Energy For Movement

Metabolism

and

Basic Energy Systems
Energy

- Energy is the capacity to perform work
- Energy can come from a number of different forms
  - Chemical
  - Electrical
  - Electromagnetic
  - Thermal
  - Mechanical
  - Nuclear
Energy

- Law of “Thermodynamics” states that all forms of energy are interchangeable.
- Energy is never lost or newly created but always changing.
- Energy originates from the sun as light energy and is converted.
  - Ultimately stored in plants
    - Carbohydrates
    - Fats
    - Proteins
Energy for Cellular Activity

- **Energy sources**
  - carbohydrates - glucose = (C6H12O6)
  - fats - fatty acids = (C16H18O2)
  - proteins - amino acids + nitrogen

- The amount of energy released in a biological reaction is calculated from the amount of heat produced.

- 1 Kilocalorie = the amount of heat energy needed to raise 1kg of water 1 degree Celsius.
Energy Sources

- The energy in food molecular bonds is chemically released within our cells then stored in the form of ATP bonds.
- The formation of ATP provides the cells with a high-energy compound for storing and conserving energy.
Carbohydrates

- Come in many kinds of foods.
- Are converted to glucose, a monosacharide (one-unit sugar) and transported by the blood to all body tissues.
- One gram yields about 4 kcal.
- Are stored as glycogen in your muscles (cytoplasm) and liver (up to 2,000 kcal)
- Without adequate carbohydrate intake, the muscles and liver stores can be depleted very quickly.
Fat

- Comes in many foods
- Broken down into free fatty acids which can be used to form ATP.
- A gram of fat yields about 9 kcal.
- Fat provides a sizable amount of energy (70,000 kcal) during prolonged, less intense exercise.
- Fat is stored intramuscularly or subcutaneously
- Fat is more difficult to break down and therefore it is less accessible for cellular metabolism.
Protein

- Can only supply up to 5% to 10% of the energy needed to sustain prolonged exercise.
- Amino acids are broken down into glucose (gluconeogenesis).
- A gram of protein yields about 4 kcal.
Bioenergetics: ATP Production

- By the ATP-PCr system
  - anaerobic (fig. 5.3, 5.4)
  - simplest energy system
  - 1 mole PCr = 1 mole of ATP
  - 1 ATP = 7.6 kcal
- By the glycolytic system
  - anaerobic (fig. 5.6)
  - 1 mole glycogen = 3 moles of ATP
- By the oxidative system
  - aerobic (fig. 5.7, 5.8)
  - energy yield = 39 moles of ATP
ATP-PCr System

- The simplest of the energy systems
- Energy released by the break-down of Creatine Phosphate (PCr), facilitated by the enzyme creatine kinase (CK), rebuilds ATP from ADP.
- This process is rapid
- Does not require oxygen (O2) and is therefore anaerobic.
- Can only sustain maximum muscle work for 3-15 seconds.
The Glycolytic System

- Involves the breakdown (lysis) of glucose via special glycolytic enzymes.
- Glucose accounts for about 99% of all sugars circulating in the blood.
- Glucose comes from the digestion of carbohydrates and the breakdown of glycogen during glycogenolysis.
- Glycogen is synthesized from glucose during glycogenesis.
The Glycolytic System

- Glucose and glycogen needs to be converted to glucose-6-phosphate before it can be used for energy. For glucose this process takes 1 ATP.
- Glycolysis ultimately produces pyruvic acid which is then converted to lactic acid in the absence of oxygen.
- Glycolysis requires 12 enzymatic reactions to form lactic acid which occur within the cells cytoplasm.
The Glycolytic System

- 1 glycogen = 3 ATP
- 1 glucose = 2 ATP
- Causes lactic acid accumulation in the muscles
  - This acidification discourages glycolysis
  - Decreases the muscle fibers’ calcium binding capacity and therefore impedes muscle contraction.
The Oxidative System (Carbohydrate)

- **Glycolysis:**
  - pyruvic acid is oxidized into acetyl coenzyme A
  - 2 or 3 ATP are formed

- **Krebs Cycle:**
  - acetyl CoA = (2ATP + H + C)
  - H accepted by NAD & FAD

- **Electron Transport Chain:**
  - the splitting of H electrons and protons provides energy to perform oxidative phosphorylation
  - (ADP+P=ATP) + H2O + CO2
  - glycogen = 39 moles of ATP
The Oxidative System (Carbohydrate)

- Cellular Respiration: energy production in the presence of oxygen.
- Occurs in the mitochondria adjacent to the myofibrils and within the sarcoplasm.
- High energy yields (39 ATP) which are used during aerobic events.
The Oxidative System (Fat)

• Lipolysis: Triglycerides are broken down into glycerol and fatty acids by lipases.

• Beta Oxidation: fatty acids are broken down into units of acetic acid and converted to acetyl- CoA

• Krebs Cycle:

• Electron Transport Chain:
  1mole of palmitic acid = 129 moles of ATP
Protein Metabolism

- Gluconeogenesis: some amino acids can be converted into glucose, pyruvate acid, or acetyl CoA
- ATP is spent in this process
- Byproducts include other amino acids or nitrogen which is excreted in urine.
- Energy from protein metabolism is ignored
The Oxidative Capacity of Muscle

- **Enzyme Activity**
- **Muscle Fiber Types**
  - slow twitch (type 1)
    - Greater oxidative capacity
  - fast twitch A (type 2a)
  - fast twitch B (type 2b)
- **Endurance Training**
  - enhances mitochondria density
  - enhances enzymes for B oxidation
- **Cardiovascular Function**
  - improved rate/depth of respiration
  - increased gas exchange & H.R.
  - Max VO2
Measuring Energy Use During Exercise

- **Direct Calorimetry**
  - Measures body heat production
- **Indirect Calorimetry**
  - *amount* of O₂ & CO₂ exchanged
  - *respiratory exchange ratio* (RER)
    - measures food source
- **Isotopic Measurements**
  - Isotopes are elements with an atypical atomic weight
  - Isotopes are traced to determine metabolism
  - measures CO₂ produced which is converted to energy expended
- **Daily Caloric Computation**
  - is a highly estimated computation
Estimates of Anaerobic Effort

- Post-Exercise O2 Consumption
  - oxygen deficit
  - steady state
  - EPOC
- Lactate Threshold
  - The point at which the blood lactate appears to increase above resting levels.
  - A clear break point when the onset of blood lactate accumulates (OBLA)
  - when expressed as a % of VO2 max is a good indication of tolerance (pace).
Energy Expenditure

- Basal Metabolic Rate: measured in O2 use per min. at rest
  - how is it affected?
    - Fat free mass
    - Body surface area = heat loss
    - Age
    - Body temperature
    - Stress
    - Hormone levels
- VO2 Max (aerobic capacity)
  - how is it affected?
    - Oxygen consumption increases with increased intensity of exercise
    - VO2 Max plateaus
    - To perform at a higher % of VO2 Max reflects a higher lactate threshold
Energy Expenditure

- Economy Of Effort
- Factors of Endurance Success
  - high VO2 max
  - high lactate threshold or OBLA
  - high economy of effort
  - high percentage of ST muscle
- Range of Total Daily Caloric Expenditure is Variable With
  - Activity level
  - Age
  - Sex
  - Size
  - Weight
  - Body Composition
Causes of Fatigue

- Decreased Energy
  - ATP-PCr
    - Phosphocreatine depletion
    - warm-up & pacing decreases fatigue
    - “hitting the wall” = no energy
  - glycolysis
    - Glycogen depletion in used muscles
    - depletion in certain muscle fiber types
    - depletion of blood glucose
  - oxidation
    - a lack of O2 increases lactic acid
      - bicarbonate & cool down
    - a causative factor of muscle strains
- Accumulation of Metabolic Bi-products (acidosis).
Causes of Fatigue

- Neuromoscular Fatigue
  - decreased nerve transmission
    - Depleted acetyl Co A
    - Sarcolemma membrane threshold might increase
    - Decreased potassium needed for nerve transmission along the sarcolemma
    - Calcium retention within the sarcoplasmic reticulum.
  - fatigue may be psychological and therefore terminate exercise before the muscles are physiologically exhausted
    - verbal encouragement
    - fight or flight mechanism
    - perceived discomfort precedes muscle physiological limitations
- Delayed Onset Muscle Soreness