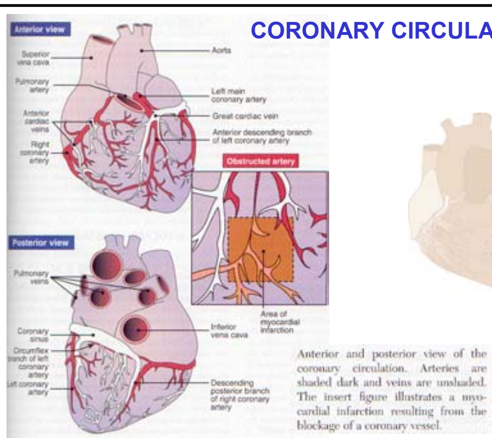
NORMAL, AUGMENTED AND VECTOR EKG LEADS



MYOCARDIAL ISCHEMIA



CORONARY CIRCULATION



Anterior and posterior view of the coronary circulation. Arteries are shaded dark and veins are unshaded. The insert figure illustrates a myocardial infarction resulting from the blockage of a coronary vessel.

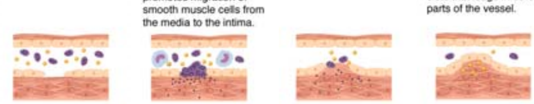
DEVELOPMENT OF ATHEROSCLEROSIS

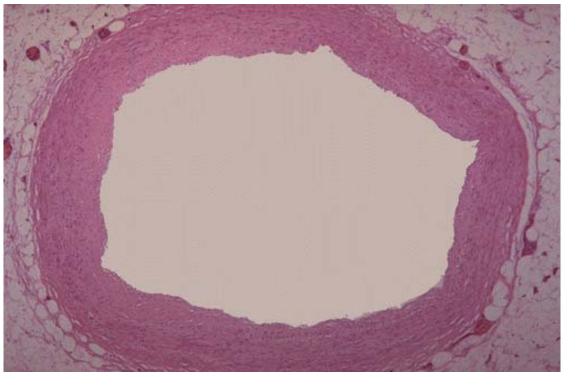
A blood-borne irritant injures or scratches the arterial wall exposing the underlying connective tissue.

Blood platelets and circulating immune cells known as monocytes are then attracted to the site of the injury and adhere to the exposed connective tissue. The platelets release a substance referred to as platelet-derived growth factor (PDGF) that promotes migration of smooth muscle cells from the media to the intima.

A plaque, which is basically composed of smooth muscle cells, connective tissue, and debris, forms at the site of injury.

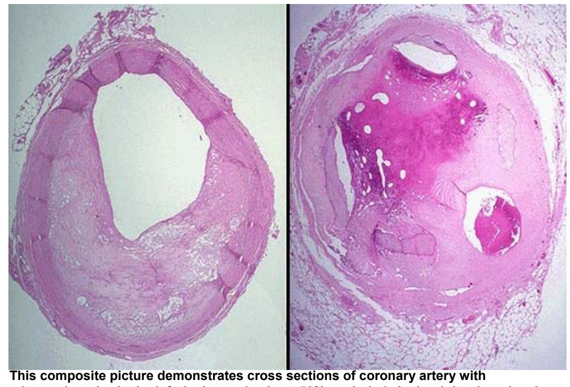
As the plaque grows, it narrows the arterial opening and impedes blood flow. Lipids in the blood, specifically low-density-lipoprotein cholesterol (LDL-C), are deposited in the plaque. When pieces of the plaque break loose they can start clots that lodge in other parts of the vessel.





This is a normal coronary artery with a nice, big, unobstructed lumen for supplying plenty of blood to the myocardium.

http://www-medlib.med.utah.edu/



This composite picture demonstrates cross sections of coronary artery with atherosclerosis. At the left the lumen is about 50% occluded. At the right, there has been thrombosis with organization and recanalization to leave three small remaining lumens.

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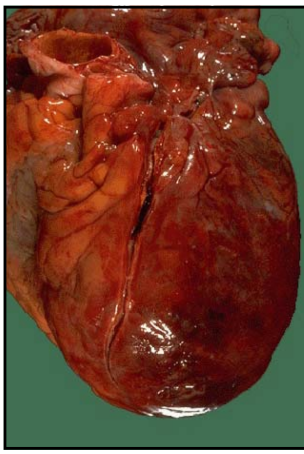

CORONARY THROMBOSIS

This is thrombosis in the left anterior descending coronary artery opened longitudinally here over the surface of the heart. This is another complication of atherosclerosis.

The purpose of thrombolytic therapy (as with streptokinase or with tissue plasminogen activator, or TPA) is to dissolve recently formed thrombi and re-establish circulation before irreversible myocardial damage has been done, or at least to prevent additional myocardial injury.

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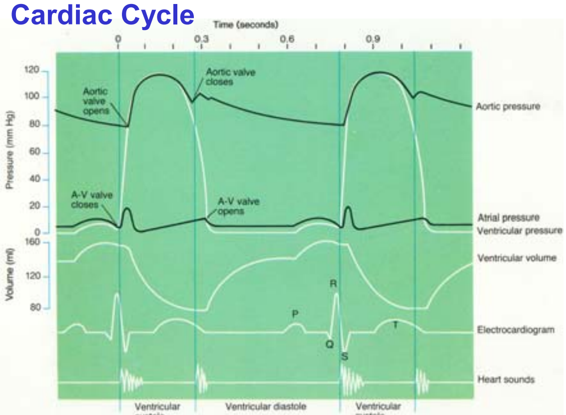
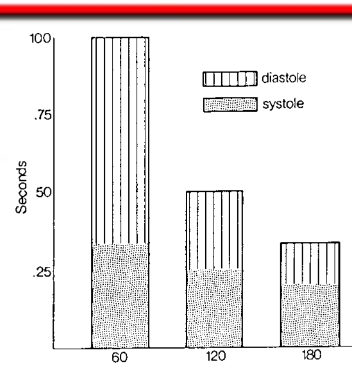
Cardiac Cycle

- Events that occur between two consecutive heartbeats (systole to systole)
- Diastole—relaxation phase during which the chambers fill with blood (T wave to QRS)
- Systole—contraction phase during which the chambers expel blood (QRS to T wave)

Cardiac Cycle



Changes in Systole and Diastole with Increasing HR



Stroke Volume and Cardiac Output

Stroke Volume (SV)

- Volume of blood pumped per contraction (per heart beat)
- End-diastolic volume (EDV)—volume of blood in ventricle before contraction
- End-systolic volume (ESV)—volume of blood in ventricle after contraction
- SV = EDV – ESV

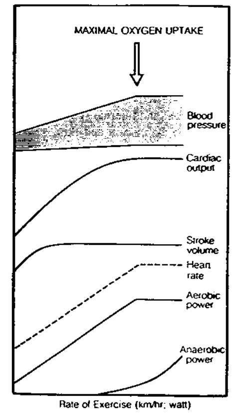
Cardiac Output ($\dot{Q}$)

- Total volume of blood pumped by the ventricle per minute
- $\dot{Q}$ = HR × SV

Cardiac Output and Stroke Volume

$$\dot{Q} = HR \times SV$$

CARDIAC OUTPUT = HEART RATE x STROKE VOLUME



Cardiac Output and Stroke Volume

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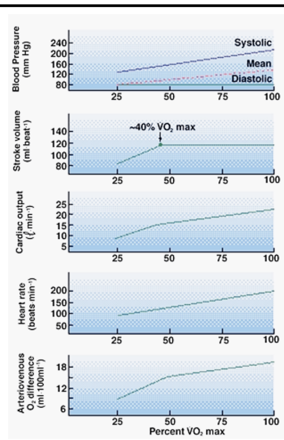


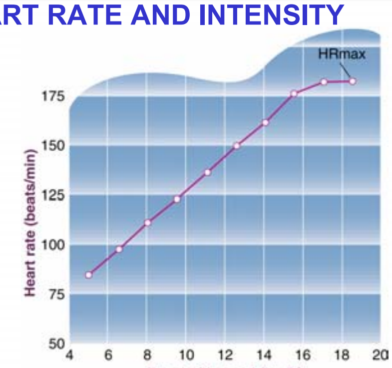
Resting Heart Rate

- Averages 60 to 80 beats per minute (bpm); can range from 28 bpm to above 100 bpm
- Tends to decrease with age and with increased cardiovascular fitness
- Is affected by environmental conditions such as altitude and temperature

Resting Heart Rate

- Decreases with endurance training due to more blood returning to heart
- In sedentary individuals can decrease by 1 beat per min per week during initial training
- Highly trained athletes may have resting heart rates of 40 beats per min or less

HEART RATE AND INTENSITY



Steady-State Heart Rate

- Heart rate plateau reached during constant rate of submaximal work
- Optimal heart rate for meeting circulatory demands at that rate of work
- The lower the steady-state heart rate, the more efficient the heart

Heart Rate During Exercise

Submaximal

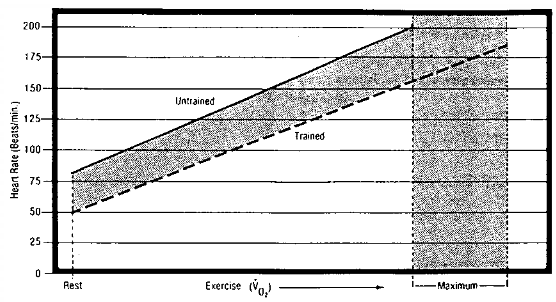
- Decreases proportionately with the amount of training completed
- May decrease by 20 to 40 beats per min after 6 months of moderate training

Maximal

- Remains unchanged or decreases slightly
- Thought to decrease to allow for optimal stroke volume and maximize cardiac output

HEART RATE AND TRAINING

HEART RATE AND TRAINING

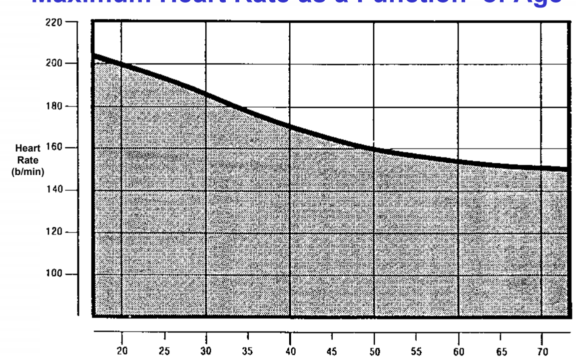


The relationship between heart rate and oxygen consumption per minute ($\dot{V}_{O_2}$) for trained and untrained subjects during exercise.

Maximum Heart Rate

- The highest heart rate value one can achieve in an all-out effort to the point of exhaustion
- Remains constant day to day and changes slightly from year to year
- Can be *estimated*: HRmax = 220 – age in years

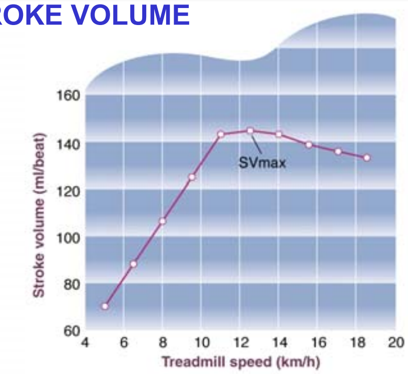
Maximum Heart Rate as a Function of Age



Stroke Volume

- Determinant of cardiorespiratory endurance capacity at maximal rates of work
- May increase with increasing rates of work up to intensities of 40% to 60% of max
- May continue to increase up through maximal exercise intensity
- Depends on position of body during exercise

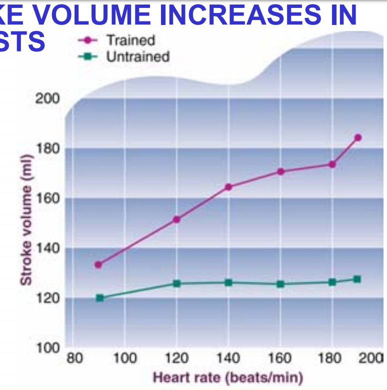
STROKE VOLUME



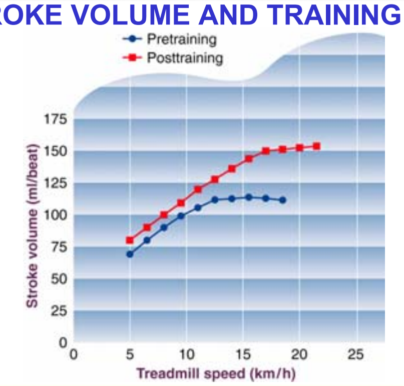
Stroke Volume Increases During Exercise

- Frank Starling mechanism—more blood in the ventricle causes it to stretch more and contract with more force.
- Increased ventricular contractility (without end-diastolic volume increases).
- Decreased total peripheral resistance due to increased vasodilation of blood vessels to active muscles.

STROKE VOLUME INCREASES IN CYCLISTS



STROKE VOLUME AND TRAINING



Key Points

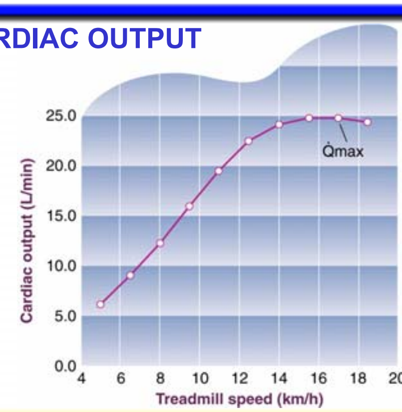
Stroke Volume Adaptations

- Endurance training increases SV at rest and during submaximal and maximal exercise.
- End diastolic volume increases, caused by an increase in blood plasma and greater diastolic filling time, contribute to increased SV.
- The increased size of the heart allows the left ventricle to stretch more and fill with more blood.

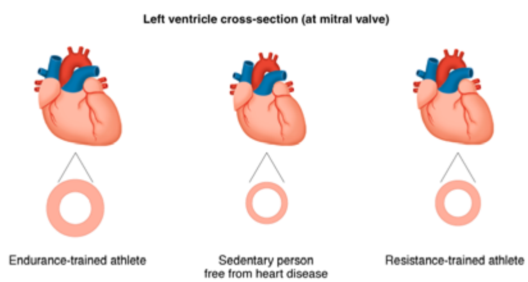
Cardiac Output

- Resting value is approximately 5.0 L/min.
- Increases directly with increasing exercise intensity to between 20 to 40 L/min.
- Value of increase varies with body size and endurance conditioning.
- When exercise intensity exceeds 40% to 60%, further increases in Q̇ are more a result of increases in HR than SV.

CARDIAC OUTPUT



LEFT VENTRICULAR HYPERTROPHY



Key Points

Heart Size Adaptations

- The left ventricle changes the most in response to endurance training.
- The internal dimensions of the left ventricle increase mostly due to an increase in ventricular filling.
- The wall thickness of the left ventricle increases, making the potential contraction of the left ventricle more forceful.

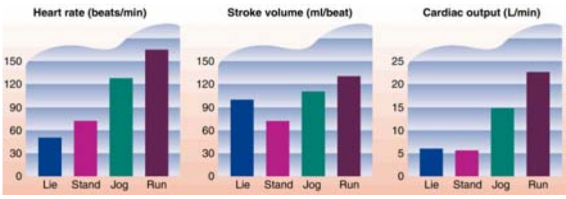
CARDIAC OUTPUT AND TRAINING

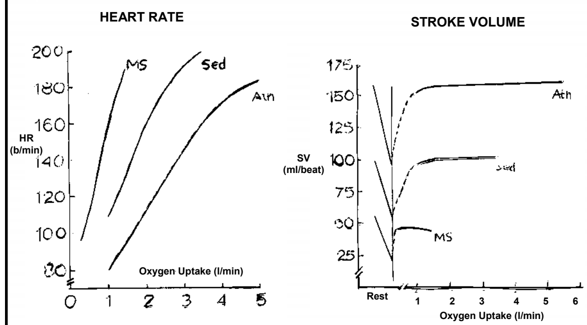
Key Points

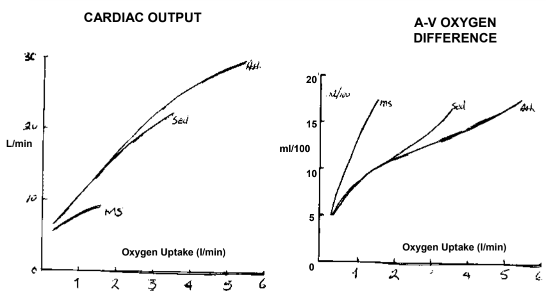
Cardiac Output Adaptations

- Q̇ doesn't change at rest or during submaximal exercise or decreases slightly.
- A slight change could be the result of an increase in the a-v̄O_2 diff due to greater oxygen extraction by the tissues.
- Q̇ increases dramatically at maximal exertion due to the increase in maximal SV.
- Absolute values of Q̇max range from 14 to 20 L/min in untrained people, 25 to 35 L/min in trained individuals, and 40 L/min or more in large endurance athletes.

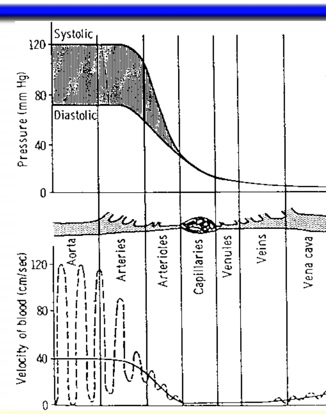
CHANGES IN HR, SV, AND Q̇







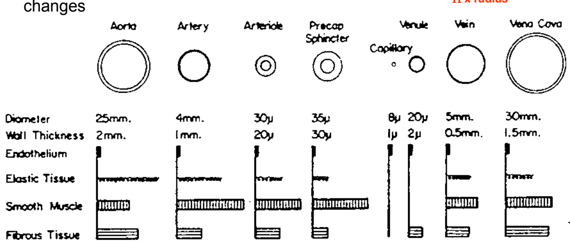
Blood Pressure



Blood Flow doubles with a 16% increase in the vessel radius and small changes in radius cause large pressure changes

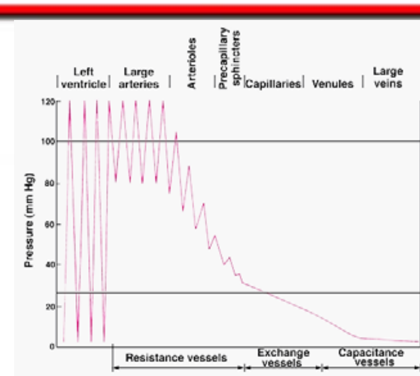
BLOOD FLOW = PRESSURE Δ / RESISTANCE

RESISTANCE = 8(viscosity) x length / Π x radius⁴

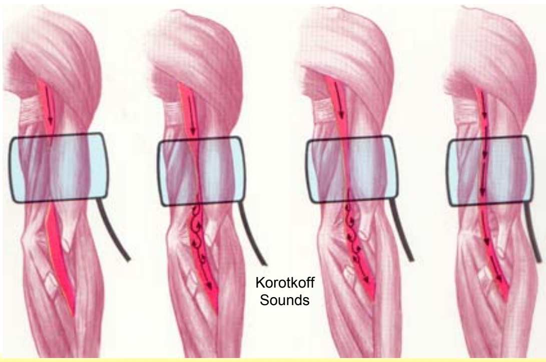


Internal diameter, wall thickness, and relative amounts of the principal components of the vessel walls of the various blood vessels that compose the circulatory system. Cross sections of the vessels are not drawn to scale because of the huge range from aorta and venae cavae to capillary.

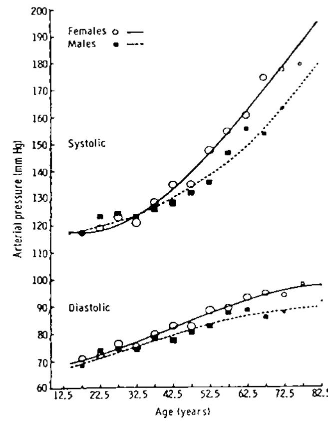
Blood Pressure



MEASUREMENT OF BLOOD PRESSURE



Blood Pressure Changes with Age in Females and Males



CLASSIFICATION OF BLOOD PRESSURE FOR ADULTS

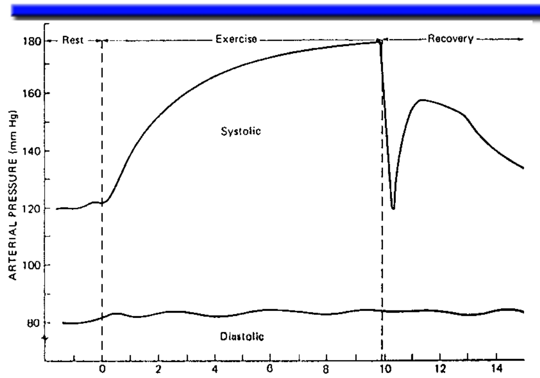
BP Classification for Adults	SP/DP (mmHg)
Optimal	<120/80
Normal	<130/85
High Normal	130-139/85-89
Hypertensive	>140/90
Mild Hypertensive	140-159/90-99
Moderate Hypertensive	160-179/100-109
Severe Hypertensive	180-209/110-119
Very Severe Hypertensive	>210/120

adapted from - New York Online Access to Health
http://noah.cuny.edu/wellconn/hiblodpres.html

CLASSIFICATION OF BLOOD PRESSURE FOR CHILDREN

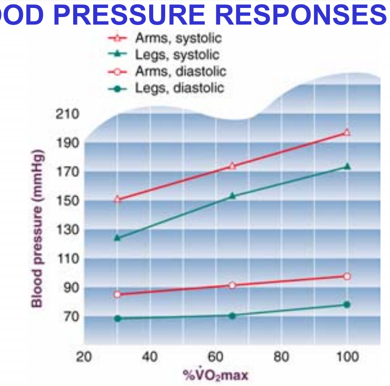
Children at Risk for Hypertension	SP/DP (mmHg)
Ages 3-5	116/76
Ages 6-9	122/78
Ages 10-12	126/82
Ages 13-15	136/86

adapted from - New York Online Access to Health
http://noah.cuny.edu/wellconn/hiblodpres.html



Systolic and Diastolic Blood Pressure Changes with Dynamic Exercise to Exhaustion

BLOOD PRESSURE RESPONSES



Blood Pressure

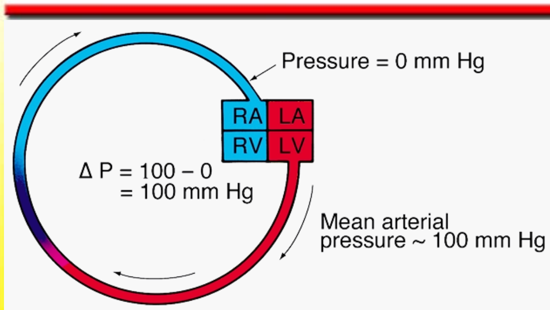
Cardiovascular Endurance Exercise

- Systolic BP increases in direct proportion to increased exercise intensity
- Diastolic BP changes little if any during endurance exercise, regardless of intensity

Resistance Exercise

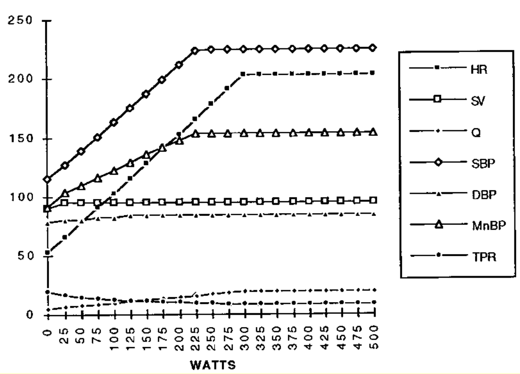
- Exaggerates BP responses to as high as 480/350 mmHg
- Some BP increases are attributed to the Valsalva maneuver

Mean Blood Pressure (MnBP)

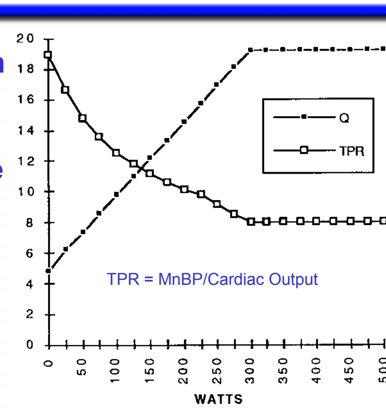


MnBP = DBP + (SBP – DBP/3.0)REST

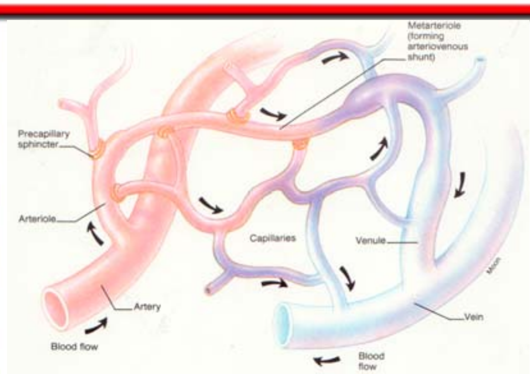
MnBP = DBP + (SBP – DBP/2.0)EXERCISE



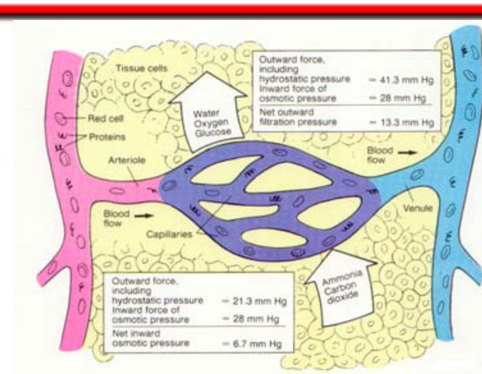
Changes in Total Peripheral Resistance with Increasing Workload



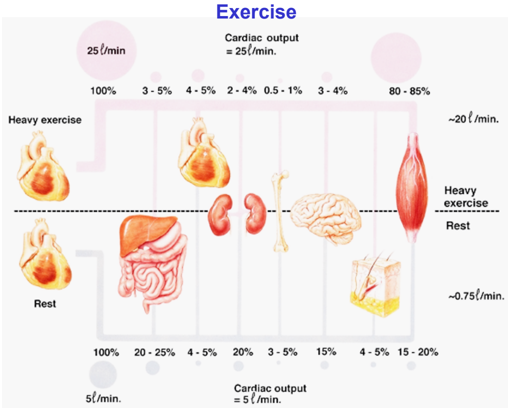
Tissue Blood Flow Control



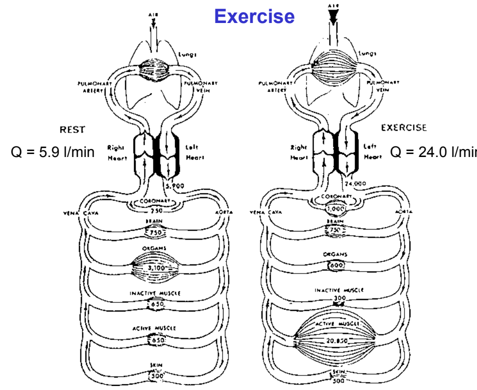
Tissue Blood Flow and Exchange

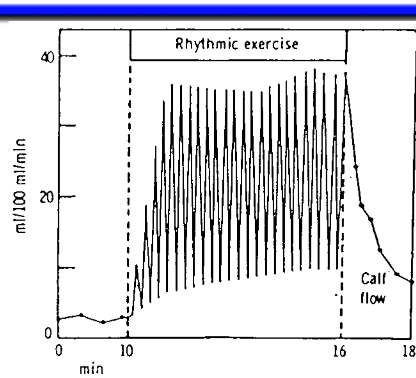


Redistribution of Blood Flow from Rest to Maximum Exercise



Redistribution of Blood Flow from Rest to Maximum Exercise





Blood flow through the calf muscles during rhythmic contractions

Venous Return
“Peripheral Heart Action”