ES.010- Chemistry of Sports -Week 3

Topics to cover:

- Workouts and Fitness assessment comments
- Training your body - focusing on lungs, and muscle
- Repair and maintenance of body

Weekly workouts

- Triathlon training
  - This week we will be Swimming at the Z center at 4 pm on Thursday February 21rd
  - Make sure you tell Patti if you want PE points –you must attend 8 classes (ie. You can miss 2)

Fitness assessments

- Did the assessment accurately predict what you though of your overall fitness level?
- Do you have goals for the term?

Personal Weekly workouts

- How are things going?
- Starting slow?
- Anyone injured?

Readings for you to have done before class (from our website)

1. Physiologic consequences of training
2. Limitations to Maximal Oxygen uptake

Optional readings

– Muscle Fatigue

– Applied Physiology of Triathlon

– Recovery from prolonged exercise: restoration of water and electrolyte balance

– Weight changes, sodium levels, and performance in the south African ironman triathlon

– Lactic Acid and Exercise Performance

Patti's new favorite book

Exercise physiology: Human bioenergetics and its applications, 4th edition (2005)

– By George A. Brooks, Thomas D. Fahey and Kenneth M. Baldwin

VO_2 Max

This is a reflection on the efficiency of your cardio respiratory system.

This is the maximum volume of oxygen that can be delivered to the working muscles

Why is this important?

VO_2 Max

The higher the VO_2 max, the more fit you are and the easier you find physical work and exercise. It is easier for you body to deliver oxygen to your muscles

VO_2 Max

The ability to supply energy for activities lasting more than 30 seconds depends on the consumption and use of oxygen.

The rate of consumption of a given volume of O_2 (VO_2 increase as activities progress from rest to easy, to difficult and finally to maximal

The maximum rate at which an individual can consume oxygen (VO_2 max) is an important determinant of the peak power output and the maximal sustained power output, or physical work capacity of which an individual is capable

Reference: Exercise Physiology, 4th edition Brooks et al.

Relationship between oxygen consumption and external work rate (power output)- graphical representation

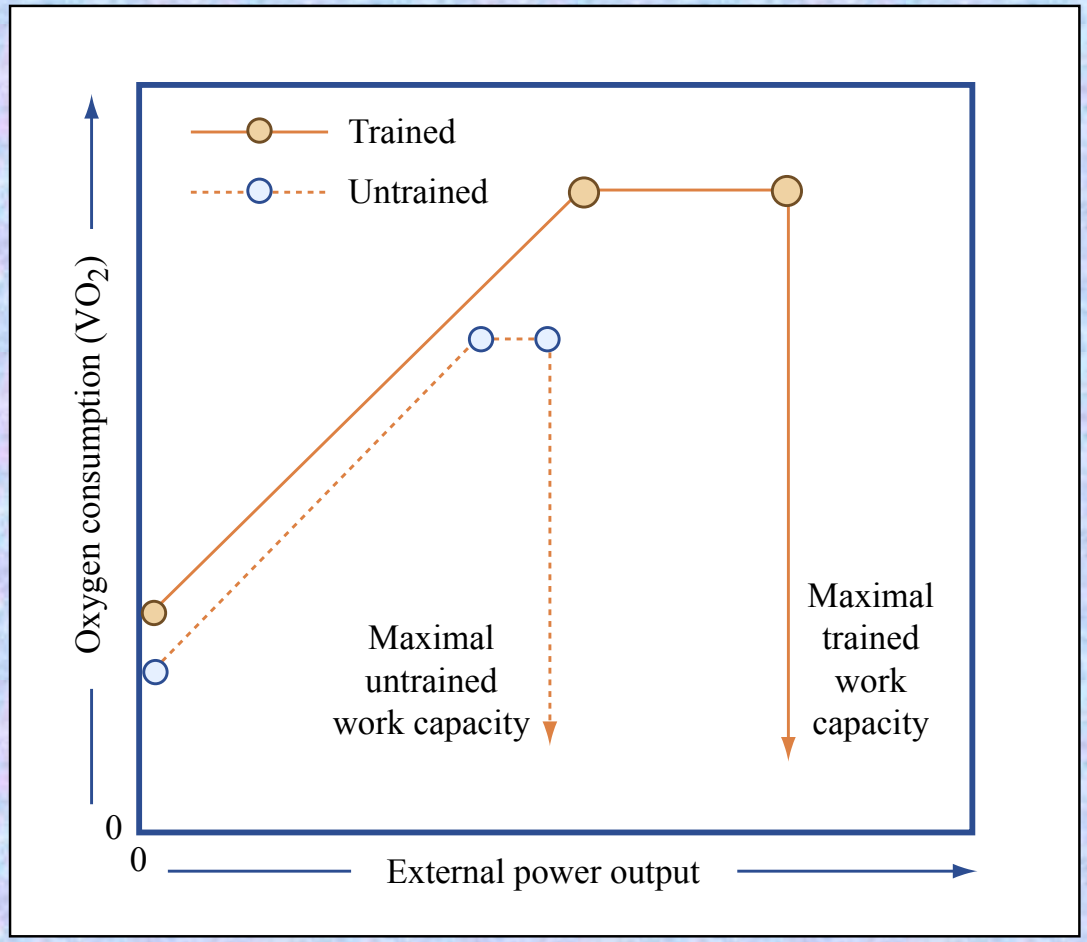


Image by MIT OpenCourseWare.

From Exercise Physiology, 4th edition, Brooks et al p6

VO_2 Max

When the VO_2 test was done in your fitness assessment, the following information was incorporated in the data:

- Workload (kg m/min)
- Heart rate at the two workloads
- Plotted HR (y-axis) vs. workload (x axis), then where the line intercepted at predicted max heart rate, is the Max O_2 (L/min)
- Divide this number by your body weight in kg (convert L to ml), then you get Max O_2 in ml/kg/min

How can we improve our VO_2

Manipulate the heart rate

– Heart is a muscle and if it gets regularly exercised, it will be more efficient.

– How can you improve your heart muscle?

Improve your heart muscle

Work out at your targeted heart rate.

First you need to calculate your maximum heart rate;

- The easiest way to do this is to use the following formula: 220 – age
- Now to improve your heart muscle, you need to work on in your target heart rate which is 55 to 85 % of your maximum heart rate
- Let us calculate the range for targeted heart rate for your age at 65 %, 70 % and 85 %

Target Heart Rate

Age	Target HR Zone 50–85 %	Maximum Heart Rate 100 %
20 years	100 – 170 beats per minute	200 beats per minute
25 year	98–166 beats per minute	195 beats per minute
30 years	95–162 beats per minute	190 beats per minute
35 years	93–157 beats per minute	185 beats per minute
40 years	90–153 beats per minute	180 beats per minute
45 years	88–149 beats per minute	175 beats per minute
50 years	85–145 beats per minute	170 beats per minute
55 years	83–140 beats per minute	165 beats per minute

How should I pace myself? (from the American Heart Association website)

When starting an exercise program, aim at the lowest part of your target zone (50 percent) during the first few weeks. Gradually build up to the higher part of your target zone (75 percent).

After six months or more of regular exercise, you may be able to exercise comfortably at up to 85 percent of your maximum heart rate. However, you don't have to exercise that hard to stay in shape.

Workload

The Maximum workload is measured in Watts (joules per second).

It is a measure of power

Think it as the maximum amount of work that you can do in a second. This is sometimes referred to as critical power

Cycling Test

The purpose of these tests is to calculate the VO_2 max.

This is accomplished by having the subject work out at 60 to 70 % of VO_2 and use this value to calculate VO_2 max

Dark-side Cycling Test

Effect of inspiratory threshold loading on ventilatory kinetics during constant-load exercise

S. Keslacy, S. Matecki, J. Carra, F. Borrani, R. Candau, C. Prefaut and M. Ramonatxo

Am J Physiol Regulatory Integrative Comp Physiol 289:1618-1624, 2005. First published Aug 4, 2005; doi:10.1152/ajpregu.00639.2004

Maximal Incremental Exercise

Each subject performed an incremental cycling exercise to volitional exhaustion. Pedaling frequency was set at 70 rpm. The incremental test began with a 5-min warm-up at 60 W. The work rate then increased by 30 W every minute until the subjects reached volitional exhaustion. A value of heart rate close to the theoretical maximal heart rate, a respiratory exchange ratio higher than 1.1, and a plateau for $\dot{V}O_2$ were considered as criteria of $\dot{V}O_{2\,max}$.

Volitional: The act or an instance of making a conscious choice or decision. Therefore the subjects decided that they were tired.

Maximum Acceptable work duration

Eur J Appl Physiol (2001) 85: 339–344
DOI 10.1007/s004210100453

ORIGINAL ARTICLE

Hsin-Chieh Wu · Mao-Jiun J. Wang

Determining the maximum acceptable work duration for high-intensity work

- Concern about high-intensity jobs (i.e. Mining, construction, forestry and fishing)
- Prolonged high-intensity work frequently causes fatigue and over exhaustion and possibly leads to occupational disorders and accidents
- Workload associated with a heart rate over 150 beats/min^{-1} is an extremely heavy workload

Conclusions from the paper

Workers should take a break after 18.8 minutes of work when the average workload is about 65 % relative VO_2 (for 85 % it is 4.1 minutes, and for 70 % it is 12.3 minutes)

Keep this is mind when you are training – you need to listen to your body and do not overtrain to exhaustion, this could lead to a physical mishap

Back to training

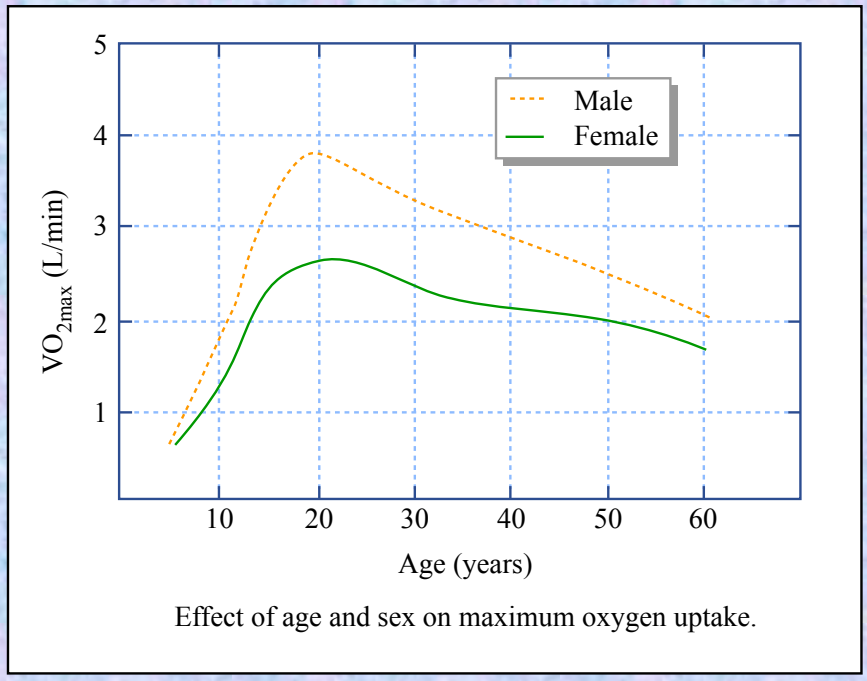
So you need to get your VO_2 up, so that you can increase your maximum workload

Limitations to Maximal oxygen uptake

- There is a very good review paper:

  Sutton, John R. "Limitations to Maximal Oxygen Uptake." *Sports Medicine* 13, no. 3 (1992): 127-133.

There is a correlation between Age and Sex on VO_2 max



Effect of age and sex on maximum oxygen uptake.

Based on averages, as you age, your VO_2 decreases but training can increase your VO_2 up 2-3 fold

From Sutton (1992)

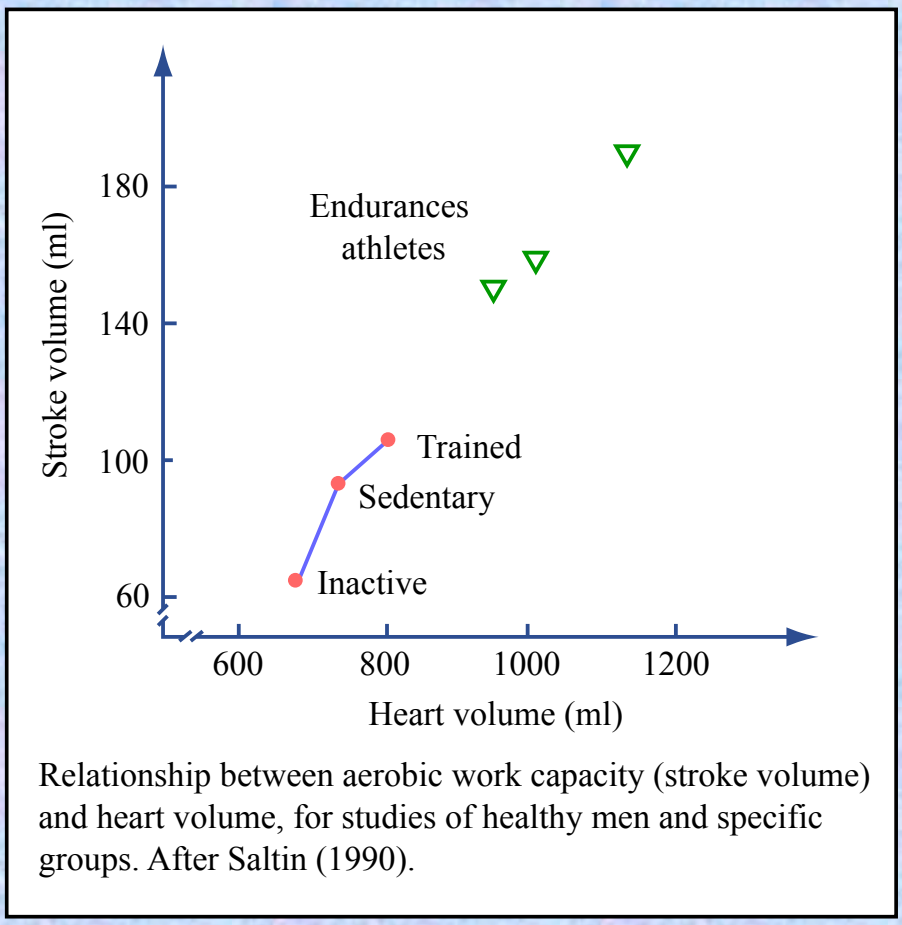
Limits to maximal oxygen uptake

Image removed due to copyright restrictions.
See Fig. 2 in Sutton, J. R. "Limitations to Maximal Oxygen Uptake." Sports Medicine 12, no. 2 (1992): 127-133.
Diagram shows individual components of the oxygen transport chain:
- Ventilation
- Hemoglobin
- Cardiac output
- Peripheral circulation
- Metabolism

From Sutton, 1992

Physical limits to improving your max O_2

Aerobic work capacity and heart volume



Relationship between aerobic work capacity (stroke volume) and heart volume, for studies of healthy men and specific groups. After Saltin (1990).

- Look at the relationship between heart volume/stroke volume and work capacity
- Compare inactive, sedentary, trained and endurance athletes.

From Sutton, 1992

Conclusions from Sutton's paper

7. Conclusion

Maximal oxygen uptake depends on the optimal linkage between all components of the oxygen transporting system from the lungs to the capillary network. Of all the determinants of maximal oxygen uptake which change with physical training the cardiovascular system is most adaptable and within that system it is the maximum increases in stroke volume which are most important.

Another predictor of VO_2 - weight

In the fitness test - Max O_2 was in ml/kg/min

One way to improve this number is to decrease the weight of your body (this will be discussed next week - Nutrition)

A word about training

Physiologically the purpose of an training session is to stress the body so that adaptation results.

Training is beneficial only as long as it forces the body to adapt to the stress of physical effort

If the stress is not sufficient to overload the body, then no adaptation occurs (hence no improvement in physical fitness)

A word about training

Now if the stress is so great that it cannot be tolerated, then injury or overtraining results

Make sure that when you are working out that you are making sure that you are not overstressing your body - listen to your body!

The greatest improvements in performance occur when appropriate exercise stresses are introduced into an individual's training program.

Hans Selye

Hans Selye was born in Vienna in 1907. As early as his second year of medical school (1926), he began developing his now-famous theory of the influence of stress on people's ability to cope with and adapt to the pressures of injury and disease. He discovered that patients with a variety of ailments manifested many similar symptoms, which he ultimately attributed to their bodies' efforts to respond to the stresses of being ill. He called this collection of symptoms--this separate stress disease--stress syndrome, or the general adaptation syndrome (GAS).

There are three stages involved in response to a stressor: alarm reaction, resistance development and exhaustion

The Alarm reaction

Initial response to the stressor involves the mobilization of systems and processes within the organism

For instance, during exercise the stress of running is supported by the strain of increasing oxygen transport through an augmentation of cardiac output and a redistribution of blood flow to active muscle

Remember that that body has a limited capacity to adjust to various stressors - homeostasis must not be affected long-term

Resistance Development

The body improves its capacity or builds its reserves during the resistance stage of GAS

This stage represents the goal of physical conditioning.

You need to make sure that you are at the critical threshold to achieve this state (not above or below)

Remember that if you are sick, that your ability to effectively workout may be diminished. You might end up hurting yourself instead of improving

Exhaustion (or distress)

This occurs when stress becomes intolerable, and can either be acute or chronic

Acute exhaustion can be fractures, sprains or strains

Chronic exhaustion (overtraining) examples include stress fractures, emotional problems, and soft tissue injuries

Overload principle

Application of an appropriate stressor will cause the body to respond and adapt

Overload is a positive stressor that can be quantified according to load (intensity and duration), repetition, rest and frequency

Load

This refers to the intensity of the exercise stressor

For strength training - load refers to the amount of resistance

For running and swimming - it refers to speed

In general, the greater the load, the greater the fatigue and recovery time required

Repetition

This is the number of times the load is applied

More favorable adaptation tends to occur (up to a point) when the load is administered more than once.

There is no agreement on the number of repetitions you should do

Rest

This is the time interval between repetitions as well as the interval between training sessions

Vitally important for obtaining an adaptation and should be applied according to the nature of the desired physiological outcome.

Resting is a necessary part of training because adaptations occur during recovery

Frequency

This is the number of training sessions per week

You need to listen to your body to decide on the total number of times you work out.

For triathlon training - you rotate through the different sports on different days generally starting with one a day workouts and building up to twice a day workouts.

Then once a week you do a brick workout (bike followed by a run)

Other Training strategies

Specificity -

– don’t over train specific part of your body - think of the body as a whole

– Also, the close the training routine to the requirements of competition, the better the outcome

Reversibility

– Inactivity will lead to performance decrement Individuality

– You need to listen to your body and adapt your training regime to fit your body

Repair and Maintenance of your body

What happens when you work out?

It's Not About the Lactic Acid: Why You're Still Sore After Yesterday's Ride

- Lactic acid is completely washed out of the muscles within 30 to 60 minutes after you finish riding. Since muscle soreness does not show up until 24 to 36 hours later, scientists have been exercising their brains to come up with another explanation.

http://www.active.com/mountainbiking/Articles/It_s_not_about_the_lactic_acid__Why_you_re_still_sore_after_yesterday_s_ride.htm

It's Not About the Lactic Acid: Why You're Still Sore After Yesterday's Ride

- Currently, the most popular theory is that when you overdue your cycling, skiing or weight work, you cause "microtrauma" to the muscle fibers—localized damage to the muscle fiber membranes and contractile elements

http://www.active.com/mountainbiking/Articles/It_s_not_about_the_lactic_acid__Why_you_re_still_sore_after_yesterday_s_ride.htm

It's Not About the Lactic Acid: Why You're Still Sore After Yesterday's Ride

- Over the 24 hours, the damaged muscle becomes swollen and sore. Chemical irritants are released from the damaged muscles and can irritate pain receptors. In addition to the injured fibers, there is increased blood flow from increased activity to the muscle, causing a swelling of the muscle tissues, which causes enough pressure to stimulate pain receptors. Instead of having free-moving muscle fibers the next morning, you have fibers that are fatigued, have microscopic tears and are swollen.

http://www.active.com/mountainbiking/Articles/It_s_not_about_the_lactic_acid__Why_you_re_still_sore_after_yesterday_s_ride.htm

So where does the lactic acid come from?

So where does the lactic acid come from?

Image removed due to copyright restrictions.
Learn more about the breakdown of glucose.
With this link: http://en.wikipedia.org/wiki/Glycolysis

Repair and Maintenance of your body

So now you need to be able to repair those muscle fibers.

What do you need to build new muscle fibers?

Repair and Maintenance of your body

So now you need to be able to repair those muscle fibers.

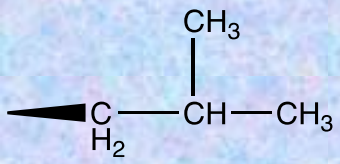
What do you need to build new muscle fibers?

Amino acids! In fact the best ones are branched Chain amino acids (BCAAs)

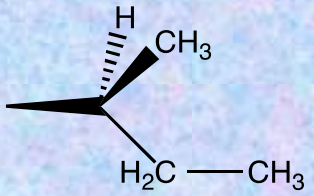
Branched-chain Amino acids

The branched-chain amino acids (BCAAs) are essential amino acids and therefore must be continuously available for protein synthesis.

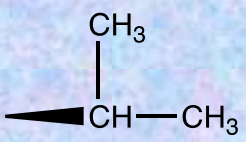
Leucine



Isoleucine



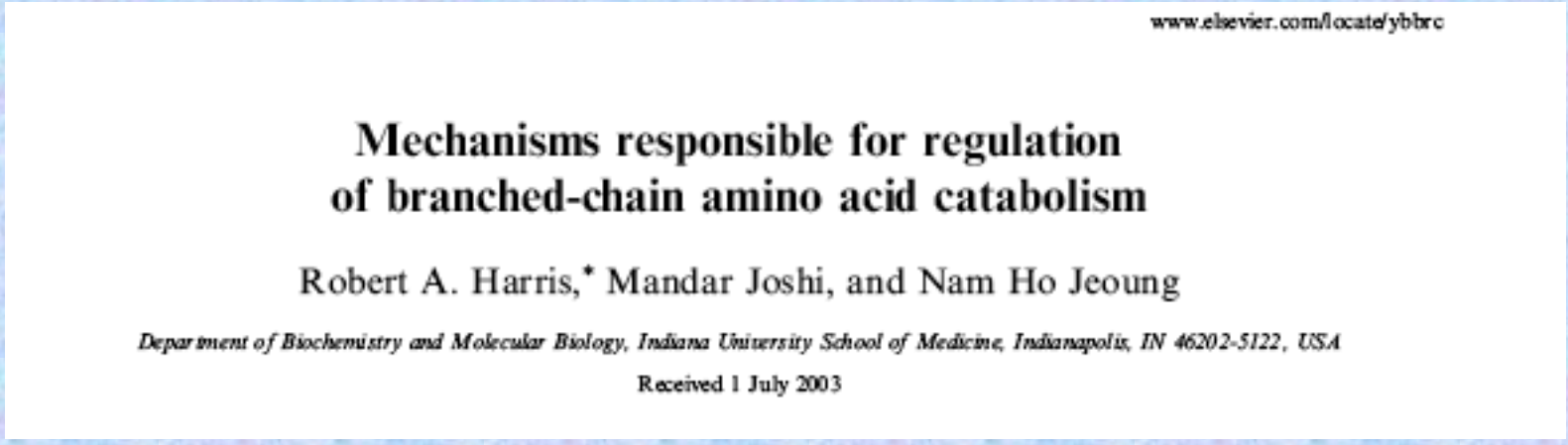
Valine



Leucine, Isoleucine and Valine appear to have the most effect on protein synthesis

Why do BCAA's increase protein synthesis?

- Leucine promotes global protein synthesis by signaling an increase in translation, promotes insulin release, and inhibits autophagic protein degradation.



www.elsevier.com/locate/ybbrc

Mechanisms responsible for regulation of branched-chain amino acid catabolism

Robert A. Harris,* Mandar Joshi, and Nam Ho Jeoung

Department of Biochemistry and Molecular Biology, Indiana University School of Medicine, Indianapolis, IN 46202-5122, USA

Received 1 July 2003

Why do BCAA's increase protein synthesis?

- However, leucine's effects are self-limiting because leucine promotes its own disposal by an oxidative pathway, thereby terminating its positive effects on body protein accretion.

Harris, Robert A., Mandar Joshi, and Nam Ho Jeoung. "Mechanisms Responsible For Regulation of Branched-Chain Amino Acid Catabolism." *Biochemical and Biophysical Research Communications* 313, no. 2 (January 2004): 391-396.

Why do BCAA's increase protein synthesis?

- A strong case can therefore be made that the proper leucine concentration in the various compartments of the body is critically important for maintaining body protein levels beyond simply the need of this essential amino acid for protein synthesis.

Harris, Robert A., Mandar Joshi, and Nam Ho Jeoung. "Mechanisms Responsible For Regulation of Branched-Chain Amino Acid Catabolism." *Biochemical and Biophysical Research Communications* 313, no. 2 (January 2004): 391-396.

Repair and Maintenance of your body

During exercise, the metabolic activity is accelerated due to an increased blood flow through muscle under circumstances of normal amino acid concentrations.

Rennie, Michael J. Julien Bohé, et. al. "Branched-Chain Amino Acids as Fuels and Anabolic Signals in Human Muscle." *Journal of Nutrition* 136 no. 1 (January 2006): 2645-2685.

Repair and Maintenance of your body

These authors state that regular exercise increases muscle mass due to a higher rate of protein synthesis in relation to protein breakdown

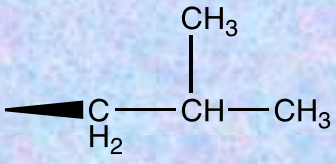
Blomstrand, Eva, Jörgen Eliasson, et. al. "Branched-Chain Amino Acids Activate Key Enzymes in Protein Synthesis after Physical Exercise." *Journal of Nutrition* no. 136, no. 1 (January 2006): 2695-2735.

From their abstract:

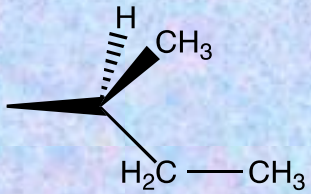
ABSTRACT BCAAs (leucine, isoleucine, and valine), particularly leucine, have anabolic effects on protein metabolism by increasing the rate of protein synthesis and decreasing the rate of protein degradation in resting human muscle. Also, during recovery from endurance exercise, BCAAs were found to have anabolic effects in human muscle. These effects are likely to be mediated through changes in signaling pathways controlling protein synthesis. This involves phosphorylation of the mammalian target of rapamycin (mTOR) and sequential activation of 70-kD S6 protein kinase (p70 S6 kinase) and the eukaryotic initiation factor 4E-binding protein 1. Activation of p70 S6 kinase, and subsequent phopsphorylation of the ribosomal protein S6, is associated with enhanced translation of specific mRNAs. When BCAAs were supplied to subjects during and after one session of quadriceps muscle resistance exercise, an increase in mTOR, p70 S6 kinase, and S6 phosphorylation was found in the recovery period after the exercise with no effect of BCAAs on Akt or glycogen synthase kinase 3 (GSK-3) phosphorylation. Exercise without BCAA intake led to a partial phosphorylation of p70 S6 kinase without activating the enzyme, a decrease in Akt phosphorylation, and no change in GSK-3. It has previously been shown that leucine infusion increases p70 S6 kinase phosphorylation in an Akt-independent manner in resting subjects; however, a relation between mTOR and p70 S6 kinase has not been reported previously. The results suggest that BCAAs activate mTOR and p70 S6 kinase in human muscle in the recovery period after exercise and that GSK-3 is not involved in the anabolic action of BCAAs on human muscle. J. Nutr. 136: 269S–273S, 2006.

Anabolic - synthesis

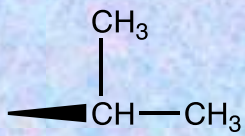
Leucine



Isoleucine



Valine



So what should you do after a workout?

Read Fitzgerald, Matt. "Chocolate Milk Wins Again." *Triathlete*. August 2011. Pg. 22

Lactate thresholds

Faude, Oliver, Wilfried Kindermann, and Tim Meyer. "Lactate Threshold Concepts: How Valid Are They?" *Sports Medicine* 39 no. 6 (2009): 469-490.

Lactate thresholds

The lactate threshold is the maximal effort or intensity that an athlete can maintain for an extended period of time with little or no increase in lactate in the blood. It is an effort or intensity and not a specific lactate level. It is most often described as a speed or pace such as meters per second, or times to achieve certain distances such as minutes per mile or kilometer for running and minutes per 100 m in swimming, or as a power measure such as watts.

Reference: http://www.lactate.com/lactate_threshold_definitions.html

See Beneke, Ralph, Renate M. Leithäuser, and Oliver Ochentel. “Blood Lactate Diagnostics in Exercise Testing and Training.” *International Journal of Sports Physiology and Performance* 6 (2011): 8-24.

Next week: Nutrition

For next week's class:
Keep track of the number of calories you consume on three days over the course of the next week

Good websites to look up calorie information:

http://www.calorieking.com/

Most restaurants have nutritional information on-line:
For instance: Subway:
http://www.subway.com/subwayroot/default.aspx

ES.010 Chemistry of Sports
Spring 2013