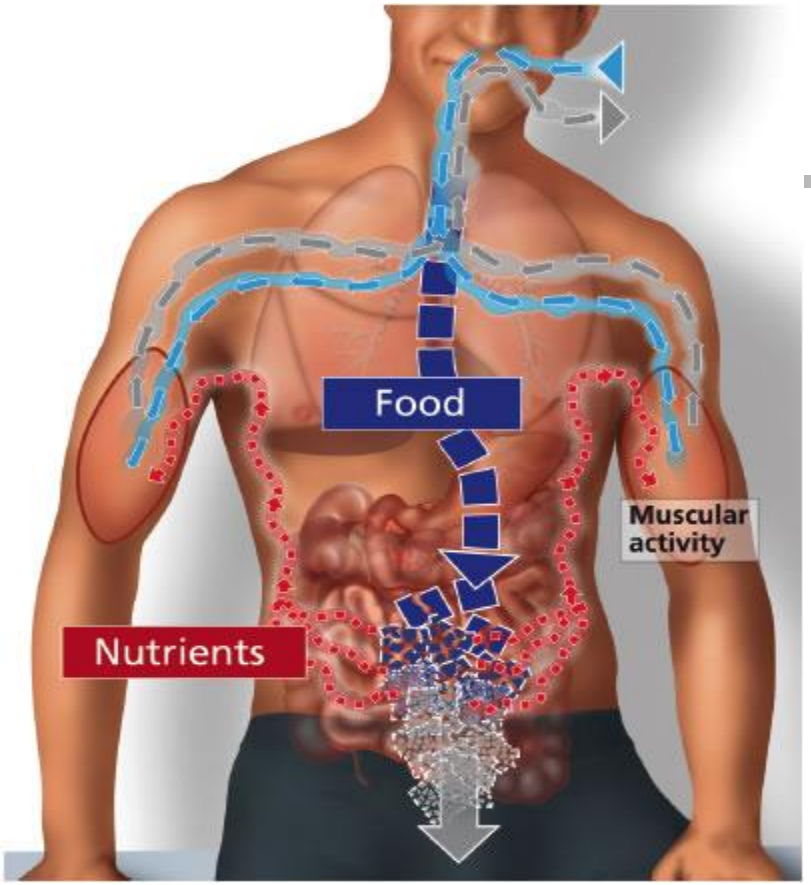
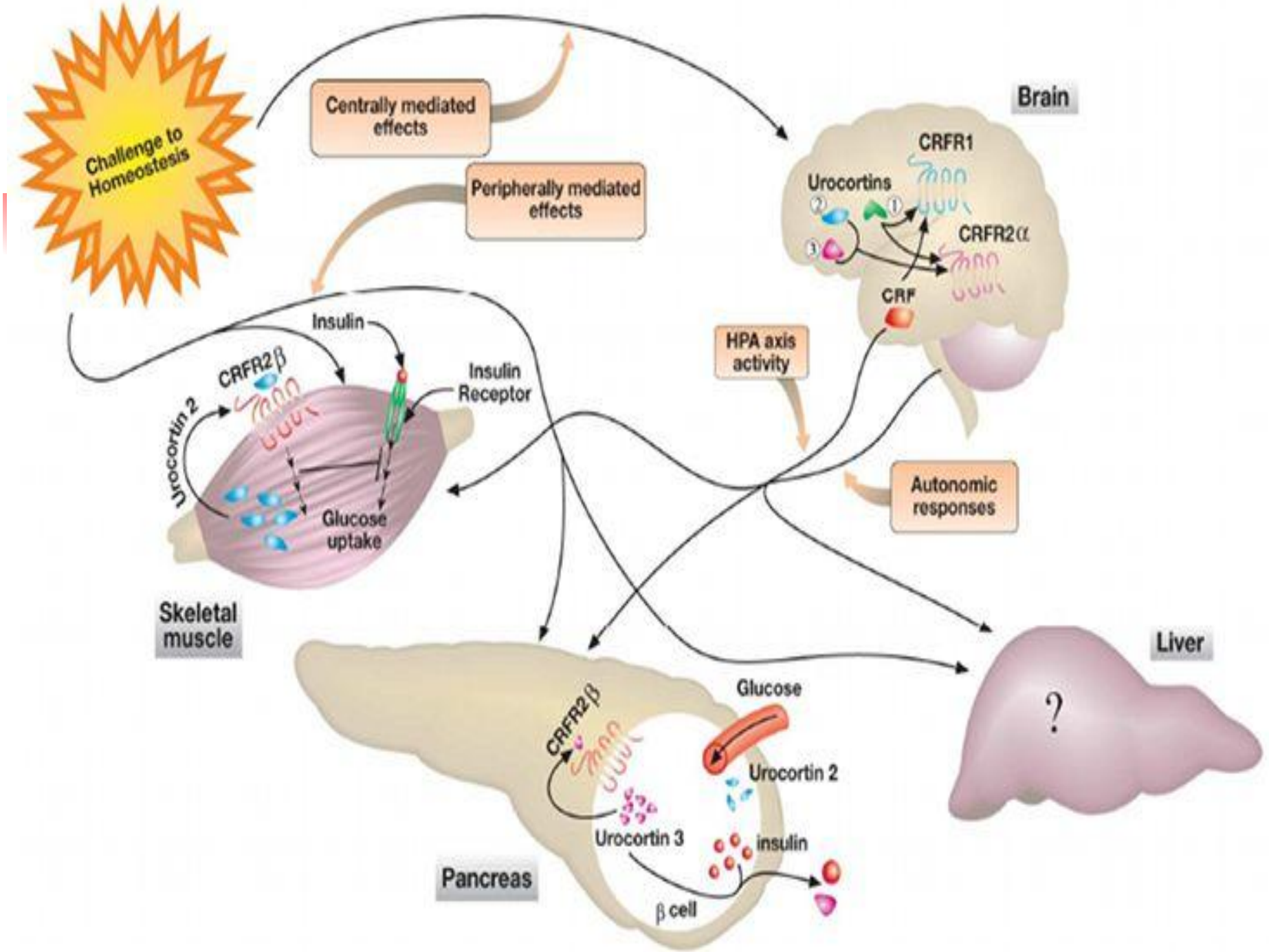
Physiology of metabolism and energy .



Types of exchange

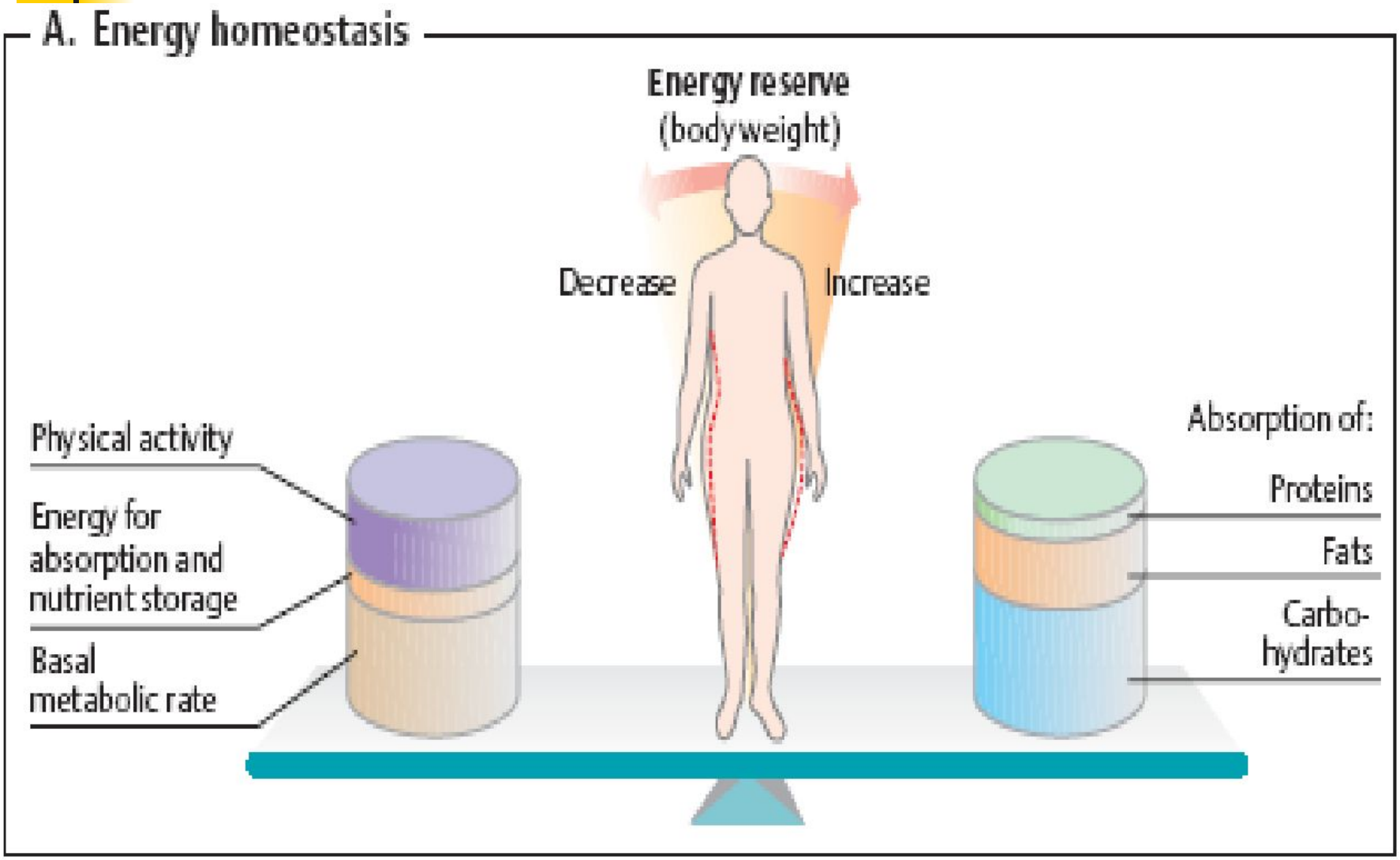
- 1. Exchange between the organism and the environment, in example circulation of substances in nature.

  2. Metabolism within the body: changing substances from the time they pass through the digestive canal to the withdrawal outside.


Challenge to Homeostesis
Centrally mediated effects
Peripherally mediated effects
Brain
CRFR1
Urocortins
CRFR2α
CRF
HPA axis activity
Autonomic responses
Insulin
Insulin Receptor
CRFR2β
Urocortin 2
Glucose uptake
Skeletal muscle
Liver
?
Glucose
Urocortin 2
Urocortin 3
insulin
β cell
Pancreas

All metabolic processes are directed by enzymes, and a set of enzymatic reactions that occur in the body are combined by the concept of “exhange of materials" or "metabolism".

Notion about basal metabolism



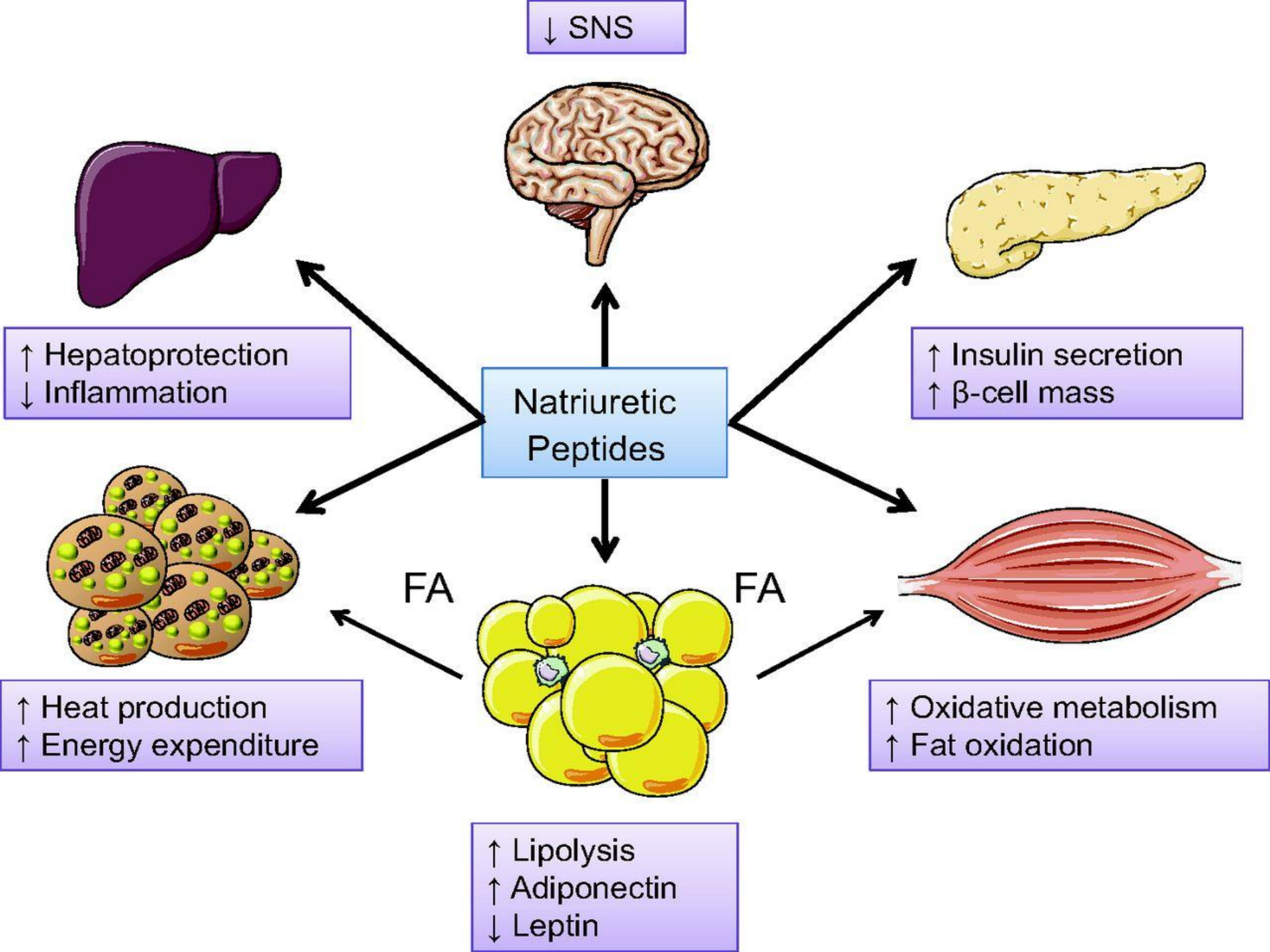
Energy balance

Energy intake

Energy expenditure

Nervous regulation

- changes the intensity of endocrine glands function
- directly activates enzymes.
- central nervous system, acting on cellular and humoral mechanisms of regulation, adequately changes metabolism processes in cells


↓ SNS
↑ Hepatoprotection
↓ Inflammation
↑ Insulin secretion
↑ β-cell mass
Natriuretic Peptides
FA
FA
↑ Heat production
↑ Energy expenditure
↑ Oxidative metabolism
↑ Fat oxidation
↑ Lipolysis
↑ Adiponectin
↓ Leptin

Humoral regulation of enzyme activity

- Means the action of hormones on enzymes, which can enhance or inhibit the activity of the enzyme.

  Some hormones directly regulate the synthesis or breakdown of enzymes and the permeability of cell membranes, altering the cell content of substrate, cofactor and ion composition.

Nutrients include .....

Fat

Minerals

Carbohydrate

Vitamins

Water

Protein

Physiological meaning of proteins

- 1. All enzymes are proteins.
- 2. Contraction of all the muscles in the body occurs due to action of contractive proteins (actin and miosin).
- 3. Proteins enter to the cell membrane structure.
- 4. Energy functions (one gram of protein gives makes **4,1** kcal of energy)
- 5. Proteins compose parts of hormones (steroids).
- 6. Transport function
- 7. Protective function
- 8. Respiratory function (hemoglobin)

Protein

Quality depends upon ….

- digestibility
- EAA profile
- Quantity of N to make new AA's

Highest quality

- Eggs & milk — *Contains right balance of all EAA's*
- Meat (fish bird, mammal)
- Vegetable / plant — *Lacking in some EAA's*

Lowest quality

Transformation of proteins in human organism

- Proteins enter our body with food. They pass through digestive tract and are broken down and later absorbed in blood as amino acids. Some amount goes to cells of different tissues, others to the liver. Liver transaminates amino acids to enzymes and blood plasma proteins and desaminates them to ammonium and ketoacids. Ammonium transfroms to urea and then uric acid.

Conversion of proteins in the body

- **First stage** - hydrolysis of proteins to aminoacids. These are absorbed into the blood stream.
- **Second** – decomposition of amino acids with the formation of toxic ammonia (NH_3), which is neutralized in the liver and transformed to urea that is excreted within the urine. Urea, uric acid, creatinine and some other substances are end products of protein fission.

Nitrogen balance.

- **Nitrogen balance is the ratio of nitrogen quantity, which enters in organism with food and distinguished by kidney, digestive tract, glands.**
- As main source of nitrogen in the body is protein, using nitrogen balance we can judge on the ratio of protein that entered and excreted from the body. In protein is 16 % of nitrogen. One gram of nitrogen is present in 6,25 gram of protein. In adult in norm must be nitrogen balance
- Thus, multiplying the amount of nitrogen found by 6.25, you can determine the quantity of assimilated protein.

- **Nitrogen balance**. It means that the amount of nitrogen ingested is equal to the amount of nitrogen excreted.
- At a state of zero nitrogen balance, the increase of amount of protein in the diet, will soon restore the zero nitrogen balance but on a new, higher level. Thus, nitrogen balance can be restored stable with significant fluctuations of protein content in food.
- **Positive nitrogen balance** occurs in case if nitrogen intake exceeds its excretion. In this case protein synthesis predominates over its breakdown. With these circumstances the retention of nitrogen occurs.
- **Negative nitrogen balance** - when the amount of nitrogen excreted from the body exceeds the amount of nitrogen ingested.

Digestibility of common proteins foods

Food source	Protein digestibility (%)
Egg	97
Milk and cheese	97
Mixed US diet	96
Peanut butter	95
Meat and fish	94
Whole wheat	86
Oatmeal	86
Soybeans	78
Rice	76

Regulation of proteins metabolism

- Central mechanism of regulation act on hypothalamus. It activates pituitary gland, that produces growth hormone; activates thyroid glands and adrenal glands. Parasympathetic influences, growth hormone, insulin, thyroid hormones, glucocorticoids (in liver) have anabolic effect.
- Sympathetic influences, glucocorticoids (in muscles, lymph tissues) have catabolic effect.

Regulation of protein exchange

- **Anabolic effects:**

- parasympathetic n.s.
- human growth hormone
- insulin
- thyroid hormones
- glucocorticoids (in liver)

- **Catabolic effects:**

- sympathetic n.s.
- glucocorticoids (in muscles, lymph tissues)

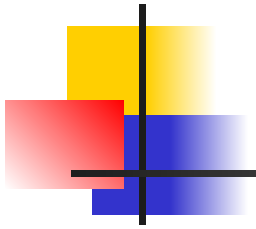
Minimum of proteins, optimum of proteins

- **Minimum** of proteins is minimal quantity of protein needed to save nitrogen balance; Daily value is about 50 gram of protein.
- **Optimum of proteins** is a quantity of protein in food, which completely fulfill necessities of organism. It is about 80-100 grams of protein a day.

Physiological meaning of fats

- 1. Lipids are a part of cell membrane structure.
- 2. Lipids are important structural components of steroid hormones.
- 3. Fat is a powerful source of energy (one gram of fats gives makes 9,3 kcal of energy)
- 4. Lipids assist in absorption of fat-soluble vitamins.

Fat



Skin & coat condtion

Source of essential fatty acids
Linoleic acid
Linolenic acid

Concentrated energy source

Palatabilit y

Functions

Brain and retinal development

Insulation and protection of organs

Fat soluble vitamins (A D E K) are stored in fat

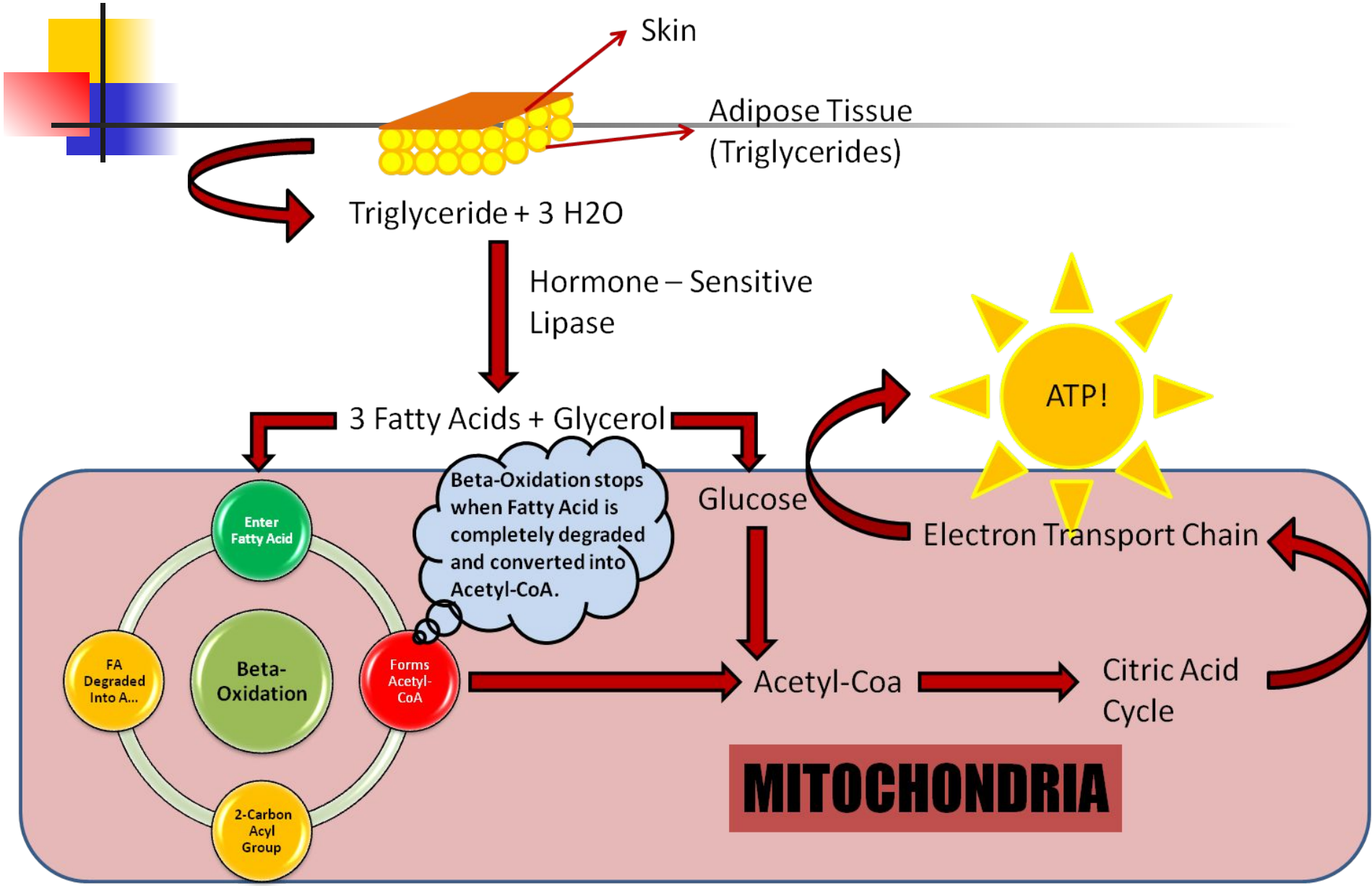
Fat digestion

- The bile acids produced by the liver act as natural detergents to dissolve fat in water and allow the enzymes to break the large fat molecules into smaller molecules, some of which are fatty acids and cholesterol. The bile acids combine with the fatty acids and cholesterol and help these molecules to move into the cells of the mucosa. In these cells the small molecules are formed back into large molecules, most of which pass into vessels (called lymphatic's) near the intestine.
- These small vessels carry the reformed fat to the veins of the chest, and the blood carries the fat to liver and than to storage depots in different parts of the body.

Fat metabolism and gluconeogenesis

- Fatty acids cannot be used directly to produce glucose. However, glycerol, a product of fat metabolism, can and does go through the gluconeogenic pathway to produce glucose. Glycerol is a minor component in fats, and accounts for only 9 to 15% of the total mass.
- Fats are much less important than proteins in the gluconeogenic process.

Fat Metabolism



Insulin and Glucagon Together Control Blood Fat Levels

Regulation of lipid metabolism

- **Anabolic effect**:

- Parasympathetic nervous system
  - Insulin
  - Glucocorticoids

  - **Catabolic effect :**
  - Sympathetic nervous system
  - Glucagon
  - Epinephrine/Norepinephrine
  - Thyroid hormone
  - Growth hormone

Physiological meaning of carbohydrates

- 1. Carbohydrates are main source of energy (one gram of carbohydrates gives makes 4,1 kcal of energy)

- 2. Carbohydrates are parts of some enzymes

Carbohydrates

- Some of our most common foods contain mostly carbohydrates. Examples are bread, potatoes, pastries, candy, rice, spaghetti, fruits, and vegetables. Many of these foods contain both starch, which can be digested, and fiber, which the body cannot digest.
- The digestible carbohydrates are broken into simpler molecules by enzymes in the saliva, in juice produced by the pancreas, and in the small intestine. Glucose and other monosaccharide is carried through the bloodstream to the liver, where it is stored or used to provide energy for the work of the body.

Feeding

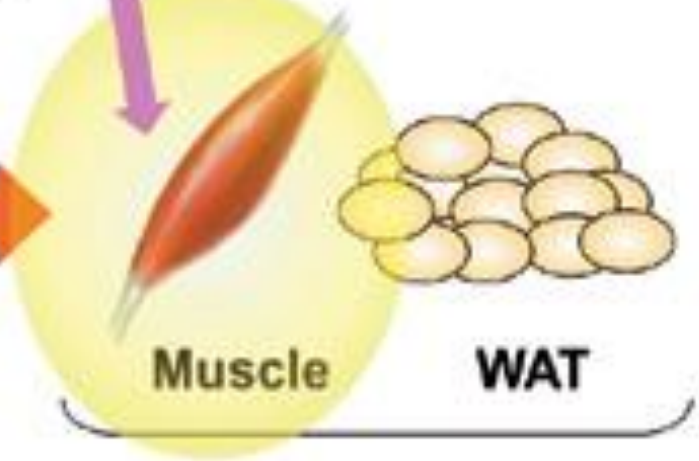
Tasting & anticipation

Hypothalamus (Orexin)

Sympathetic nerve

Liver

Blood glucose



Muscle

WAT

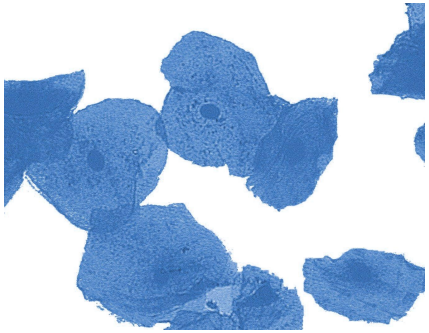
Insulin

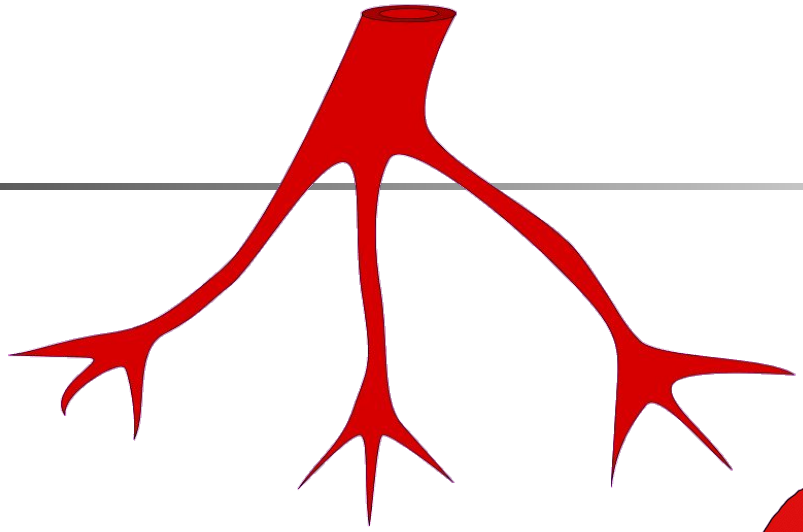
Insulin

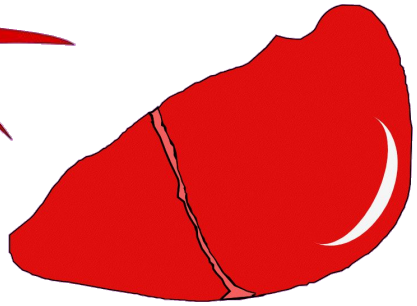
Extracting Energy from Glucose

- Two different pathways are involved in the metabolism of glucose: one anaerobic and one aerobic.
- The anaerobic process occurs in the cytoplasm and is only moderately efficient.
- The aerobic cycle takes place in the mitochondria and is results in the greatest release of energy. As the name implies, though, it requires oxygen.

The glucose is then used in 3 different ways…

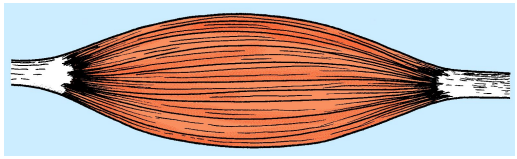






Body Cells

Glucose diffuses easily into the cells and is used to meet their energy demands.



Skeletal Muscle

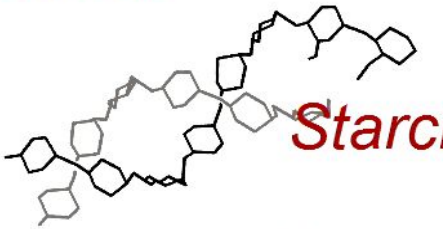
Glucose is stored here as **glycogen** and is used when the body is working harder.

Liver

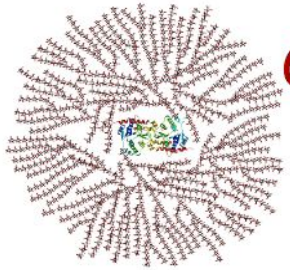
Here some of the glucose is stored as **glycogen** and used to maintain blood sugar levels.

Glucose metabolism

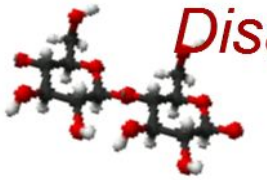
Intake:



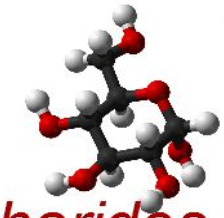
Starch



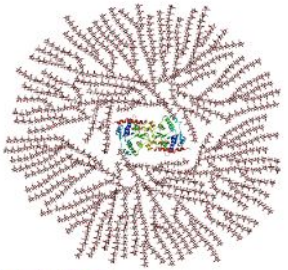
Glycogen



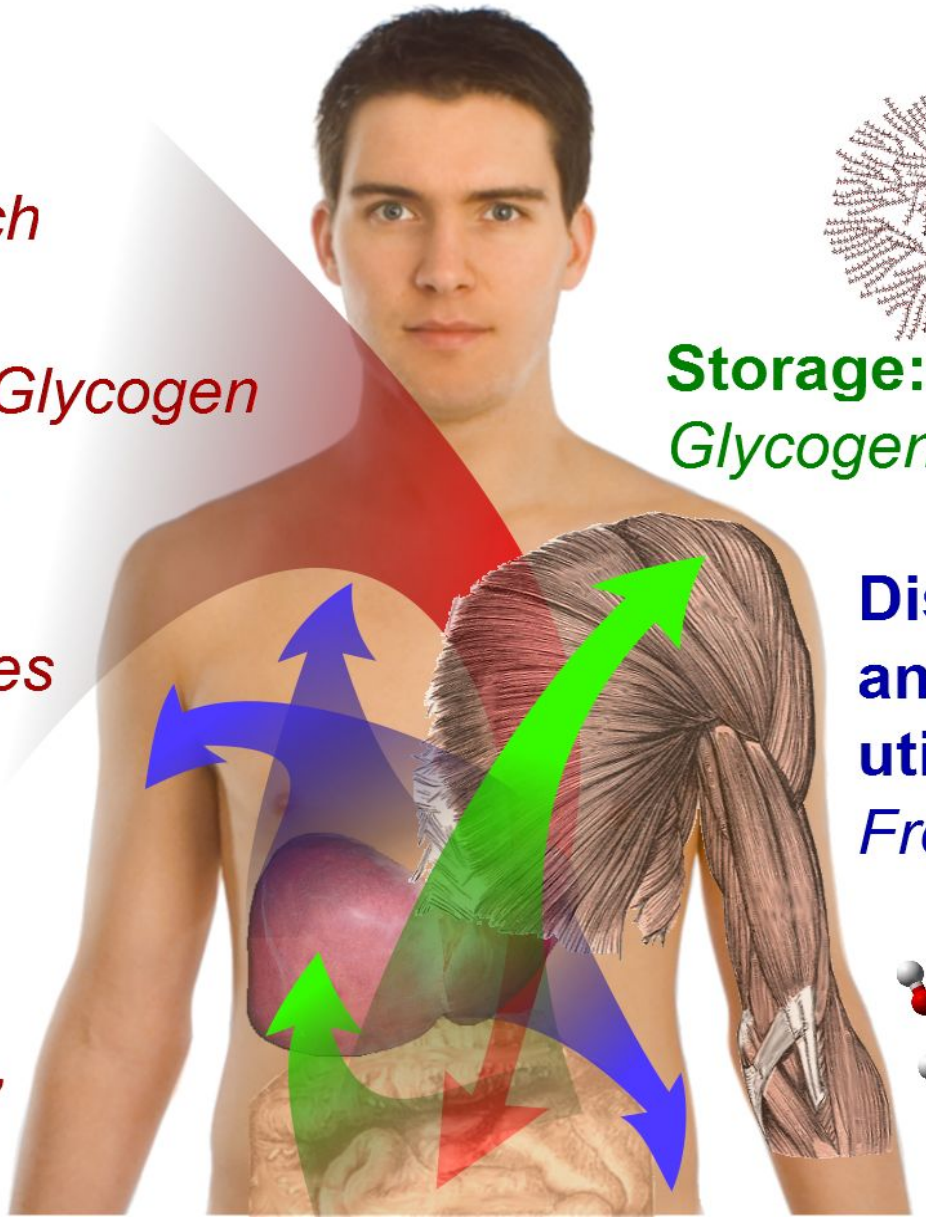
Disaccharides



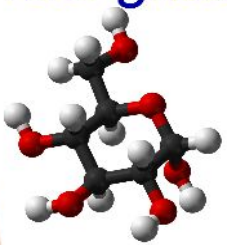
Monosaccharides (glucose, fructose, galactose)



Storage:
Glycogen



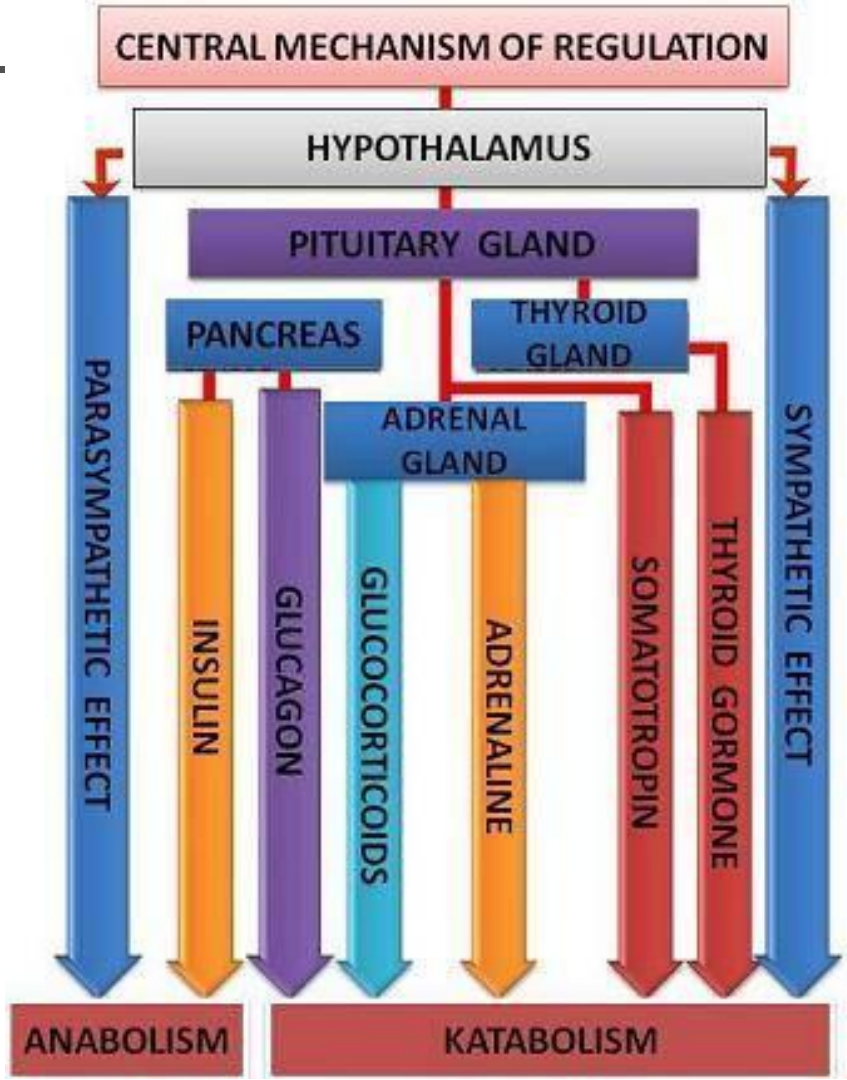
Distribution and utilization:
Free glucose



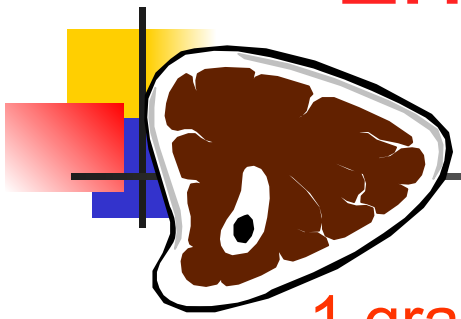
Aerobic Respiration – With Oxygen

The Process of Aerobic Respiration

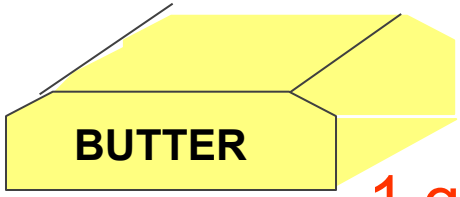
Regulation of carbohydrates metabolism



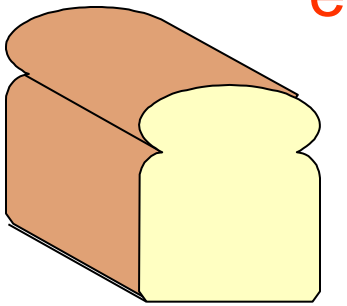
Energy content of food



1 gram of protein equals 4.1kcal of energy

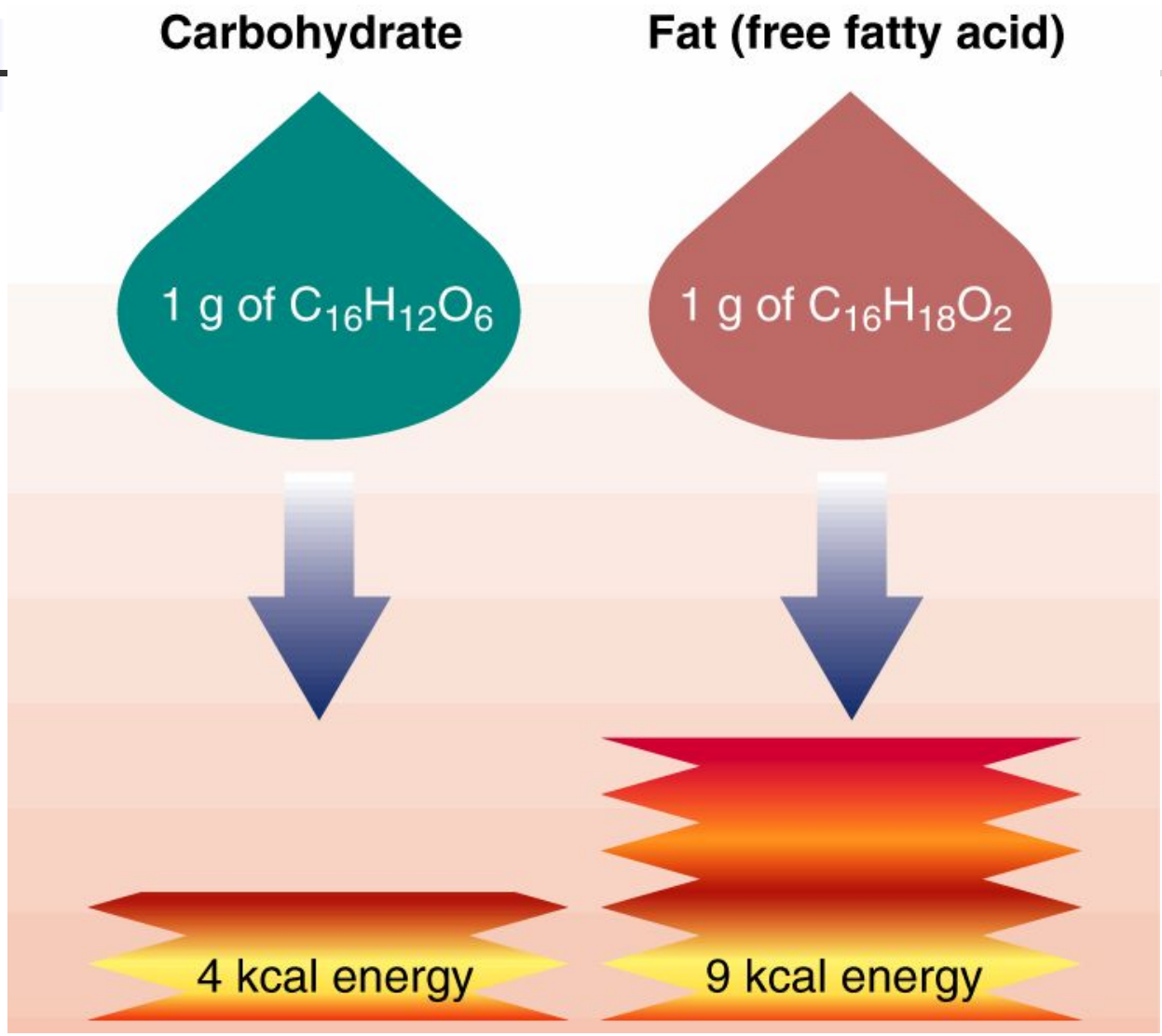


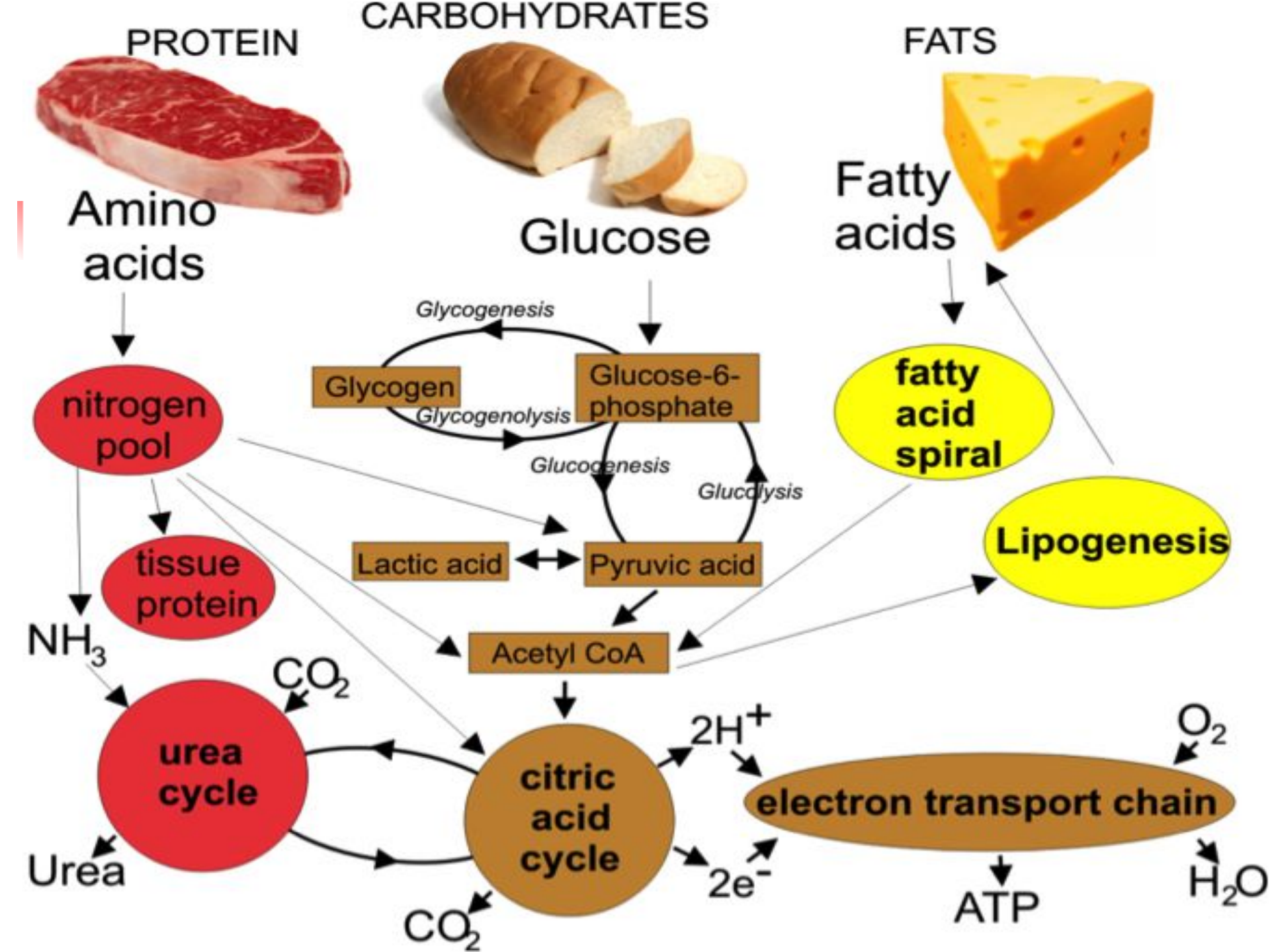
1 gram of fat equals 9.3kcal of energy



1 gram of carbohydrate equals 4.1kcal of energy

CARBOHYDRATE vs FAT




PROTEIN
CARBOHYDRATES
FATS
Amino acids
Glucose
Fatty acids
Glycogenesis
Glycogen
Glucose-6-phosphate
Glycogenolysis
Glucogenesis
Gluconeogenesis
nitrogen pool
fatty acid spiral
tissue protein
Lactic acid
Pyruvic acid
Lipogenesis
NH_3
Acetyl CoA
CO_2
urea cycle
citric acid cycle
$2H^+$
O_2
electron transport chain
Urea
$2e^-$
ATP
H_2O
CO_2

Water

- Contains hydrogen and oxygen
- ESSENTIAL for normal function
- Function
  - required for all body fluids
  - carrier of vitamins (C, B)
  - dissolves nutrients and transports them around the body
  - heat exchange
- Source - e.g. vegetables, meat

Minerals

- Inorganic elements (referred to collectively as Ash)
- divided into macrominerals eg calcium, phosphorous
  microminerals (trace elements)
- In excess most are toxic
- Important for
  - bones & teeth, e.g. calcium and phosphorous
  - body fluids, e.g. sodium and potassium
  - components of many enzymes

Vitamins

- Organic compounds which help to regulate body processes
  - fat soluble e.g. A, D, E, K (generally stored in the body)
  - water soluble e.g. B, C (excess generally excreted)
- Function:
  - eyesight - vitamin A
  - antioxidants - vitamin C and E
  - skeleton - vitamin D
  - metabolism - vitamin E
- Sources:
  - cereal, fish oils, nuts, liver, fruit & vegetables

Methods of studying organisms' energy consumption

- Direct calorimetry
- Indirect calorimetry with complete gas analysis
- Indirect calorimetry with incomplete gas analysis