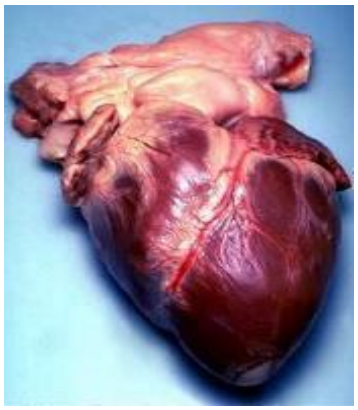
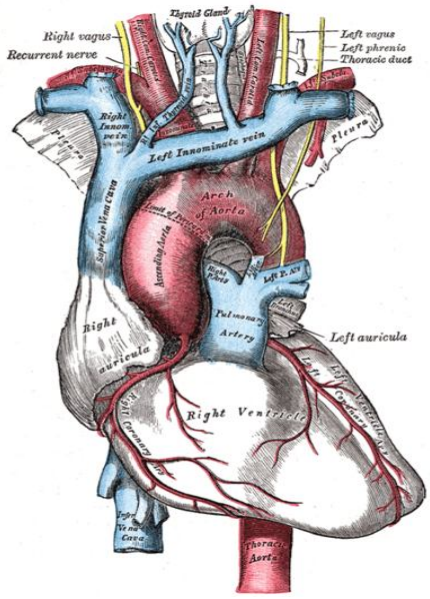
Cardiovascular Physiology and Adaptations





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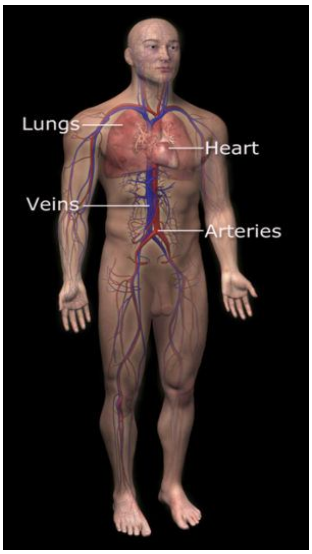
Components of the Cardiovascular System

Cardiovascular system - composed of *blood*, the *heart*, and the *vasculature* within which blood is pumped throughout the body.

Pulmonary circulation - concerning blood flow to, within and from the lungs

Systemic circulation - concerning blood flow to, within and from the remainder of the body, and consists of tissue/organ specific circulation beds, eg: *renal*, *hepatic*, *cranial*, *gastric*, *intestinal*, *skeletal muscle*, *cutaneous*, etc.



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Blood

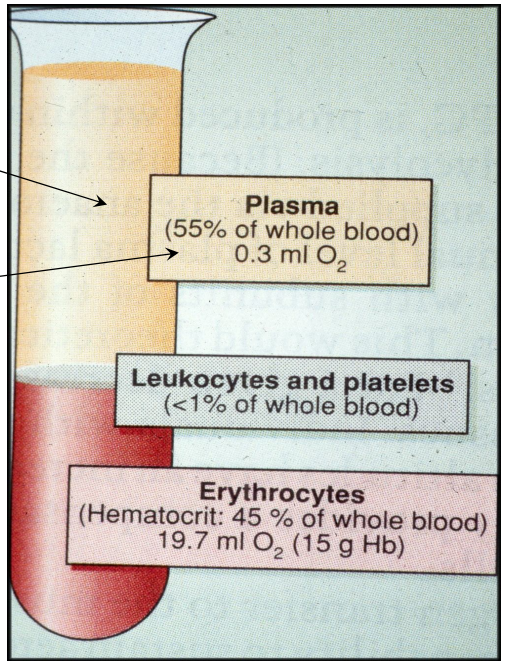
water, clotting proteins, transport proteins, lipoproteins, glucose, fatty acids, antibodies, transferrin, waste products (eg. urea, ammonia, etc.)

plasma - the liquid component of blood and all of it's non-cellular content

serum - what remains of plasma after blood has clotted

polycythemia - excess production of red blood cells

anemia - abnormally low red blood cell counts



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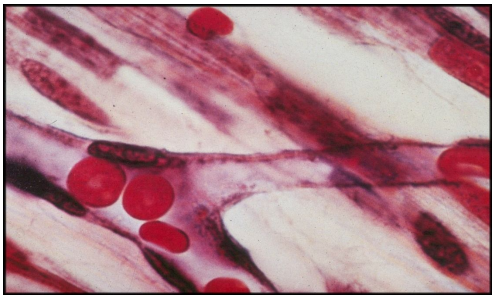
Blood Constituent	Concentrations
Cell Matter	
Packed cell volume (hematocrit; %)	35 - 50
Red blood cells (erythrocytes; cells/mm^3)	4.3 - 5.8 x 10^6
Platelets	
White blood cells (leukocytes; cells/mm^3)	4 - 11 x 10^3
Granulocytes	
- neutrophils	3 – 7 x 10^3
- Eosinophils	100 - 400
- Basophils	20 - 50
Agranulocytes	
- lymphocytes	1.5 – 3.0 x 10^3
- monocytes	100 - 700
Liquid Component (Plasma)	
Plasma Volume (%)	50 - 65
Cations	
Sodium (mEq/L)	135 - 145
Potassium (mEq/L)	3.5 - 5.0
Calcium (mEq/L)	2.2 - 2.5
Magnesium (mEq/L)	1.5 - 2.0
Anions	
Chloride (mEq/L)	95 - 107
Bicarbonate (mEq/L)	22 - 16
Lactate (mEq/L)	1.0 - 1.8
Sulfate (mEq/L)	1.0
Phosphate (mEq/L)	2.0
Proteins	
Albumin (g/L)	34 - 50
Total globulin (g/L)	22 - 44
Transferrin (mg/L)	2500
Ferritin (µg/L)	15 - 300
Total Protein (g/L)	60 - 80
Osmolality (mOsmol/kg H_2O)	285-295

Constituent	Origin/Source	Function(s)
Water	Ingestion Metabolism	Dissolves or suspends all other blood constituents; heat absorption and transfer
Platelets	Megakaryocytes	Blood clotting
Albumin	Liver	Main contributor to osmolality; transports certain lipid molecules; buffers protons
α and β-Globulin	Liver	Transports lipid molecules
γ-Globulin	B-Lymphocytes	Antibodies released during immune responses
Transferrin	Liver	Blood protein that transports iron from the intestine to the liver
Ferritin	Mucosal cells	Protein that binds iron from digested food
Calcium	Ingestion	Blood clotting
Bicarbonate	Metabolism	Proton buffering



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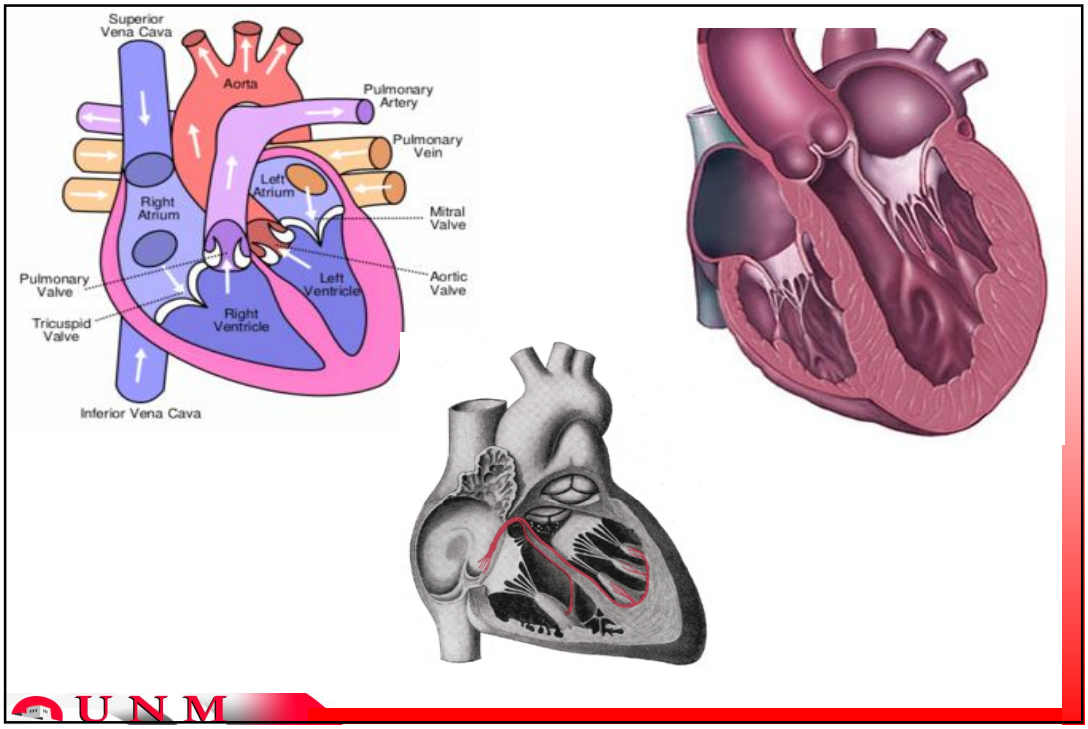
Superior Vena Cava
Aorta
Pulmonary Artery
Pulmonary Vein
Left Atrium
Right Atrium
Mitral Valve
Pulmonary Valve
Left Ventricle
Aortic Valve
Tricuspid Valve
Right Ventricle
Inferior Vena Cava
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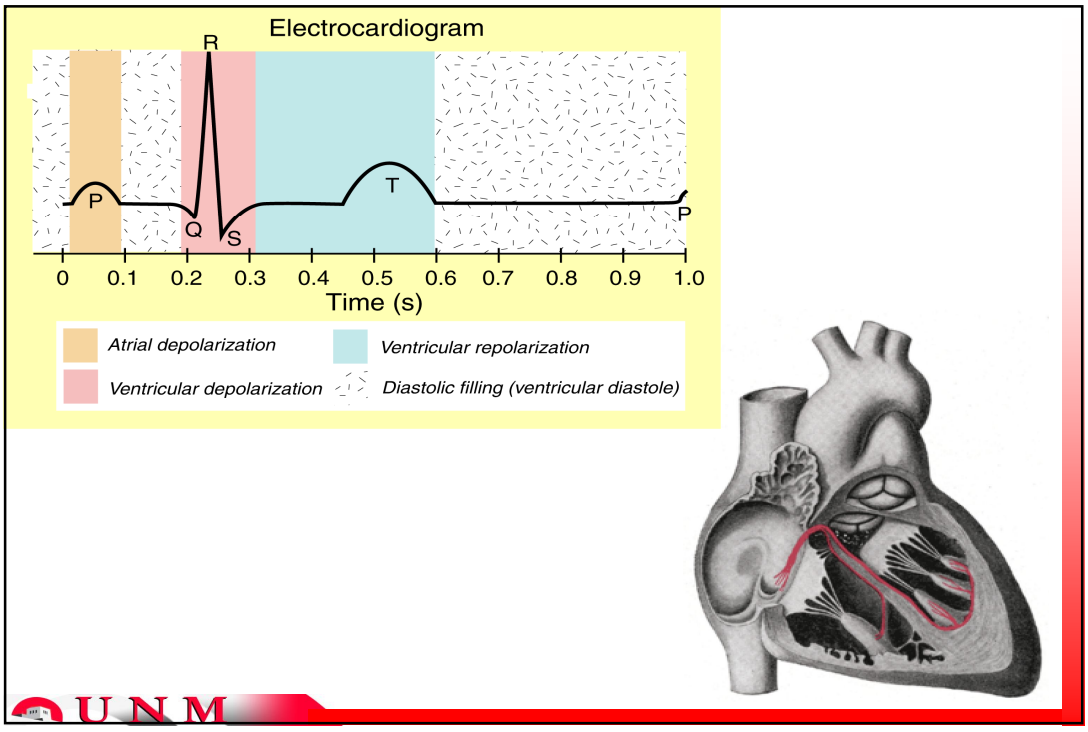
Electrocardiogram
R
P
Q
S
T
P
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Time (s)
Atrial depolarization
Ventricular repolarization
Ventricular depolarization
Diastolic filling (ventricular diastole)
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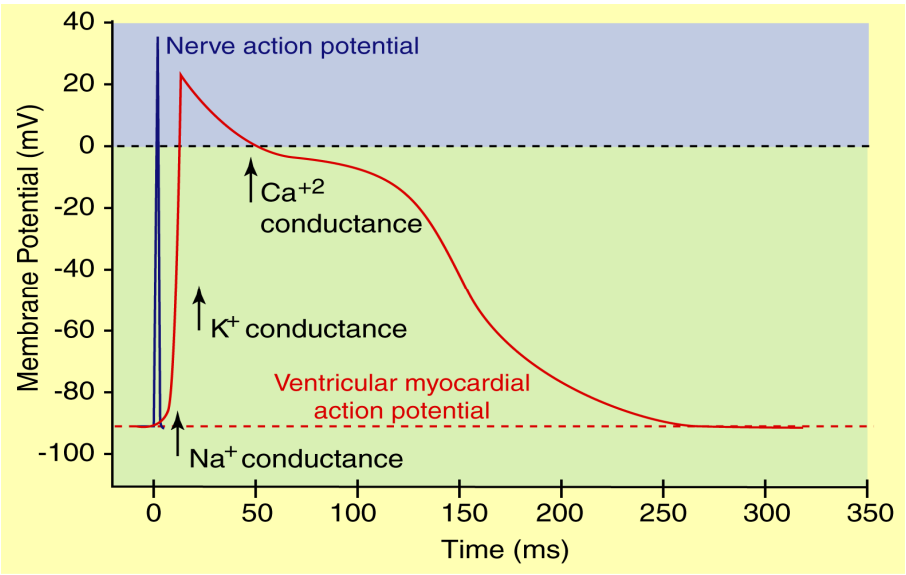

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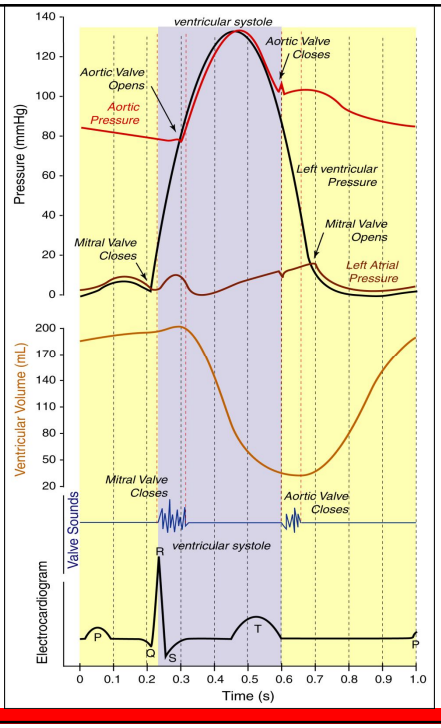
Cardiac Cycle

- Preload
- Afterload
- Systole
- Diastole
- EDV
- Ejection Fraction
- Stroke Volume
- Heart Rate
- Cardiac Output
- ECG
- Heart Sounds
- Valve Function
- Response to Exercise



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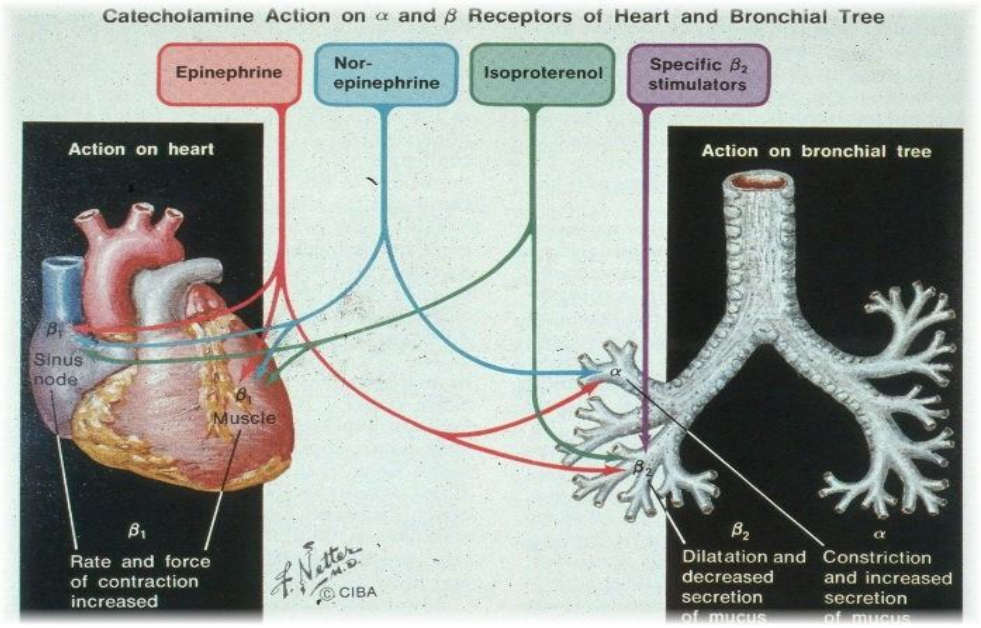
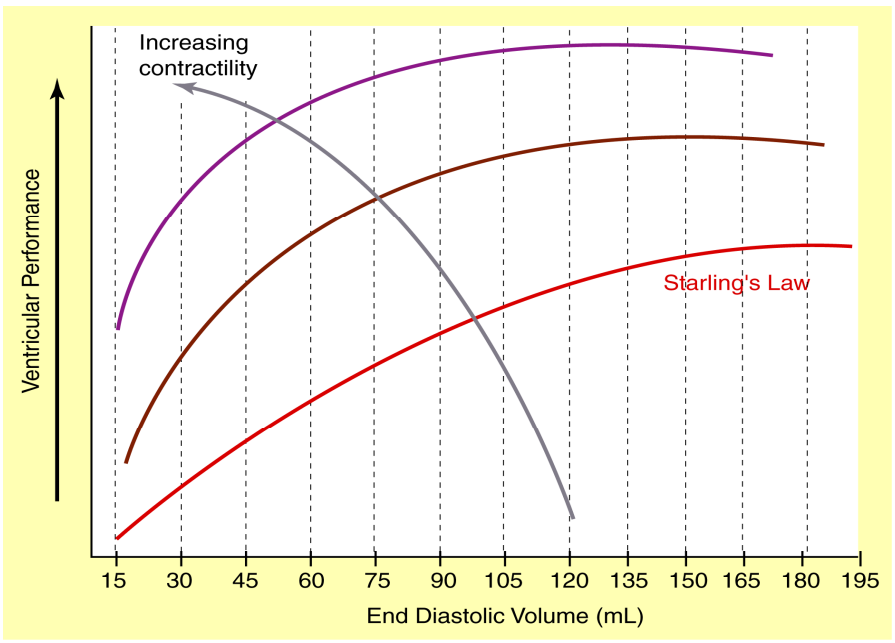
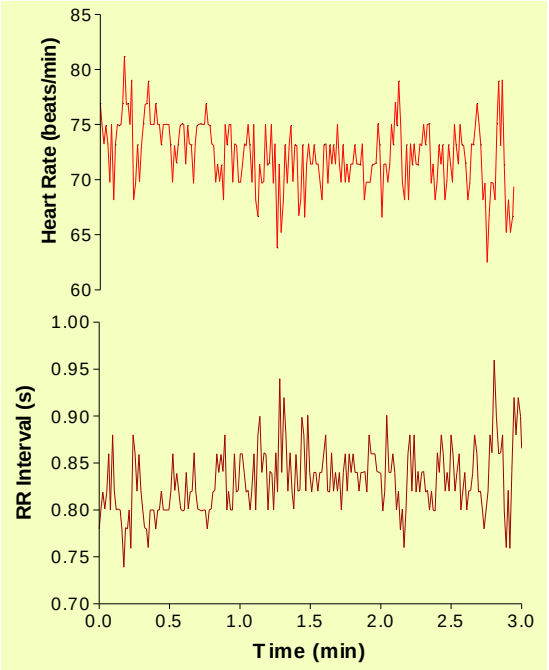


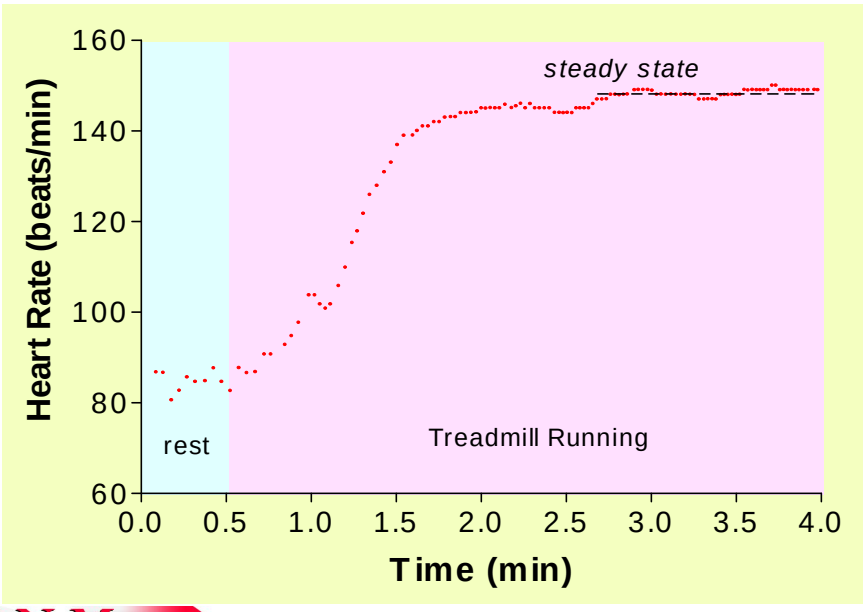
Circulatory Component	Sympathetic Regulation	Parasympathetic Regulation
SA Node	β1, β2: increased rate of depolarization	M2: decreased rate of depolarization
Myocardium	β1, β2: increased contractility	M2: decreased contractility
AV Node	β1: increased rate of conduction	M2: decreased rate of conduction
Vascular smooth muscle	M3: Contracts α: Contracts β2: Relaxes	



Resting heart rate is inherently variable!



Heart Rate Can Detect Steady vs. Non-Steady State



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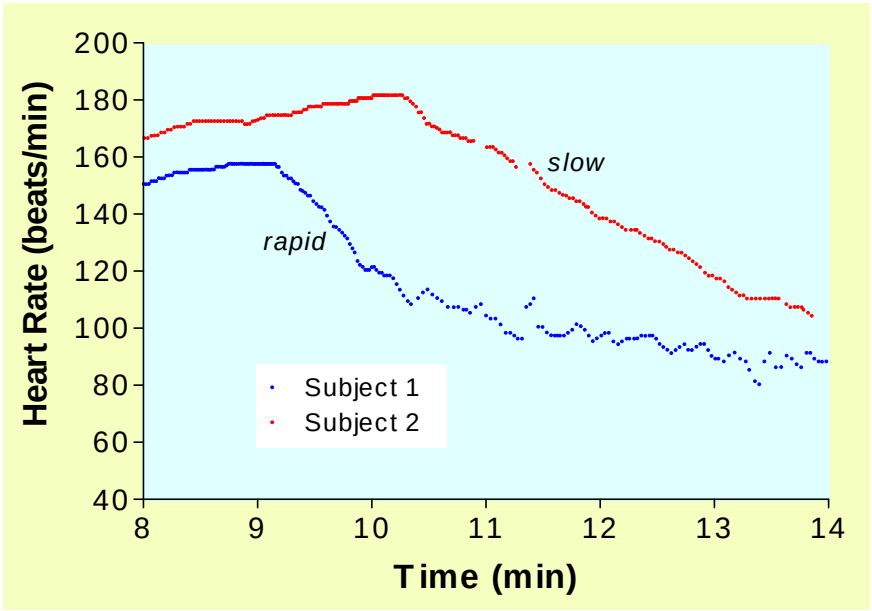
Recovery Heart Rate Is Influenced by Fitness



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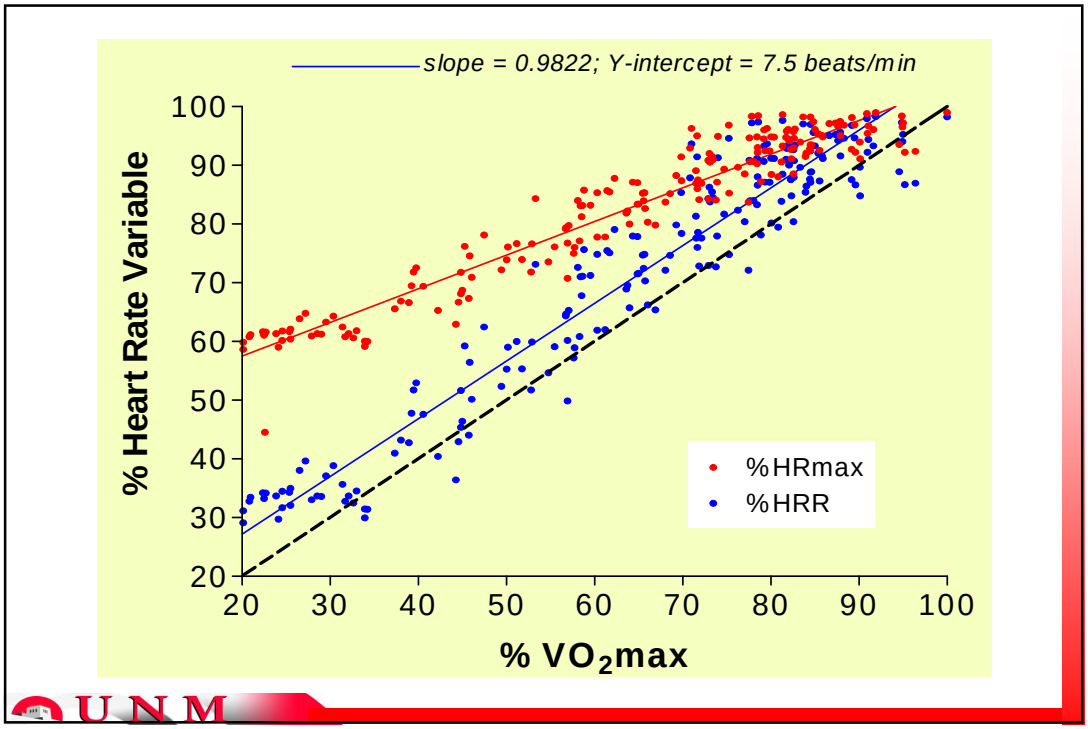
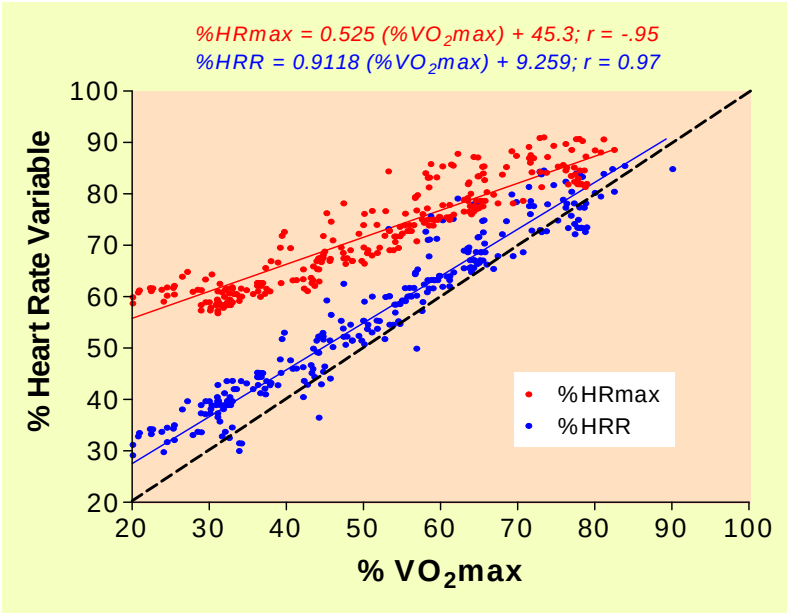


Relative Heart Rate Can Be Used to Express Intensity



%VO_2max	%HRR	%HRmax
20	27	56
30	37	61
40	46	66
50	55	72
60	64	77
70	73	82
80	82	87
90	91	93
100	100	98

%HRR=0.9118(%VO2max) + 9.259

%HRmax=0.525 (%VO2max) + 45.3

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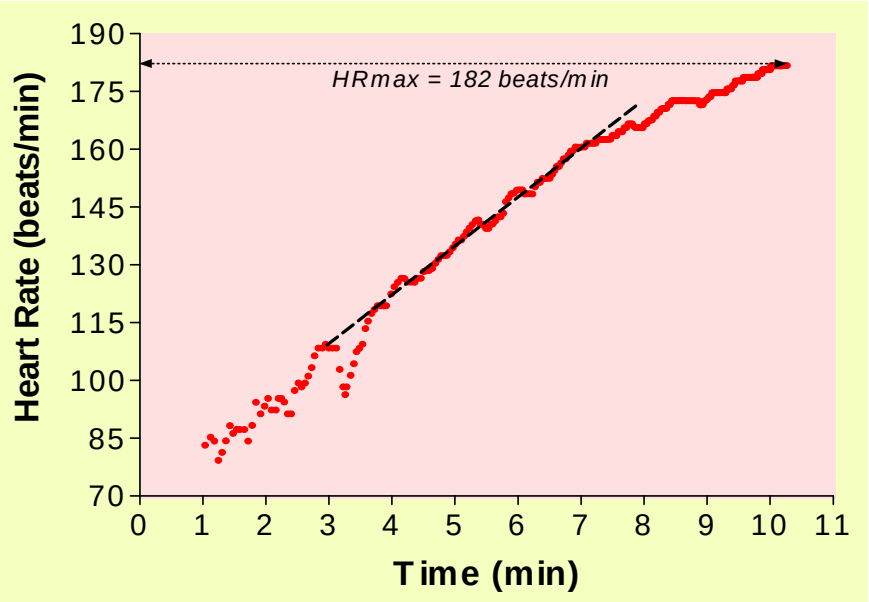
Heart Rate Slope May Change at Metabolic Threshold



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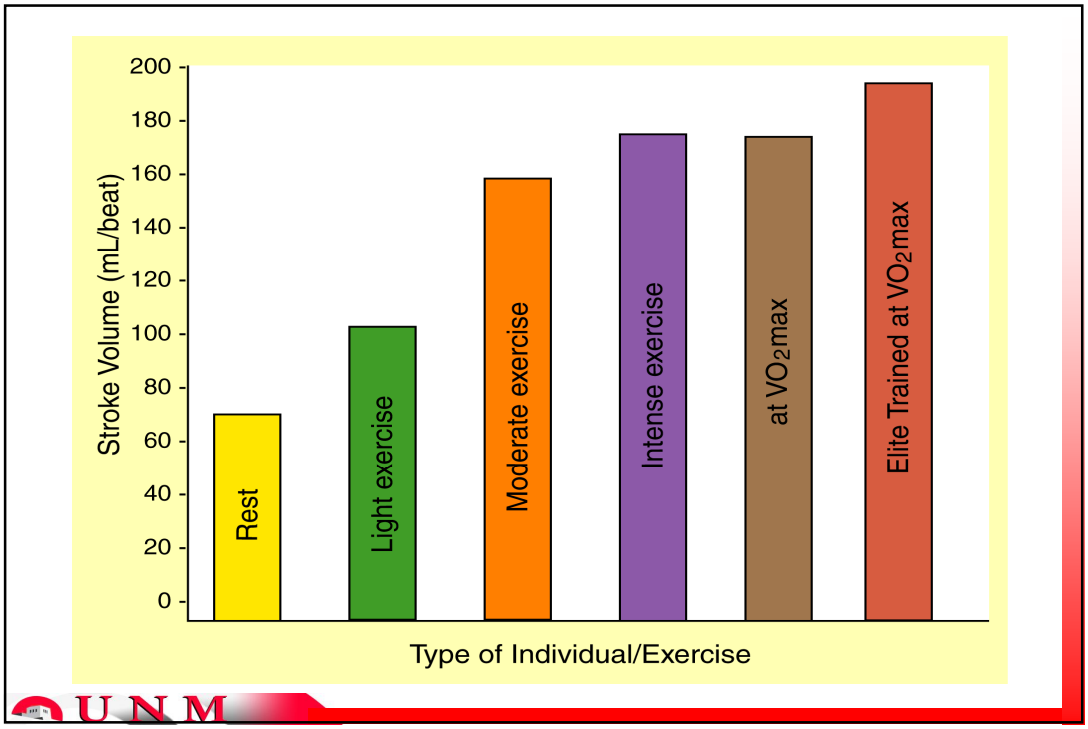
Stroke Volume (mL/beat)
200
180
160
140
120
100
80
60
40
20
0
Rest
Light exercise
Moderate exercise
Intense exercise
at VO2max
Elite Trained at VO2max
Type of Individual/Exercise
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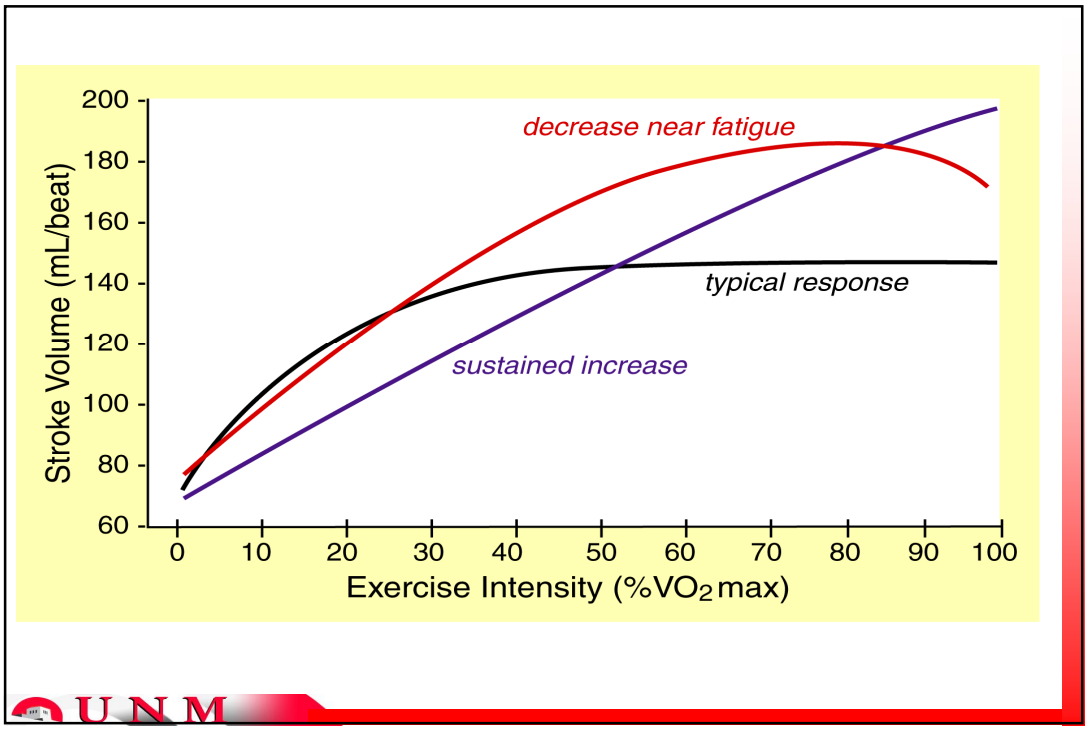
Stroke Volume (mL/beat)
200
180
160
140
120
100
80
60
decrease near fatigue
typical response
sustained increase
0
10
20
30
40
50
60
70
80
90
100
Exercise Intensity (%VO2max)
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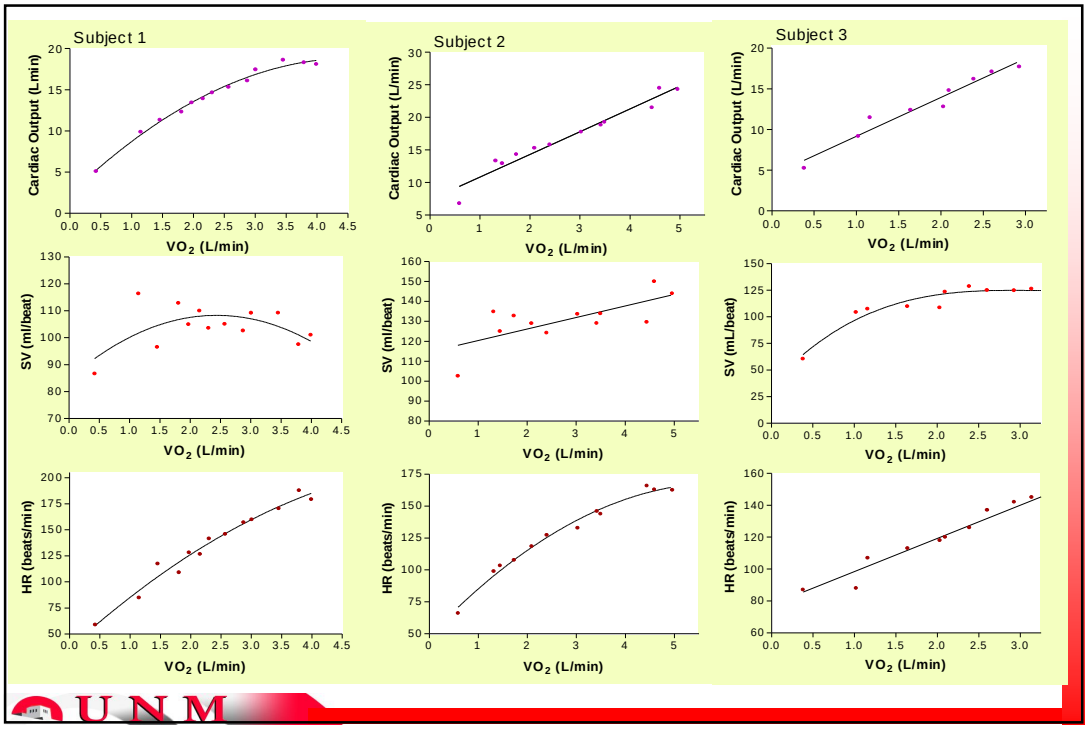

Redistribution of Cardiac Output