FITNESS & NUTRITION EXPERT PROGRAM

FITNESS SESSION 5:

Bioenergetics & Cardiorespiratory System

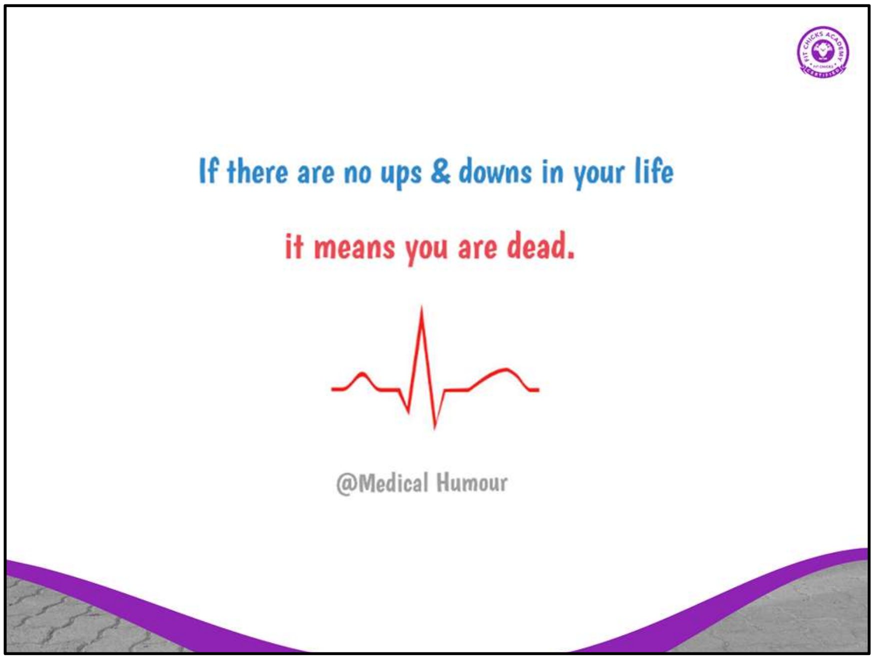
What we are going to cover

BIOENERGETICS

- Muscle Metabolism: The role of ATP
- How energy is created in the Human Body
  - Cellular Respiration and the different energy systems
- Burning Fat vs. Burning Carbs
- Why interval training is so effective
- Muscle soreness and recovery

CARDIORESPIRATORY CONCEPTS

- Anatomy of the Cardiorespiratory System
- Heart Rate, Blood Pressure, VO2MAX, Stroke Volume, Cardiac Output,
- How to determine your Heart Rate Training Zone
- Training adaptations



https://me.me/i/if-there-are-no-ups-downs-in-your-life-3079860

What you need before we start

1. Water
2. Put your finger tips together
3. Take 3 deep breaths

Bioenergetics

Definitions

Bioenergetics
- The study of how energy flows in the human body

Energy
- The ability to do work. Comes in various forms.

Metabolism
- The sum total of all the chemical reactions that take place in our body that either create or use energy

Catabolism
- The breakdown of organic substances in the body

Anabolism
- The synthesis of new organic substances in the body

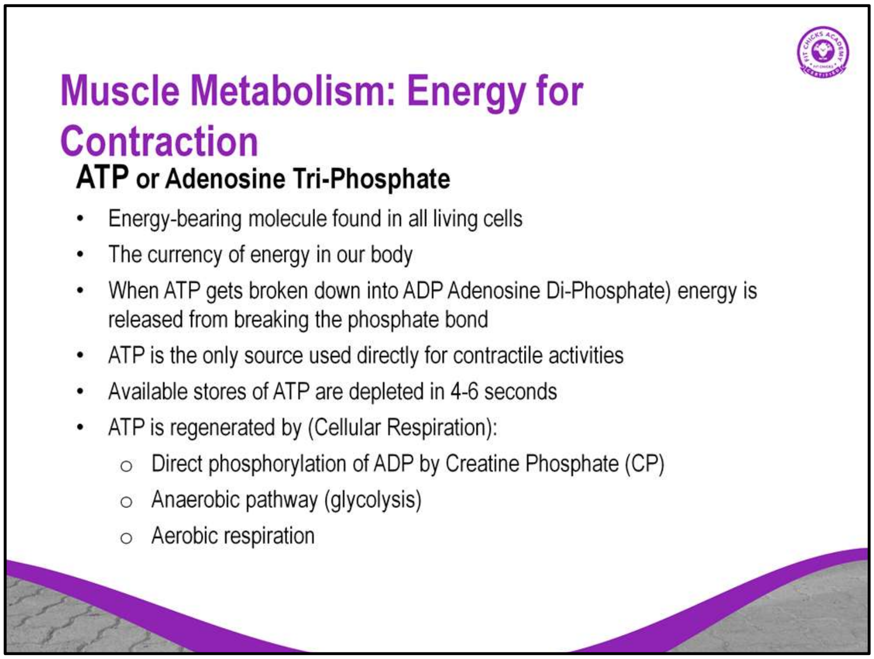
Cellular Respiration
- The metabolic processes and reactions occurring inside the cells of an organism to covert nutrients into ATP

http://kidshealth.org/teen/your_body/body_basics/metabolism.html

Every living organism needs these metabolic processes to live.

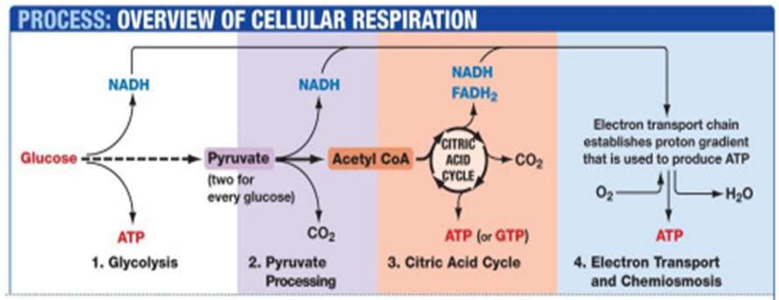
Martini, F.H., Ober, W.C., Bartholomew, E.F., Nath, J.I. (2013). Visual Essentials of Anatomy and Physiology. 559

Catabolism = breaking down - ex. Glycolysis
Anabolism = building up - ex. The synthesis of proteins from amino acids

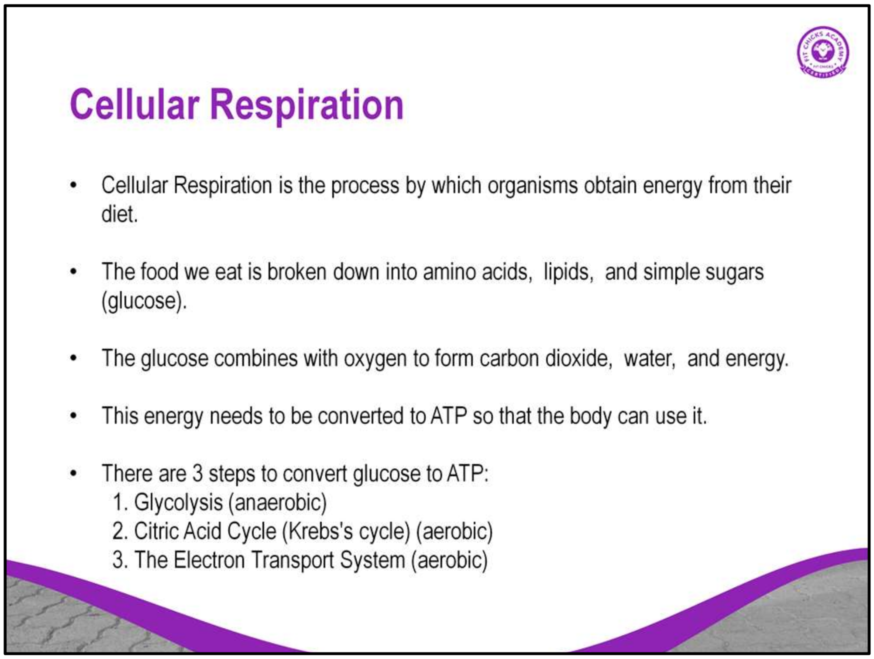


Phosphorylation means adding a phosphorus molecule

Cellular Respiration



https://biochemistry3rst.wordpress.com/tag/krebs-cycle/



https://biochemistry3rst.wordpress.com/tag/krebs-cycle/

Glycolysis can be both anaerobic and aerobic. It depends on if there is oxygen present or not.
Anaerobic = no oxygen
Aerobic = oxygen

Anaerobic vs Aerobic Energy Systems

Anaerobic Energy Systems (without oxygen)

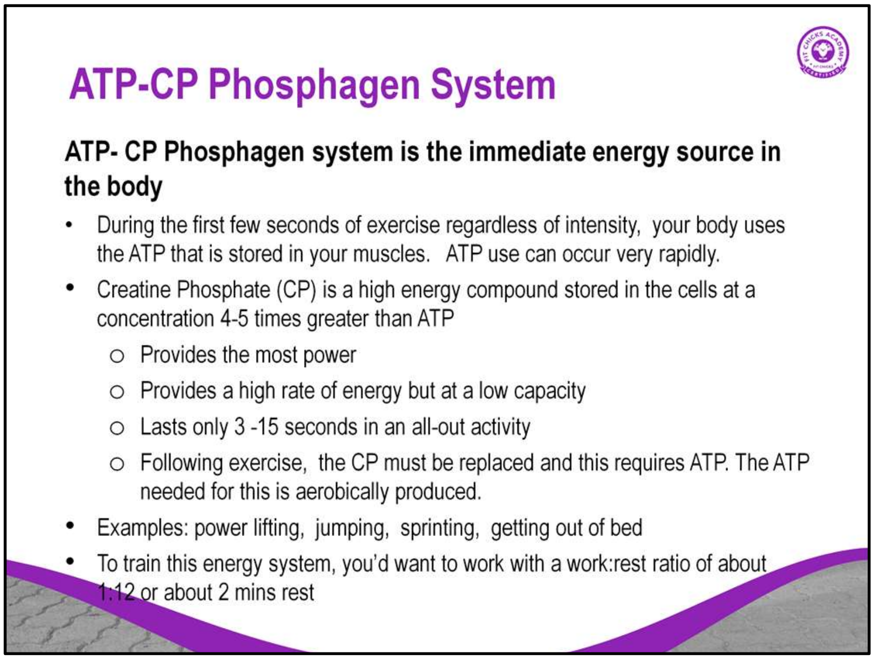
- Used at the beginning of exercise or during periods of high intensity
  - ATP-CP Phosphagen System
  - Glycolytic System

Aerobic Energy Systems (with oxygen)

- Used after 2 mins of activity during light to moderate exercise
  - Aerobic Glycolysis
  - Fatty Acid Oxidation

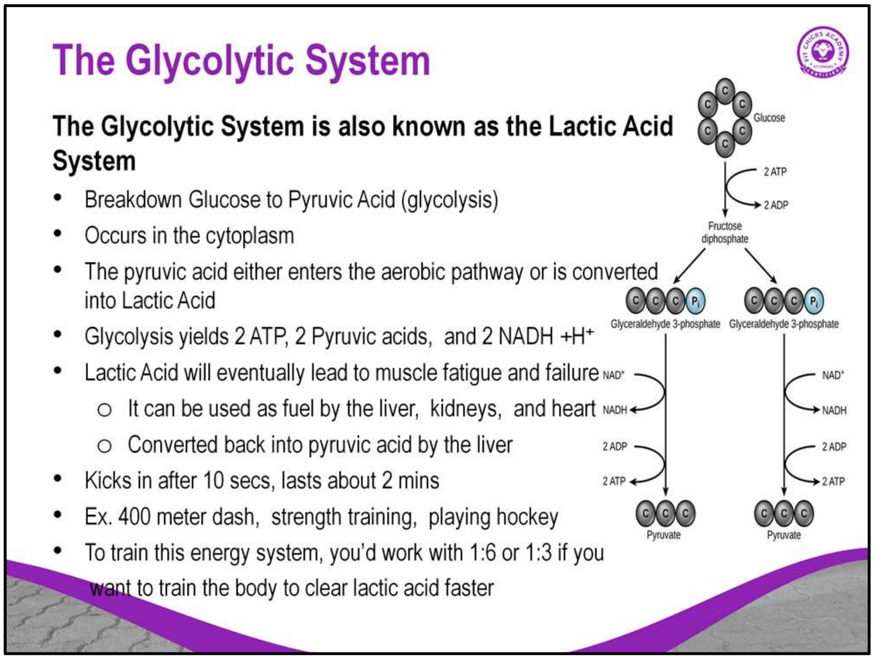
System	Power (rate of ATP production)	Capacity (total ability to produce ATP)	Fuels Used
phosphagen system	very high	very low	creatine phosphate stored ATP
glycolysis	high	low	blood glucose muscle & liver glycogen
aerobic system	low	very high	blood glucose muscle & liver glycogen adipose & intramuscular fat

https://www.ideafit.com/fitness-library/the-three-metabolic-energy-systems



http://www.ptdirect.com/training-design/anatomy-and-physiology/the-atp-pc-system

If activity continues beyond this immediate period, the body must rely on other energy systems to produce ATP as the limited stores of both ATP and PC will be exhausted and will need time to replenish.
These stores are replenished after about two minutes rest.
You need about a 1:12 ratio for work to adequate recovery or about 2 mins

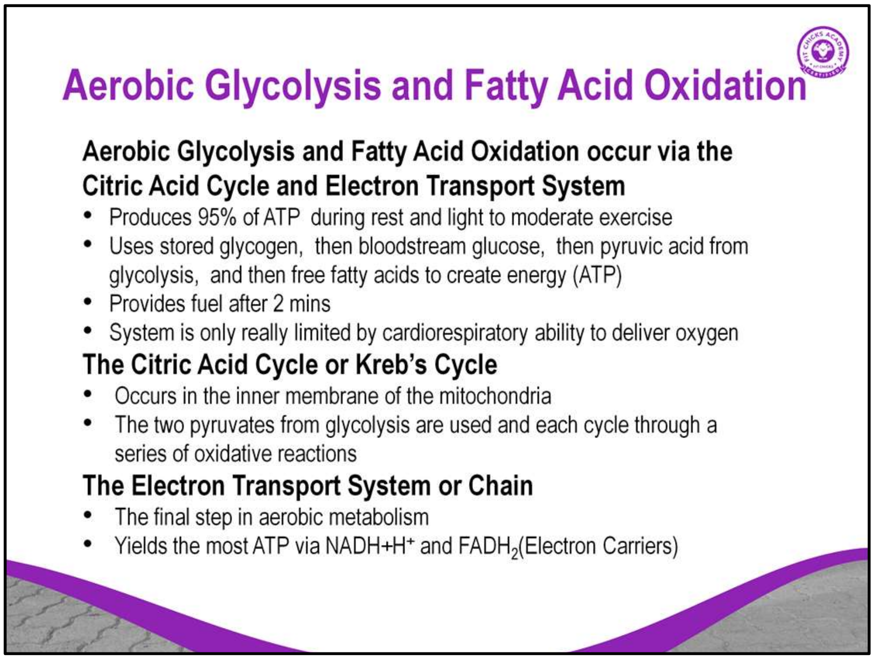


https://i.pinimg.com/originals/2e/65/11/2e6511146ab8eeedac0674bb51847126.jpg

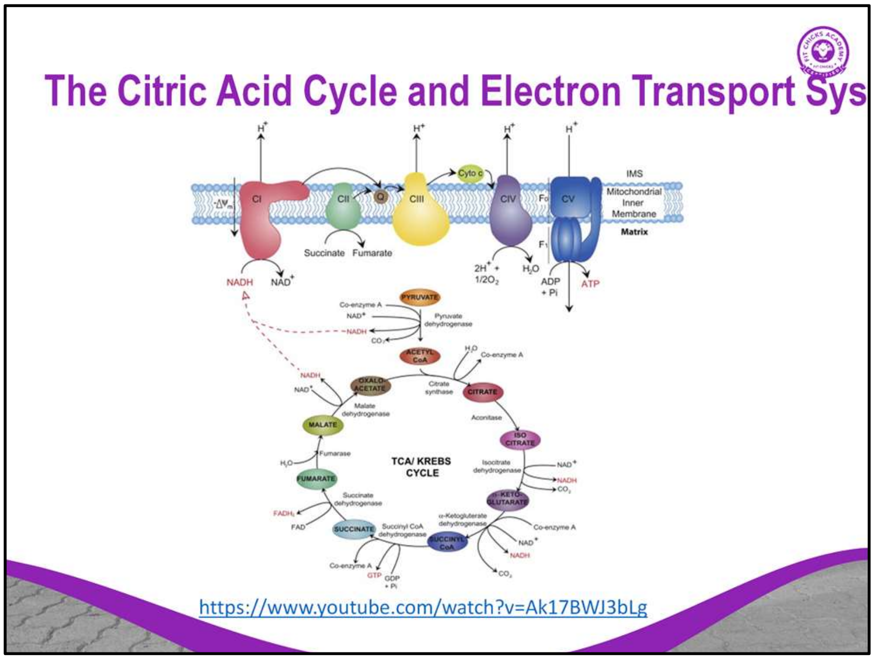
If glucose isn't readily available the body will breakdown glycogen into glucose (Glycogenolysis)
If neither glucose nor glycogen is available the body will form glucose form protein and fat (Gluconeogenesis)

NADH+H^+ will yield 3 ATP each through the Electron Transport System – Part of the aerobic pathway

In glycolysis, glucose, a 6-carbon compound, is eventually **broken down** to two 3-carbon compounds called pyruvate molecules. Two ATP molecules are invested into this step so that a net gain of two ATP can be made, as well as two pyruvates and two NADH. This process occurs **without the presence of oxygen** in the cytoplasm of cells.



https://www.khanacademy.org/science/biology/cellular-respiration-and-fermentation/overview-of-cellular-respiration-steps/v/overview-of-cellular-respiration

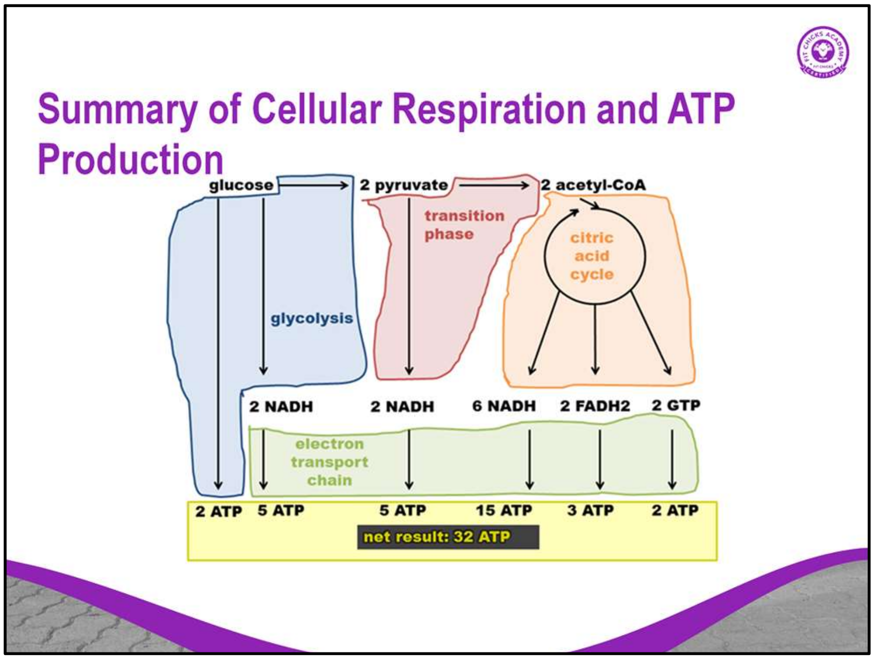


https://www.researchgate.net/figure/Bioenergetics-of-the-electron-transport-chain-and-the-TCA-Kerbs-cycle-Pyruvate-is_fig1_233737352

Aerobic Glycolysis vs Fatty acid oxidation

- Uses glucose as fuel
- Moderate intensity exercise
- Ex. running, a fitness class, a swim
- To train this system: A sustained effort, or a 1:1 with active 'rest' portions

- Uses fat as fuel
- Low intensity exercise
- Ex. Yoga, walking, sitting
- To train this system: A sustained effort, or a 1:1 with active 'rest' portions

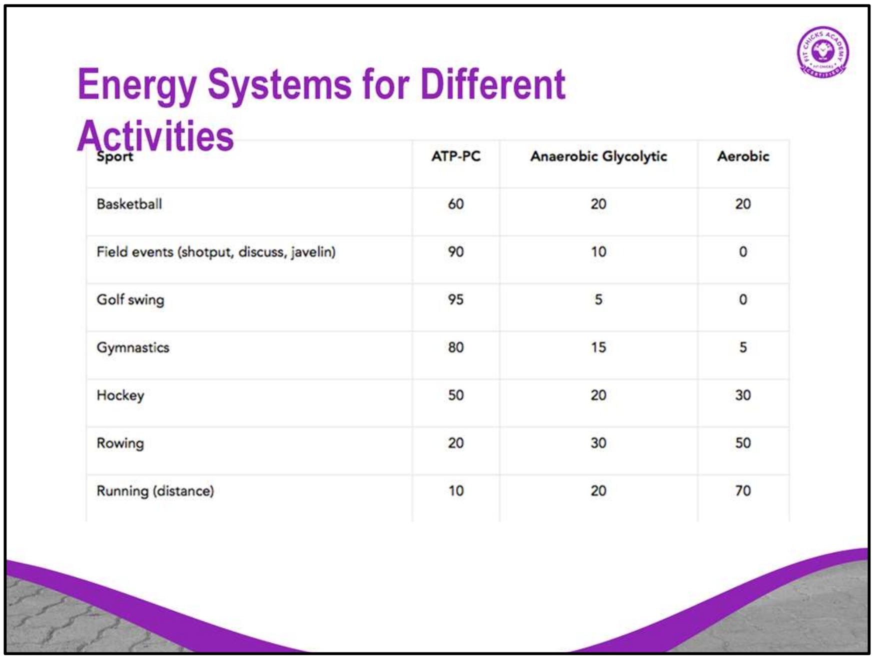


http://www.cureffi.org/wp-content/uploads/2013/11/energy-flow-diagram.png

Summary of the Energy Systems

	Anaerobic systems		Aerobic system	
Characteristics	ATP-CP (alactic)	Anaerobic glycolysis (lactic acid)	Aerobic (glycolysis)	Aerobic (lipolysis)
Duration (predominant)	6–10 seconds	30–60 seconds	2–3 hours	>4 hours
Peak power	2–5 seconds	5–15 seconds	Not applicable	Not applicable
Intensity (% HR_{max})	Not applicable	Not applicable	>75–100%	Rest – 75%
Intensity (% VO_{2max})	Not applicable	Not applicable	>65–100%	Rest – 65%
Perceived exertion	Maximal	Maximal	Moderate–very hard	Very light–moderate
Fuel source(s)	CP	Carbohydrate	Mostly carbohydrate Fat	Mostly fat Carbohydrate
ATP yield (per molecule)	<1	2	36–38	>100
Byproducts	C + P	Lactic acid (Lactate + H^+)	$H_2O + CO_2$ + heat	$H_2O + CO_2$ + heat
[Blood lactate] (mM)	Not applicable	>6	2–16	<2
Training effect	Alactic power	Alactic power Alactic capacity Lactic power Lactic capacity	Aerobic power Aerobic capacity	Aerobic power Aerobic capacity Fat oxidation
Typical events	100 m track sprint	400 m track sprint 100 m freestyle	10 000 m run 40 km TT (cycling)	Ironman triathlon Road cycling (4 + hours)

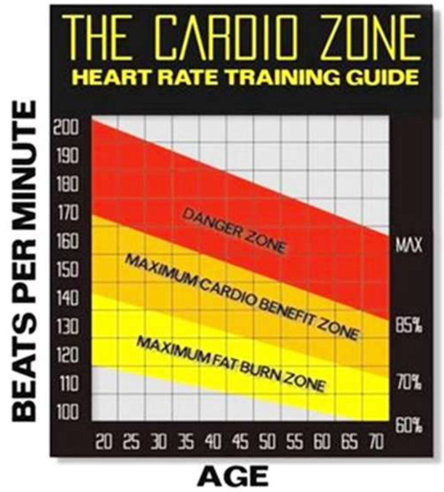
https://mur0016sportscience.weebly.com/energy-systems.html

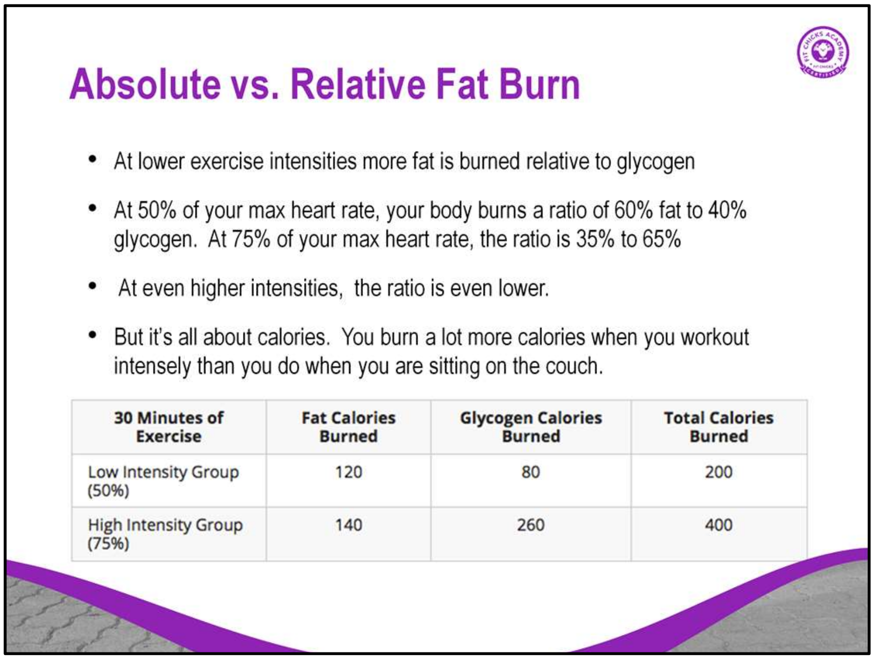


Energy Systems for Different Activities

Sport	ATP-PC	Anaerobic Glycolytic	Aerobic
Basketball	60	20	20
Field events (shotput, discuss, javelin)	90	10	0
Golf swing	95	5	0
Gymnastics	80	15	5
Hockey	50	20	30
Rowing	20	30	50
Running (distance)	10	20	70

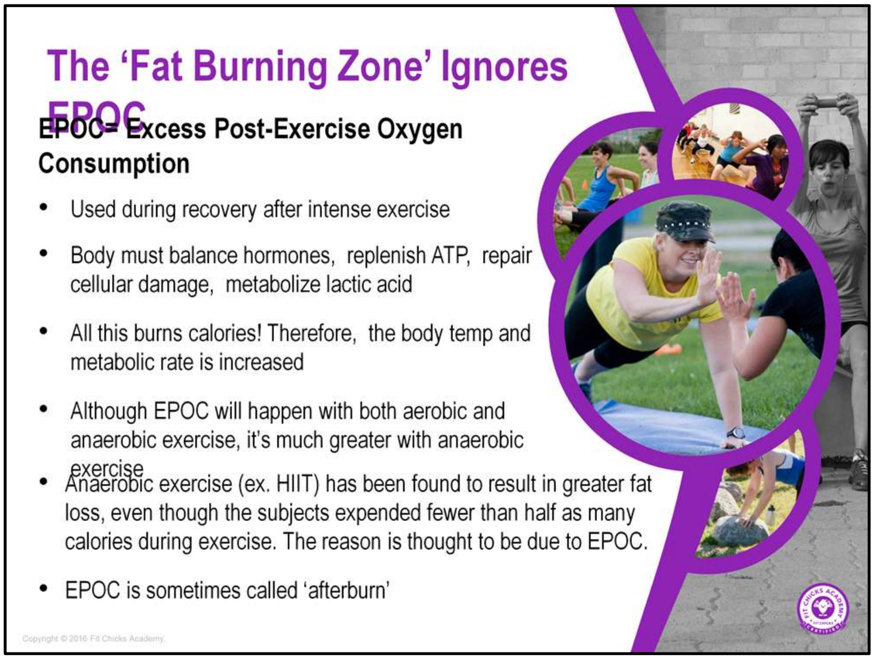
This chart shows the % of which system is used for each activity


THE CARDIO ZONE
HEART RATE TRAINING GUIDE
BEATS PER MINUTE
200
190
180
170
160
150
140
130
120
110
100
DANGER ZONE
MAXIMUM CARDIO BENEFIT ZONE
MAXIMUM FAT BURN ZONE
MAX
85%
70%
60%
20 25 30 35 40 45 50 55 60 65 70
AGE



http://www.builtlean.com/2013/04/01/fat-burning-zone-myth/

So if your goal is fat loss, is it better to work out at a lower intensity or higher intensity?



http://en.wikipedia.org/wiki/Excess_post-exercise_oxygen_consumption

https://www.youtube.com/watch?v=SLgNRg3mh6s

Muscle Soreness and Recovery

Muscle Soreness

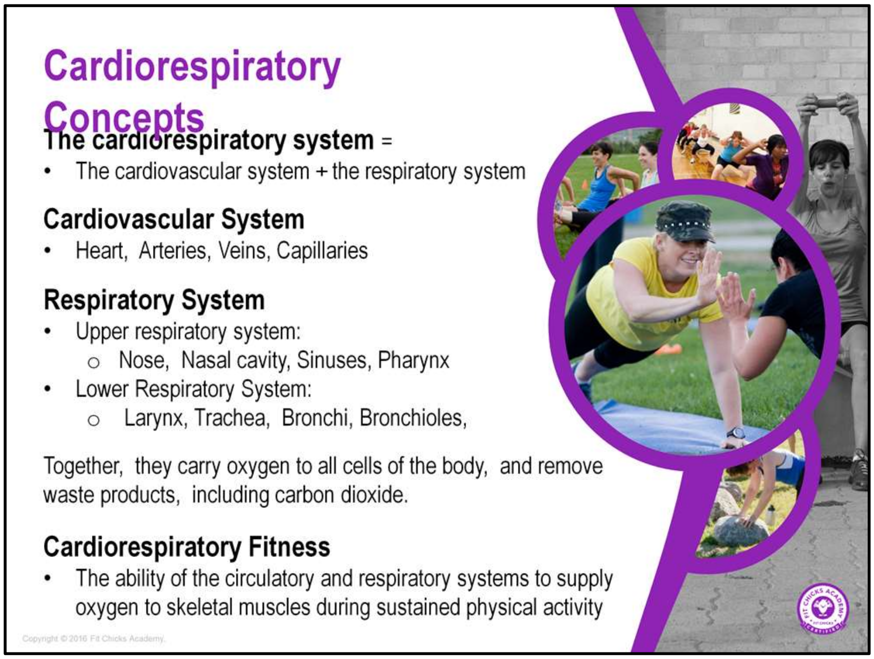
- Acute muscle soreness may be pain due to ischemia, accumulation of end products (H+ and H_2O)
- Delayed onset muscle soreness (DOMS)
  - Not directly related to lactate buildup
  - Observed with eccentric vs concentric contractions
  - Symptoms include: increased muscle enzymes and myoglobin, tissue damage (small micro tears), local muscle pain, soreness, and swelling

Muscle Recovery

- Possible decreased muscle force
- Body initiates inflammatory response to repair muscle
- Once soreness has occurred, you are protected from an increase in soreness for 3-4 weeks
- After each bout of same activity, recovery rate is faster

Ischemia – low blood flow
Increase pressure in the muscle which stimulates pain receptors
Some muscle enzymes and myoglobin are muscle specific but when the muscle is damaged they find their way into the bloodstream
Myoglobin – the muscles version of hemoglobin, iron binding molecule
Decreased muscle force can persist for several weeks (after running a marathon)

Cardiorespiratory Concepts



http://en.wikipedia.org/wiki/Cardiorespiratory_fitness

Http://hes.ucfsd.org/gclaypo/repiratorysys.html

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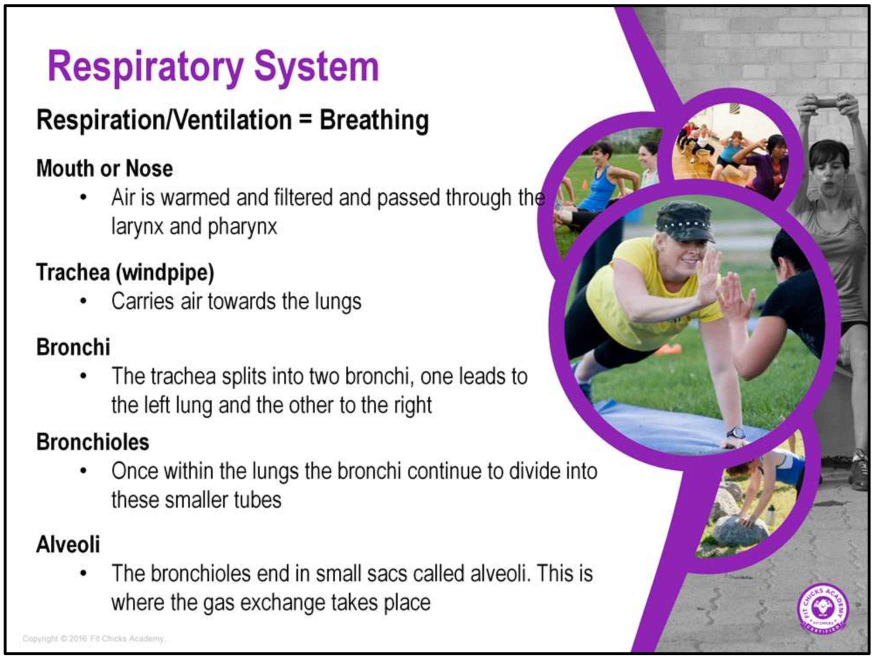
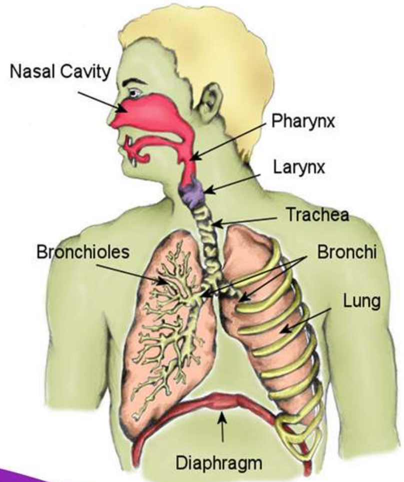


http://www.teachpe.com/anatomy/respiratory_system.php

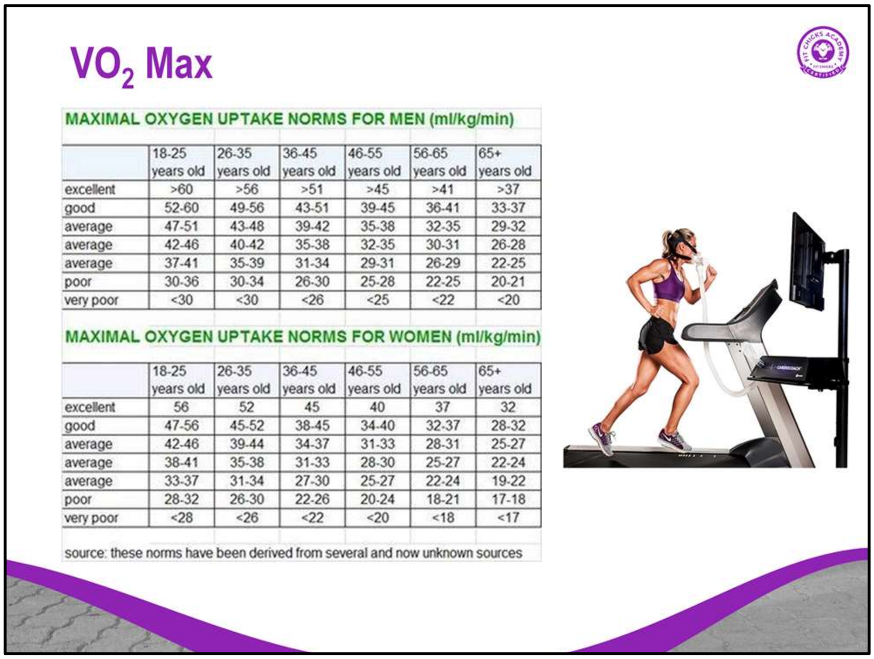
Respiratory System



VO_2 Max

- The maximum amount of oxygen that someone can use during maximal exercise
- Considered the best indicator of an athlete's cardiovascular fitness
- The more oxygen you can use during high intensity exercise, the more ATP you can produce
- Measure in ml of Oxygen used in 1 min per kg of body weight
- Tests are done under strict protocol in Sports Performance Labs

http://sportsmedicine.about.com/od/anatomyandphysiology/a/VO2_max.htm



VO_2 Max

MAXIMAL OXYGEN UPTAKE NORMS FOR MEN (ml/kg/min)

	18-25 years old	26-35 years old	36-45 years old	46-55 years old	56-65 years old	65+ years old
excellent	>60	>56	>51	>45	>41	>37
good	52-60	49-56	43-51	39-45	36-41	33-37
average	47-51	43-48	39-42	35-38	32-35	29-32
average	42-46	40-42	35-38	32-35	30-31	26-28
average	37-41	35-39	31-34	29-31	26-29	22-25
poor	30-36	30-34	26-30	25-28	22-25	20-21
very poor	<30	<30	<26	<25	<22	<20

MAXIMAL OXYGEN UPTAKE NORMS FOR WOMEN (ml/kg/min)

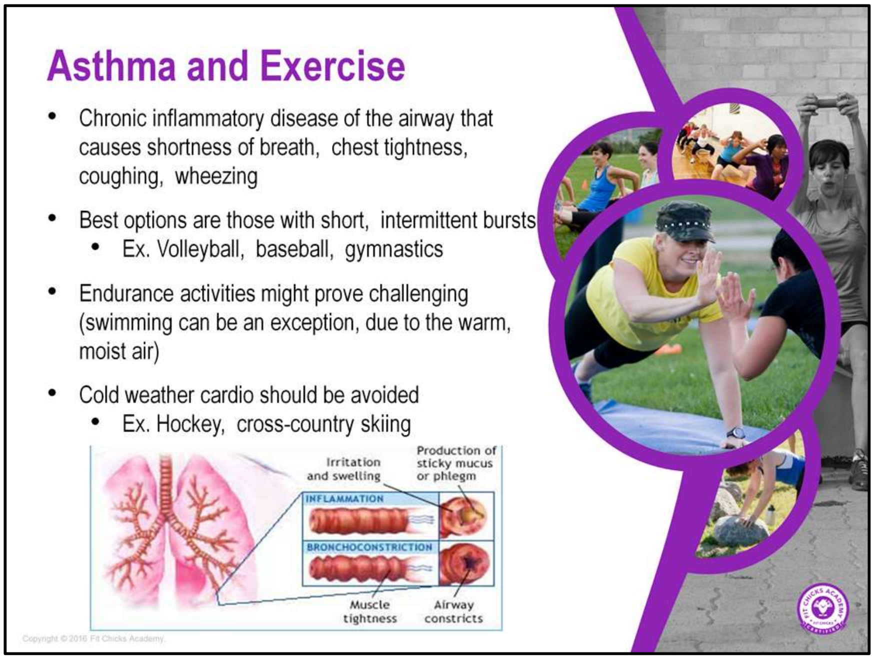
	18-25 years old	26-35 years old	36-45 years old	46-55 years old	56-65 years old	65+ years old
excellent	56	52	45	40	37	32
good	47-56	45-52	38-45	34-40	32-37	28-32
average	42-46	39-44	34-37	31-33	28-31	25-27
average	38-41	35-38	31-33	28-30	25-27	22-24
average	33-37	31-34	27-30	25-27	22-24	19-22
poor	28-32	26-30	22-26	20-24	18-21	17-18
very poor	<28	<26	<22	<20	<18	<17

source: these norms have been derived from several and now unknown sources

https://endurelite.com/blogs/free-nutrition-supplement-and-training-articles-for-runners-and-cyclists/the-two-things-every-endurance-athlete-should-focus-on-improving-for-optimal-performance-part-1

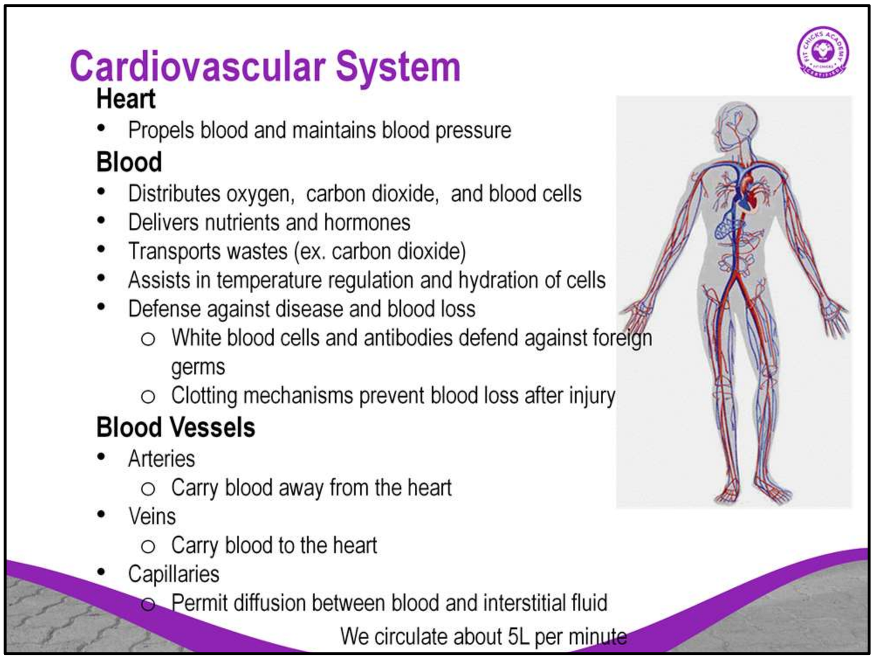
https://www.therunningcenter.com/vo2-max-testing-max-heart-rate-testing/

VO2 max testing can be done on a treadmill or bicycle, and either incline, speed or resistance can be manipulated.



https://www.youtube.com/watch?v=4aK76DoxKGk

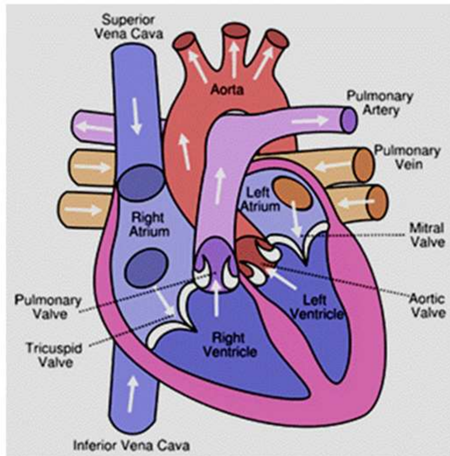
https://asthma.ca/what-is-asthma/



http://www.innerbody.com/image/cardov.html#full-description

Martini, F.H., Ober, W.C., Bartholomew, E.F., Nath, J.I. (2013). Visual Essentials of Anatomy and Physiology. 385

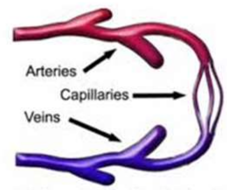
Blood vessels are the body's highways that allow blood to flow quickly and efficiently from the heart to every region of the body and back again.



https://www.youtube.com/watch?v=T2iVqTckmPQ

Blood Flow

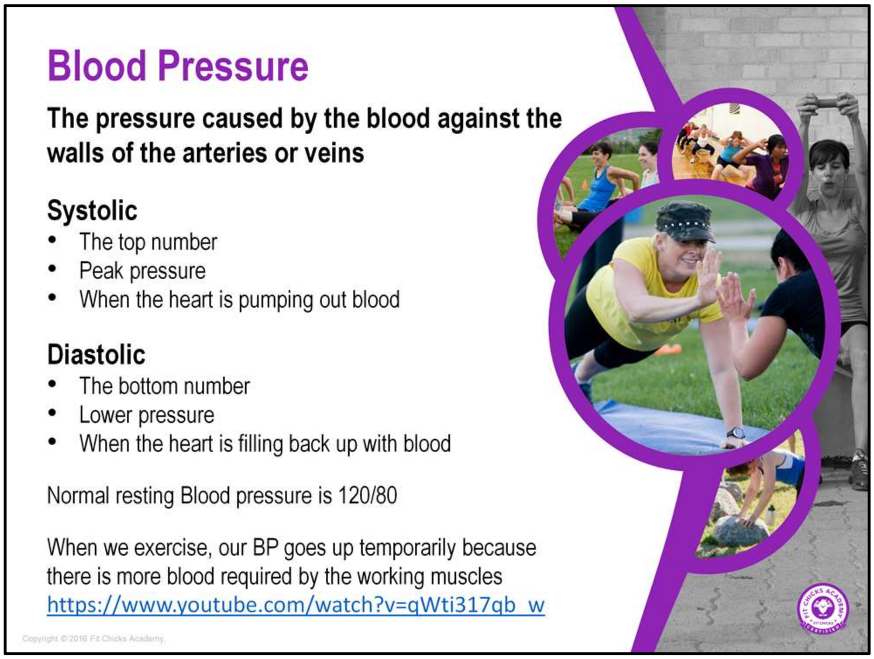
- Blood gets pumped from the heart into the aorta
- The aorta branches off into other arteries that carry the blood away from the heart
- The arteries branch off into arterioles
- Arterioles branch into capillaries
    - capillaries carry blood very close to the cells of the tissues of the body in order to exchange gases, nutrients, and waste products.
- The capillaries then form venules
- The venules turn into veins that carry the blood back to the heart



All I'm sa'in is circulation is the name of the game

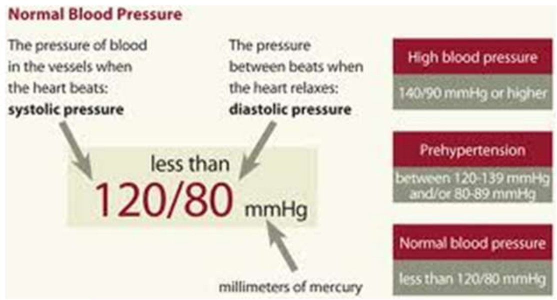
Heart ➡ Arteries ➡ Arterioles ➡ Capillaries ➡ Venules ➡ Veins ➡ Heart

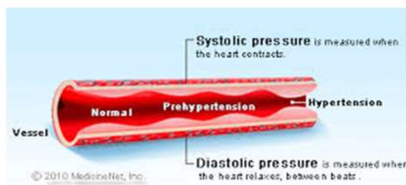
Capillaries

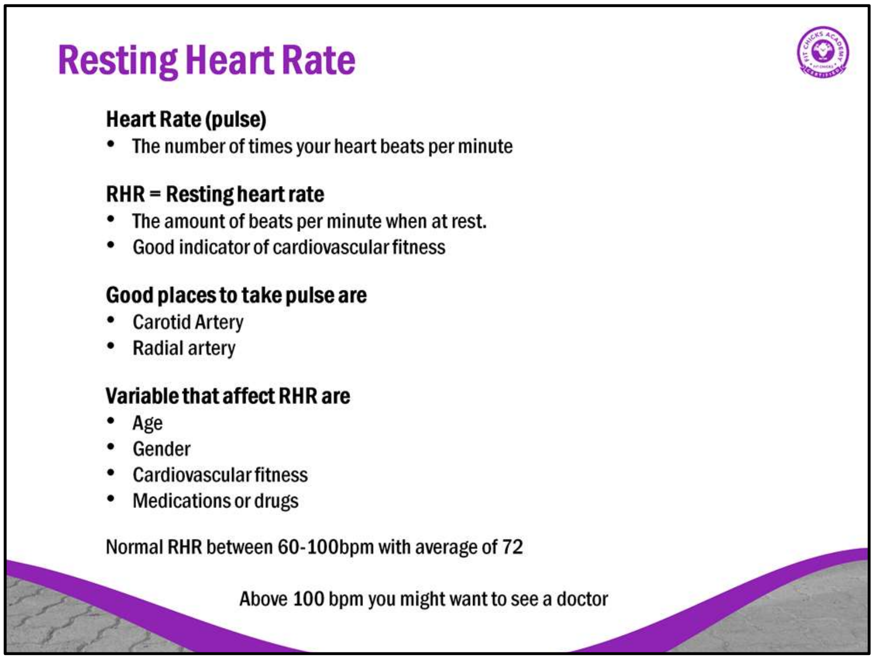


https://www.youtube.com/watch?v=qWti317qb_w

Blood Pressure







might want to check into heart rate app
take a moment for everyone to take their RHR

Let's take our RHR!

Resting Heart Rate

Resting Heart Rate for MEN

Age	18-25	26-35	36-45	46-55	56-65	65+
Athlete	49-55	49-54	50-56	50-57	51-56	50-55
Excellent	56-61	55-61	57-62	58-63	57-61	56-61
Good	62-65	62-65	63-66	64-67	62-67	62-65
Above Average	66-69	66-70	67-70	68-71	68-71	66-69
Average	70-73	71-74	71-75	72-76	72-75	70-73
Below Average	74-81	75-81	76-82	77-83	76-81	74-79
Poor	82+	82+	83+	84+	82+	80+

Resting Heart Rate for WOMEN

Age	18-25	26-35	36-45	46-55	56-65	65+
Athlete	54-60	54-59	54-59	54-60	54-59	54-59
Excellent	61-65	60-64	60-64	61-65	60-64	60-64
Good	66-69	65-68	65-69	66-69	65-68	65-68
Above Average	70-73	69-72	70-73	70-73	69-73	69-72
Average	74-78	73-76	74-78	74-77	74-77	73-76
Below Average	79-84	77-82	79-84	78-83	78-83	77-84
Poor	85+	83+	85+	84+	84+	84+

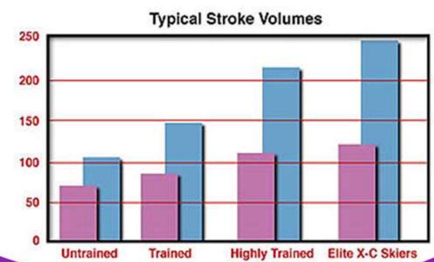
Stroke volume

Stroke Volume

- Amount of blood ejected by the left ventricle per beat

Average SV for a male is 70ml per beat

As we get more fit, our SV increases

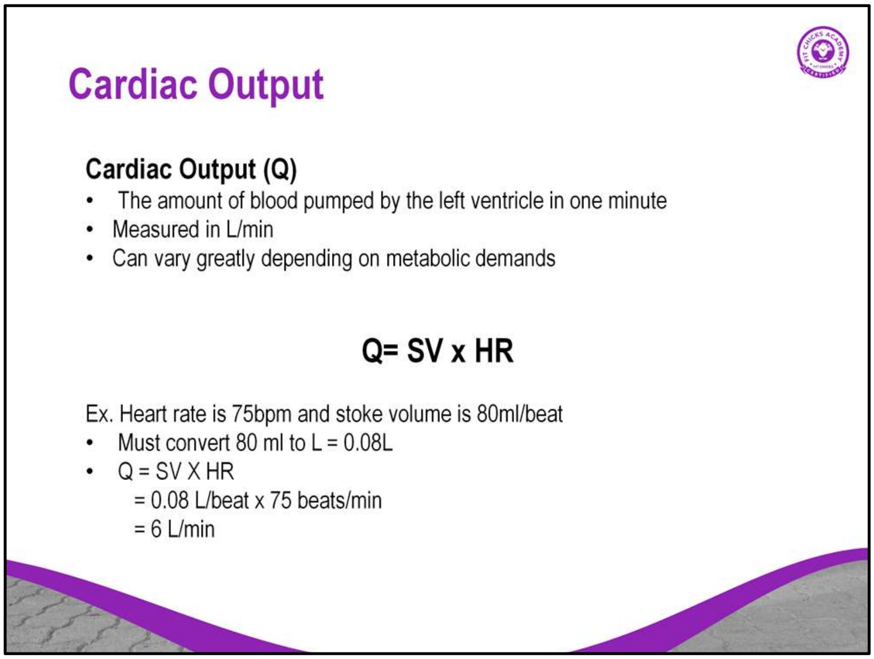


https://en.wikipedia.org/wiki/Stroke_volume

Relationship between SV and RHR

Why does RHR go down when we are fitter?

- The heart is a muscle that gets bigger and stronger as we get fitter
- A bigger and stronger heart causes more blood to be pumped each beat;
- Therefore, SV goes up.
- With increased SV, we are circulating more blood per beat
- Since we are circulating more blood per beat, we don't need as many beats
- Therefore RHR goes down!



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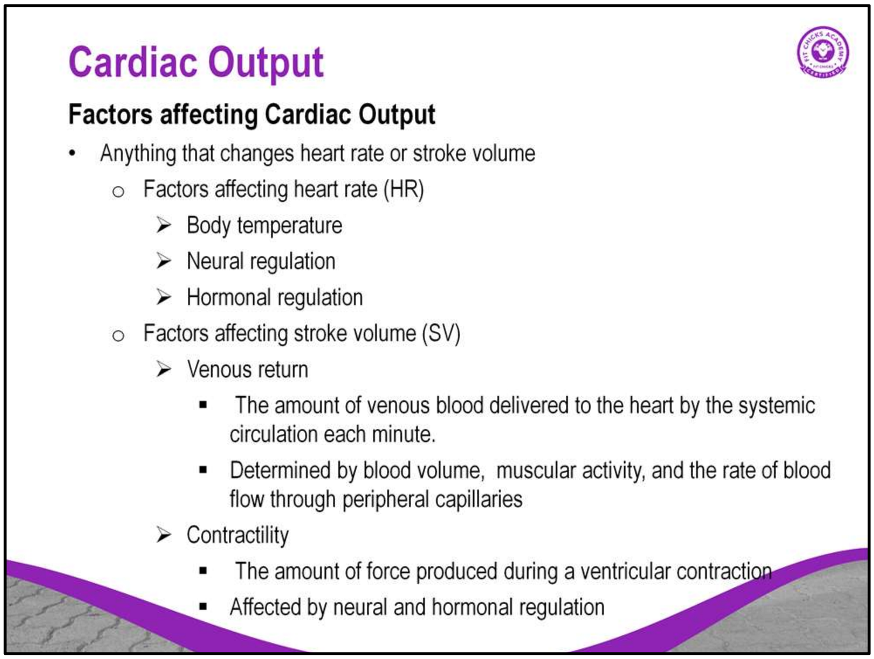

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Body temp rises – HR goes up
Body temp decreases – HR goes down

Sympathetic (fight or flight) regulation increases HR, parasympathetic (rest and digest) decreases HR

Hormones that increase HR – epinephrine and thyroid hormones

Max Heart Rate

Human heart can only beat 220 x per minute (only a young child)

HR Max

- 220 - Age

To determine a target HR %

- (220-age) x %

So let's figure out 55% of my MAX HR (I'm 34)

- Ex. (220 – Age) x %
  = (220-34) X 55%
  = (186) X 0.55
  = 102bpm

HR Zones

50-70% Low Intensity

- Ideal range for warming up and cooling down
- Helps to improve blood flow and circulation to your working muscles.
- It is also the desired zone for LISS (low intensity steady state training), such as walking.
- This is the "Fat Burning Zone"

70-80% Moderate Intensity

- Great for developing endurance and burning calories.
- Training in this zone will cause your body to rely on both carbs and fats for energy.
- This is a good zone for building general fitness.

80- 95% High Intensity

- This is anaerobic zone and therefore not sustainable for a long time
- It takes you out of your comfort zone (HIIT training)
- This is going to give maximum EPOC

Let's Practice

Denise is 25 years old and is looking for her target heart rate zone for LISS (50-70%)

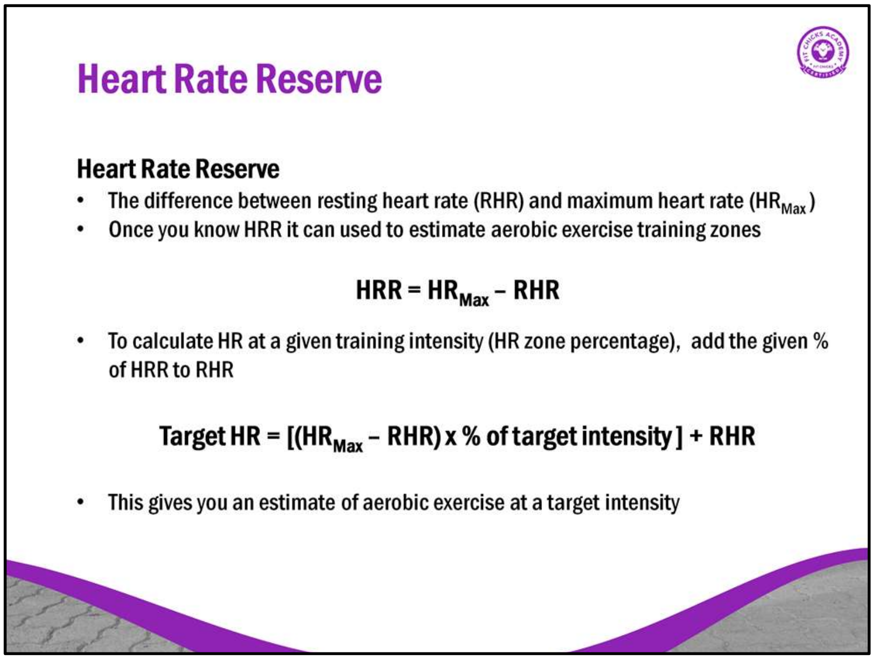
Let's Practice - Denise

We need to calculate Denise's HR at both 50% and 70% to get her target HR for LISS

Lower target heart rate:
(220-25) x .5
=195 x .5
=97.5

Upper target heart rate:
(220-25) x .7
= 195 x .7
= 136.5

So, Denise's target heart rate for her goals would be between 98 to 137bpm



https://support.polar.com/ca-en/support/faqs/Heart_Rate_Reserve_HRR

Using HRH to calculate target intensity will give a more specific heart range for your client because it takes into account resting HR.

For example: Target intensity 70 % HRR for a person with HR_{max} 201 bpm and HR_{rest} 50 bpm

Exercise HR= [(201-50) x 70%] + 50
= (151 x .7) + 50
= 105.7 + 50
Exercise HR=155 bpm

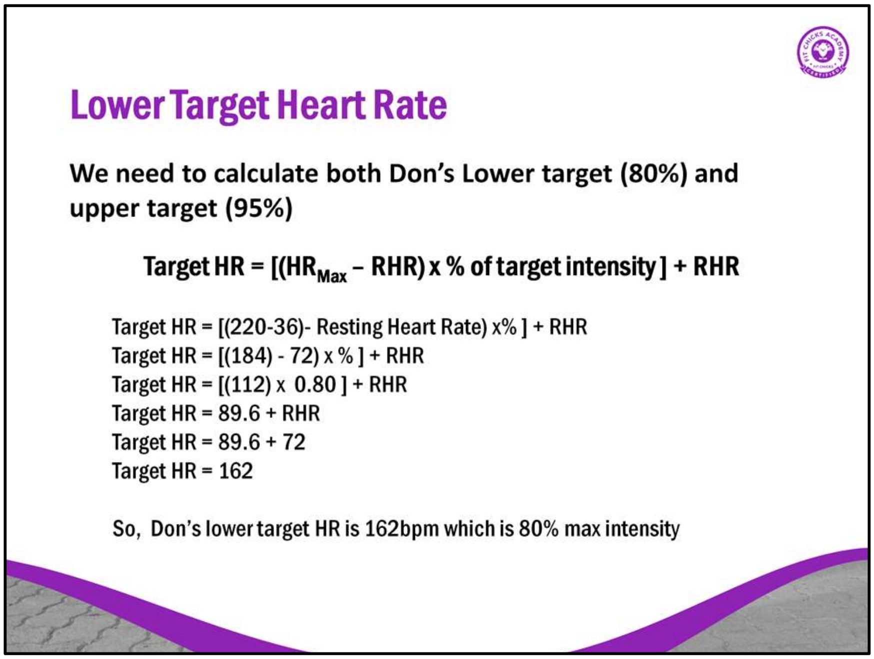
If you didn’t use RHR and the heart rate reserve calculation and just calculated a 70% target intensity you would get a different number:
Exercise HR = (220 –age) x 70%
= 201 x .70
Exercise HR=140 bpm

Without knowing resting heart rate, this persons target HR at 70% would be 140bpm but knowing RHR, their target HR at 70% would actually be 155bpm. If they were just going by max HR then this client would be working at a lower capacity then what they should be.

Let's Practice!

Target HR = [(HR_{Max} – RHR) x % of target intensity] + RHR

Don is 36 and has a RHR of 72 and wants to do HIIT training (80-95% of Max HR). What should his target HR be during the high intensity intervals?



First we calculate Max heart rate (220-age):
Then we calculate HRR (HR_{Max} – RHR):
Then we calculate % target HR:

Going back to the previous discussion about target HR. If you didn't know Don's RHR then you would just use the (220-age) x Target % which would give you 147bpm. With this as his target, he would be working at a lower capacity and not actually reaching his 80% target.

Upper Target Heart Rate

We do the same thing to calculate Don's upper target heart rate

Target HR = [(HR_{Max} – RHR) x % of target intensity] + RHR

Target HR = [(220-36)- RHR) x %] + RHR
Target HR = [(184) - 72) x %] + RHR
Target HR = [(112) x 0.95] + RHR
Target HR = 106.4 + RHR
Target HR = 106.4 + 72
Target HR = 178

So, Don's upper target heart rate is 178bpm which is at 95% max intensity

Therefore, Don's target heart rate for HIIT (80-95% of HR max) is **162 – 178 bpm**

Measuring Exertion

There are other ways to measure exertion other than HR

Modified Borg Scale

- Measures the exerciser's **Rate of Perceived Exertion (RPE)**
- Borg scale 6-20
- Modified Borg scale 1-10 (More widely used)
  - 1 – 4: No effort, daily living
  - 5 – 7: Light Effort, body temperature is raised, breathing a little heavier but can talk and sustain for a long period of time
  - 7 – 8: Definitely feels like work. Breathing heavier but can still talk. Sustainable for 15-40 mins, depending on fitness
  - 8 – 9.5: Everything you have. Breathless. Can't sustain it longer than 1 min or so.

Measuring Exertion

Talk Test

- Aerobic
  - Should be able to talk, but not sing!

- Anaerobic
  - Should be able to answer a question, but not ask it!

FITT for Cardio

Frequency
- 3-5 x per week

Intensity
- 50-85% of HR Max

Time
- 20 – 45 mins

Type
- LISS (50-75%) for cardiovascular endurance adaptations
- HIIT (75-90%) for fat loss and to train for certain sports

Quiz!

What is ATP?

Define Aerobic vs. Anaerobic

Which energy system produces the most ATP?

Which energy system would I be using if I am working at very high intensity?

Explain why I shouldn't stay in my Fat Burning Zone

What is EPOC?

What's normal BP? Stroke Volume?

Why does our HR go down when we get fitter?

What is HRR?

Recap

BIOENERGETICS

- Muscle Metabolism: the role of ATP
- How energy is created in the Human Body
  - Cellular Respiration and the different energy systems
- Interval Training
- Burning Fat vs. Burning Carbs
- Why interval training so effective
- Muscle soreness and recovery

CARDIORESPIRATORY CONCEPTS

- Anatomy of the Cardiorespiratory System
- Heart Rate, Blood Pressure, VO2MAX, Stroke Volume, Cardiac Output,
- How to determine your Heart Rate Training Zone
- Training adaptations

Any questions or inquiries, please email:

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