METABOLISME ENERGI

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Pendahuluan

- Tubuh kita menggunakan makanan yg kita makan untuk:
  1. Menyediakan energi
  2. Membangun & memperbaiki jaringan
  3. Mengatur metabolisme
- Of these three functions, the human body ranks energy production first and will use food for this purpose at the expense of the other two functions in time of need.
- Energy represents the capacity to do work.
- Work is one form of energy, often called mechanical energy.

1 teaspoon sugar = 5 grams carbohydrate = 20 Calories

1 teaspoon salad oil = 5 grams fat = 45 Calories

Contoh

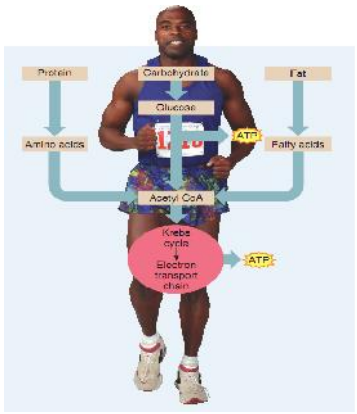
- Eight ounces of orange juice will provide enough
- chemical energy to enable an average man to produce enough
- mechanical energy to run about one mile (1,6 km).

Bagaimana energi disimpan dalam tubuh?

- Sumber energi di bumi adalah matahari.
- Tanaman mendapatkan sinar matahari, dan C, H, O, N dari lingkungan → membentuk KH, lemak, protein → Makanan ini menyimpan energi.
- Makanan dimakan oleh manusia, dicerna kmd diserap tubuh dan didistribusikan ke seluruh sel-sel tubuh.
- Sel tubuh dapat mengubah energi kimia yg tersimpan dalam makanan mjd bentuk energi lain yg bisa digunakan oleh tubuh.

Bentuk-bentuk energi di dalam tubuh

- ATP (adenosine tri phosphate) → energi yg dapat digunakan dg cepat saat dipecah oleh enzim, misalnya saat kontraksi otot. Disimpan dlm tubuh dalam jumlah sedikit. ATP dpt dibentuk dari KH, lemak, & protein sesudah mengalami perubahan biokimiawi di dalam tubuh.
- PCr (phosphocreatine) → ditemukan di dlm jaringan dlm jumlah sedikit. Meskipun tdk dpt digunakan sbg sumber energi yg cepat, namun bisa scr cepat membentuk ATP.



Energy source	Major storage form
ATP	Tissues
PCr	Tissues
Carbohydrate	Serum glucose Liver glycogen Muscle glycogen
Fat	Serum-free fatty acids Serum triglycerides Muscle triglycerides Adipose tissue triglycerides
Protein	Muscle protein

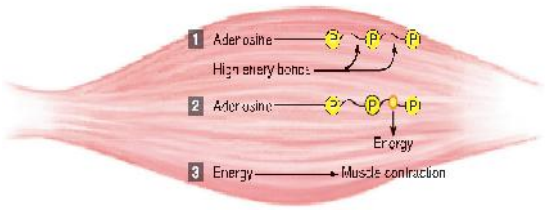


FIGURE 3.7 ATP, adenosine triphosphate. *(1)* ATP is stored in the muscle in limited amounts. *(2)* Splitting of a high-energy bond releases adenosine diphosphate (ADP), inorganic phosphate (P), and energy, which *(3)* can be used for many body processes, including muscular contraction. The ATP stores may be used maximally for fast, all-out bursts of power that last about one second. ATP must be replenished from other sources for muscle contraction to continue.

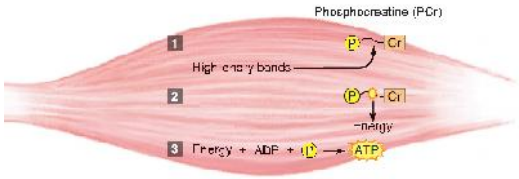


FIGURE 3.8 Phosphocreatine (PCr). *(1)* PCr is stored in the muscle in limited amounts. *(2)* Splitting of the high-energy bond releases energy, which *(3)* can be used to rapidly synthesize ATP from ADP and P. ATP and PCr are called phosphagens and together represent the ATP-PCr energy system. This system is utilized primarily for quick, maximal exercises lasting about 1 to 6 seconds, such as sprinting.

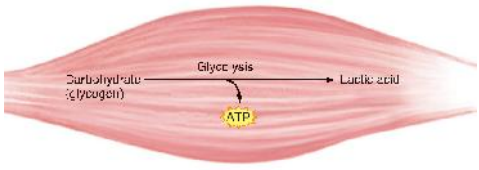
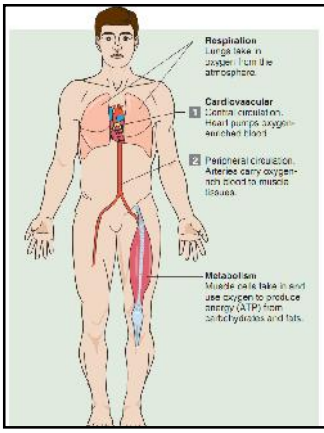


FIGURE 3.9 The lactic acid energy system. Muscle glycogen can break down without the utilization of oxygen. This process is called anaerobic glycolysis. (See appendix G, figure G.1, for more details.) ATP is produced rapidly, but lactic acid is the end product. Lactic acid may be a major cause of fatigue in the muscle. The lactic acid energy system is utilized primarily during exercise bouts of very high intensity, those conducted at maximal rates for about 30 to 120 seconds.



Proses fisiologi pengambilan O2

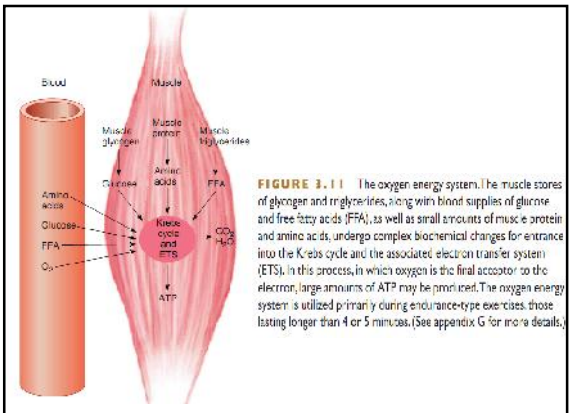
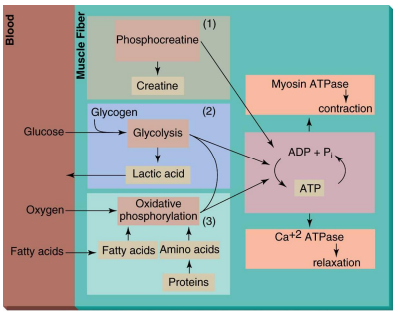


FIGURE 3.11 The oxygen energy system. The muscle stores of glycogen and triglycerides, along with blood supplies of glucose and free fatty acids (FFA), as well as small amounts of muscle protein and amino acids, undergo complex biochemical changes for entrance into the Krebs cycle and the associated electron transfer system (ETS). In this process, in which oxygen is the final acceptor to the electron, large amounts of ATP may be produced. The oxygen energy system is utilized primarily during endurance-type exercises those lasting longer than 4 or 5 minutes. (See appendix G for more details.)

Sources of ATP for Muscle Contraction



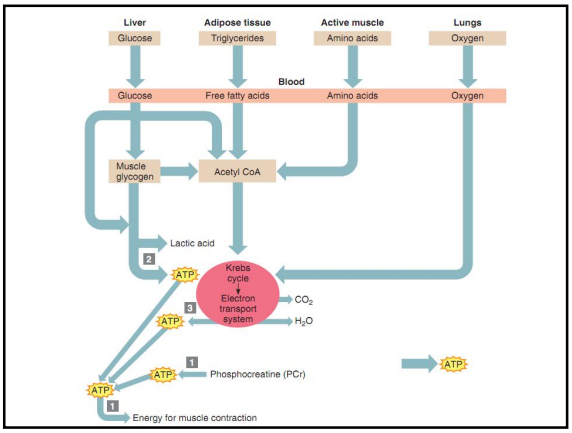


FIGURE 3.12 Simplified flow diagram of the three energy systems. The major nutrients and oxygen are transported to the cells for energy production. In the muscles, ATP is the immediate source of energy for muscle contraction. (1) The ATP-PCr system is represented by muscle stores of ATP and phosphocreatine (PCr); PCr can replenish ATP rapidly. (2) Glucose or muscle glycogen can produce ATP rapidly via the lactic acid system. (3) The oxygen system can produce large amounts of ATP via the aerobic processes in the Krebs cycle. Numerous other energy pathways exist, and some are described in chapter 4 (carbohydrates), chapter 5 (fats), and chapter 6 (protein).

Key Concept Recap

- Carbohydrates and fats are the primary energy nutrients, but protein may also be an energy source. In the human body one gram of carbohydrate = 4 Calories, one gram of fat = 9 Calories, and one gram of protein = 4 Calories. Alcohol is also a source of energy; one gram = 7 Calories.
- The potential energy sources in the body include ATP and PCr; serum glucose, glycogen in the liver and muscle; serum free fatty acids (FFA); triglycerides in the muscle and in adipose tissue; and muscle protein.
- Three human energy systems have been classified on the basis of their ability to release energy at different rates of speed; they are the ATP-PCr, lactic acid, and oxygen energy systems.

Key Concept Recap

- Human metabolism represents the sum total of all physiological processes in the body, and the metabolic rate reflects the speed at which the body utilizes energy.
- The basal metabolic rate (BMR) represents the energy requirements necessary to maintain physiological processes in a resting, postabsorptive state, while the resting metabolic rate (RMR) is a little higher due to eating and prior muscular activity. The terms BEE and REE represent total basal energy expenditure and resting energy expenditure, respectively, over a 24-hour period.
- A number of different factors may affect the REE, including body composition, drugs, climatic conditions, and prior exercise.
- Eating a meal increases the metabolic rate as the digestive system absorbs, metabolizes, and stores the energy nutrients, a process termed the thermic effect of food (TEF).

TABLE 3.5 Classification of physical activities based upon rate of energy expenditure*

Light, mild aerobic exercise (< 5 Calories/min)		
Archery	Bowling	Horseback riding (walk)
Badminton, social	Dancing, waltz	Swimming (20–25 yards/min)
Baseball	Golf (Cart)	Walking (2–3 mph)
Bicycling (5 mph)		
Moderate aerobic exercise (5–10 Calories/min)		
Badminton, competitive	Golf (carrying clubs)	Swimming (30–40 yards/min)
Basketball, recreational	Rope skipping (60 rpm)	Tennis, recreational
Bicycling (10 mph)	Running (5 mph)	Walking (3–4.5 mph)
Dancing, aerobic	Skiing, cross-country (2.5 mph)	Weight training
Moderately heavy to heavy aerobic exercise (> 10 Calories/min)		
Bicycling (15–20 mph)	Rope skipping (120–140 rpm)	Swimming (50–70 yards/min)
Calisthenics, vigorous	Running (6–9 mph)	Tennis, competitive
In-line skating (10–15 mph)	Skiing, cross-country (5–6 mph)	Walking (5.0–6.0 mph)

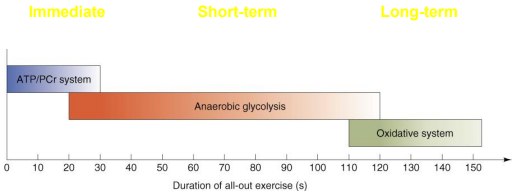
Key Concept Recap

- The thermic effect of exercise (TEE), or exercise metabolic rate (EMR), provides us with the most practical means to increase energy expenditure.
- The metabolic rate during exercise is directly proportional to the intensity of the exercise, and the exercise heart rate may serve as a general indicator of the metabolic rate.
- Activities that use the large muscle groups of the body, such as running, swimming, bicycling, and aerobic dance, facilitate energy expenditure.
- The total daily energy expenditure (TDEE) is accounted for by BEE (60–75%), TEF (5–10%), and TEE (15–30%), although these percentages may vary.
- The Estimated Energy Requirement (EER) is defined as the dietary intake that is predicted to maintain energy balance in a healthy adult of a defined age, gender, height, weight, and level of physical activity consistent with good health. Changing from a sedentary Physical Activity Level (PAL) to a very active PAL is a very effective means to increase TDEE and EER.

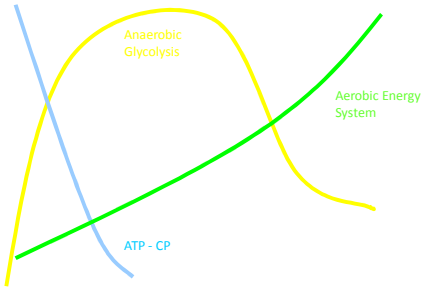
TABLE 3.7 Major characteristics of the human energy systems*

	ATP-PCr	Lactic acid	Oxygen
Main energy source	ATP; phosphocreatine	Carbohydrate	Carbohydrate
Intensity level	Highest	High	Lower
Rate of ATP production	Highest	High	Lower
Power production	Highest	High	Lower
Capacity for total ATP production	Lowest	Low	High
Endurance capacity	Lowest	Low	High
Oxygen needed	No	No	Yes
Anaerobic/aerobic	Anaerobic	Anaerobic	Aerobic
Characteristic track event	100-meter dash	200–800 meters	5,000-meter (5 km) run
Time factor	1–10 seconds	30–120 seconds	5 minutes or more

INTERACTION OF ENERGY SYSTEMS



Energy Transfer Systems and Exercise



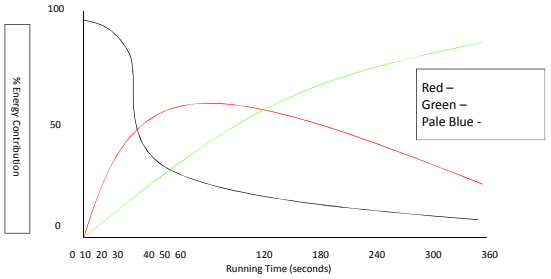
Key Concept Recap

- The ATP-PCr and lactic acid energy systems are used primarily during fast, anaerobic, power-type events, while the oxygen system is used primarily during aerobic, endurance-type events.
- Fats serve as the primary source of fuel during mild levels of exercise intensity, but carbohydrates begin to be the preferential fuel as the exercise intensity increases.
- A sound training program and proper nutrition are important factors in the prevention of fatigue during exercise.

Metabolisme Energi

Energy Pathway	Anaerobic Pathway		Aerobic Pathway		
	Alactic	Lactic			
Fuel	ATP-CP system	Lactic acid system	Glycolyitic	Fat	Protein
Duration	0-10 sec	40-70 sec	2 min	6 min	25 min-3 jam
Sport events	Sprinting 100 dash Throws Jumps Weight Lifting	200m-400m Most gym events Cycling tract 50m swimming	100m swimming 800m track 500m canoeing Cycling track 1000m	Middle distance track, swimming Boxing Wrestling Martial arts	Long distance track, swimming, canoeing Cycling road racing
Skills	Mostly Acyclic		Acyclic & cyclic		Cyclic

The Three Energy Systems



Task – Identify the energy system at work.

Activity	ATP-CP	Lactic Acid	Aerobic
Golf Swing			
Javelin			
Marathon			
200m Swim			
Volleyball Spike			
1500m Run			
Walking			
30 sec Burst			
Power-lifting			
Beep Test			

Task - Answers

Activity	ATP-CP	Lactic Acid	Aerobic
Golf Swing	X		
Javelin	X		
Marathon			X
200m Swim		X	
Volleyball Spike	X		
1500m Run		X	
Walking			X
30 sec Burst	X		
Power-lifting	X		
Beep Test			X

Using your notes on energy systems, complete the following table:

	Description	Source of Energy	Time (predominately used)	Classification	Example
ATP – CP (immediate)					
Lactic Acid (short term)					
Aerobic (long term)					

Answers

	Description	Source of Energy	Time (predominately used)	Classification	Example
ATP – PC (immediat)	Used in high intensity, extremely short activities.	ATP stored in the muscle cells.	0-10 sec	Anaerobic (Does not require O2, and so does not cause a build up of lactic acid).	Sprint starts, weight lifting, shot put…
Lactic Acid (short term)	Used in short term, high intensity exercise.	Carbohydrates (glycogen)	30 sec – 2 mins	Anaerobic (Does not require O2, but used carbos only, large amounts of lactic acid build up-hence decreased performance).	200m sprint, sit ups/ press ups…
Aerobic (long term)	Light – moderate intensive exercise. (The body can work for extended time without experiencing fatigue)	Carbohydrates and fats.	2-3mins + (These intensive may vary from very easy to very hard)	Aerobic (Because this system requires oxygen to burn carbos and fats, lactic acid does not build up-hence no effect on performance).	Marathon runner or swimmer…