Energy and Nutrient status of food
&
Energy Requirement

Energy

- **Energy is defined as the capacity to do work, and is derived by animals through the catabolism of dietary carbohydrates, lipid and protein within the body.**
- Many forms of energy exist in nature i.e. radiant, chemical, mechanical, heat, and electrical energy.
- Energy is essential for the maintenance of life processes such as cellular metabolism, growth, reproduction, and physical activity.
- **Life on earth is dependent on radiant solar energy and its subsequent fixation and conversion by green plants during photosynthesis into stored chemical energy (ie. carbohydrates) for use as an energy source by plants and animals**

Laws of thermodynamics

- All forms of energy are inter-convertible and obey the laws of thermodynamics. The first law of thermodynamics states that energy may be transformed from one form into another, but can never be created or destroyed.

Solar energy → Chemical energy + Heat energy
photosynthesis

- The second law of thermodynamics states that no transformation of energy will occur unless energy is degraded from a concentrated form to a less concentrated or more dispersed form, and further that no transformation is 100% efficient.

Solar energy (high energy form) → Chemical energy (low energy form)
photosynthesis

Energy units

- Energy is usually expressed in terms of heat units, since all forms of energy are convertible into heat energy.

- The basic heat unit normally used is the **calorie**. One calorie is defined as the amount of heat required to raise the temperature of one gram of water by one degree centigrade.

- Since for many purposes the calorie (cal) is too small a unit of measurement, the kilocalorie (kcal) is often used; 1 kcal = 1000 cal.

- In many scientific studies the calorie is now being replaced by the joule (J) as the unit of energy; 4.184 J = 1 cal.

Dietary energy sources

- The major dietary source of energy for living organism are carbohydrates, fats and proteins.

- **Carbohydrates** are the cheapest and most abundant source of energy for animals.

- **Fats** are the principal form of energy storage in plants and in animals. Fat contains more energy per unit weight than any other biological product.

- **Protein**: In nature, carnivorous fish consume diets which are about 50 percent protein. Fish have a very efficient system for excretion of waste nitrogen from protein which is catabolised for energy

Energy Status of food

- **Carbohydrates** give average gross energy values of **4.2** kcal or 17.6 kJ per gram

- **Fat** gives **9.4 kcal**, or 39.4 kJ per gram

- **Protein** gives **5.65** kcal or 23.7 kJ per gram

Energy metabolism

- Metabolism is usually the largest part of energy budget and it has central role to play in physiological traits like growth and energy storage.

- **Metabolism**
  - **Anabolism (synthesis)**
  - **Catabolism (breakdown)**

- **Energy metabolism** is concerned with the catabolism and oxidation of carbohydrates, lipid and protein within the animal body, and the consequent release and use of the liberated energy as work for the maintenance of the life process.

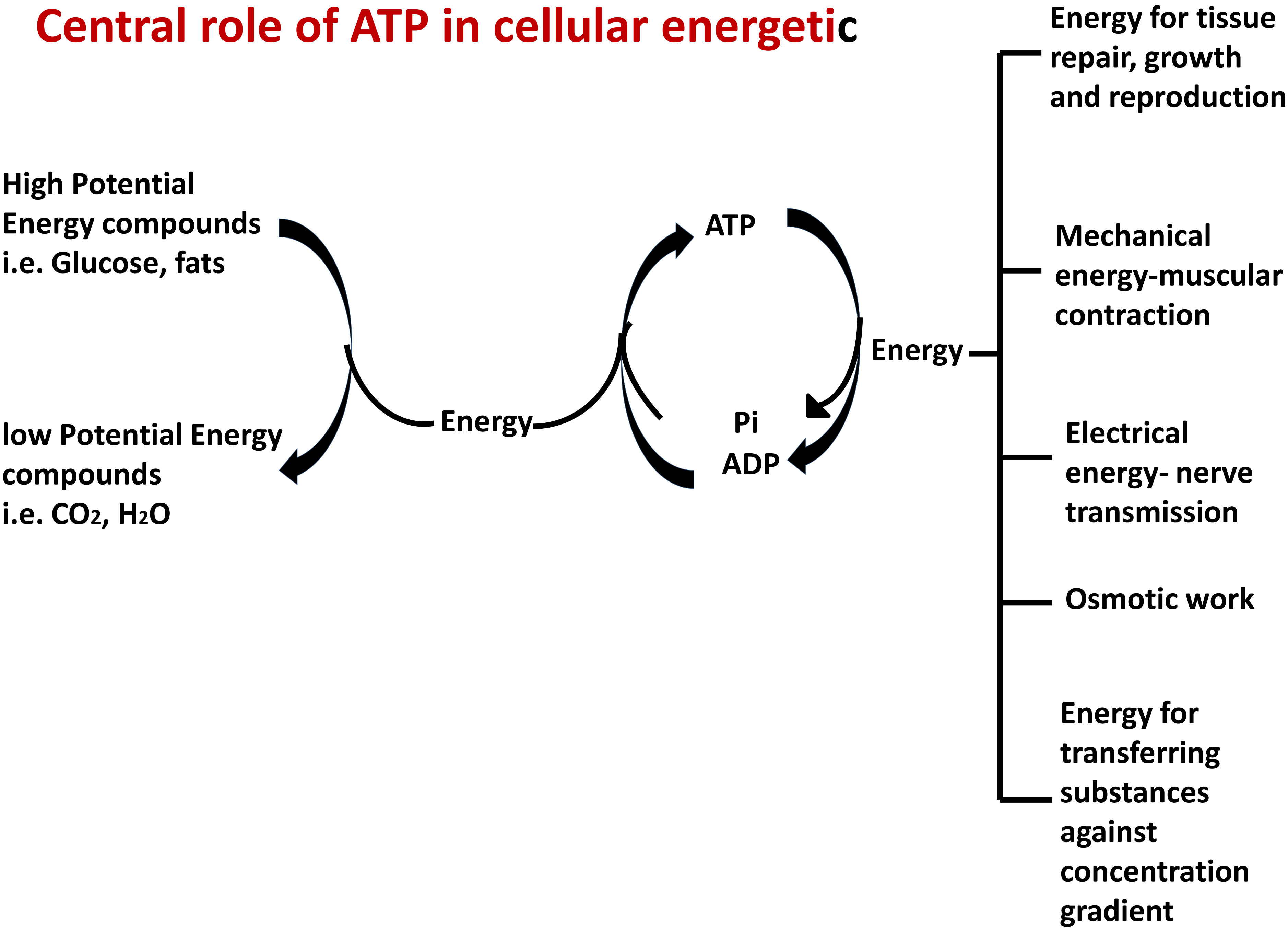
ATP (Energy Currency of cell)

- The free energy liberated from the catabolism and oxidation of the major food nutrients is not utilized directly by the animal, but rather is trapped in the chemical form of the energy-rich phosphorus bond of adenosine tri phosphate (ATP).

- It is ATP which is the principal driving force in the energy-requiring biochemical processes of life.

- Aerobic respiration consumes the glucose, produces 30 or 32 moles of ATP, equivalent to 262.8 kcal. Anaerobic: produces only 2 moles, equiv to 21.9 kcal.

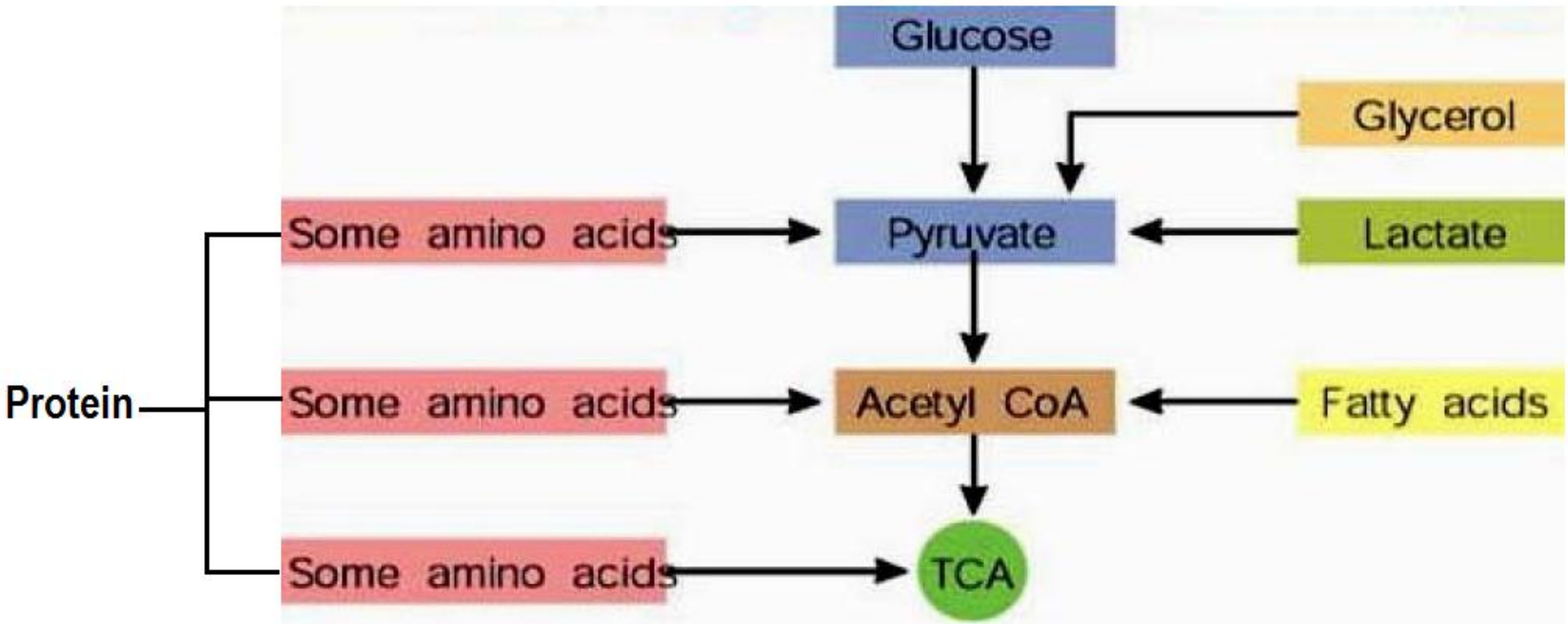
Central role of ATP in cellular energetic

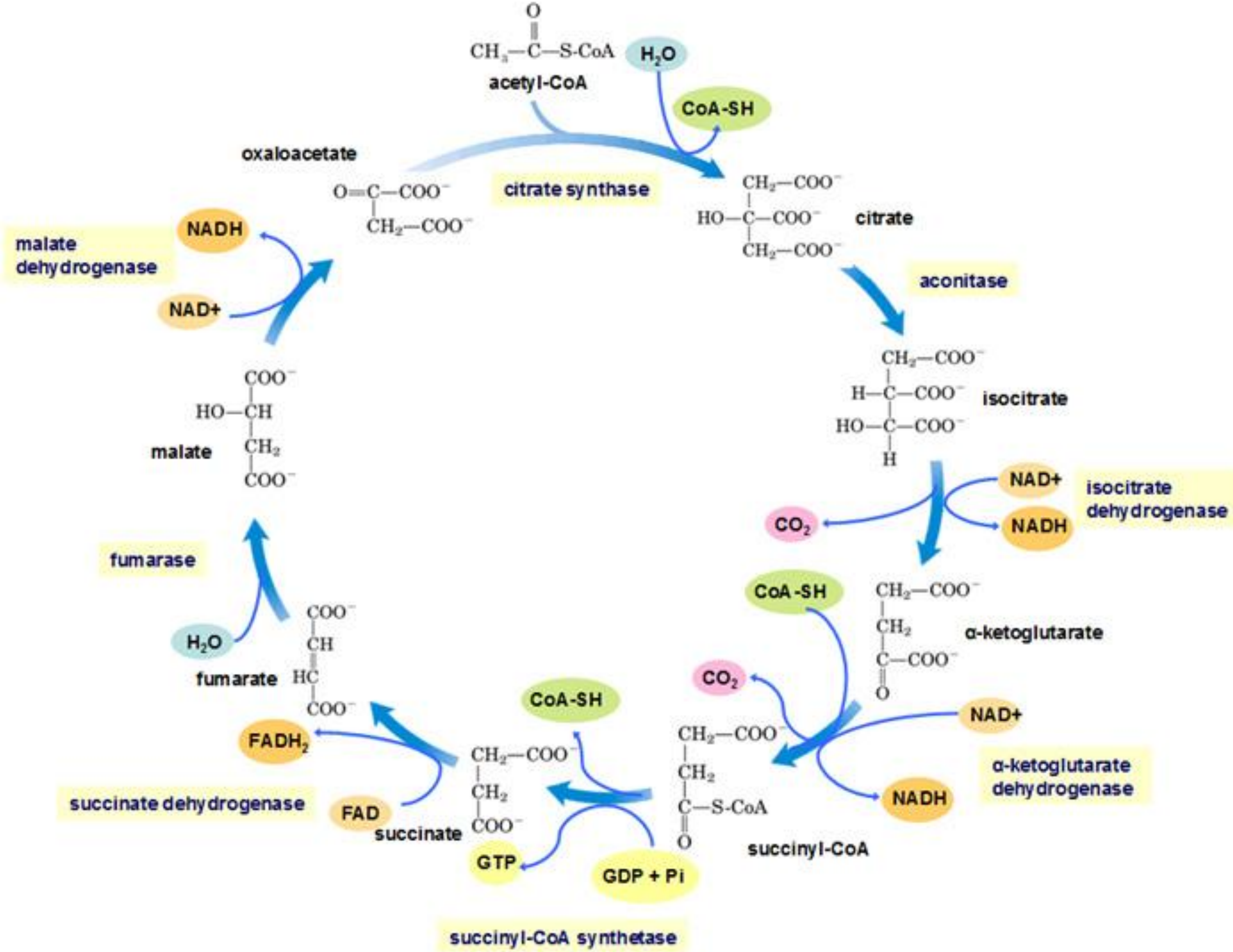


Extraction of Energy from Foodstuffs

- **In the first stage**, large molecules in food are broken down into smaller units. Proteins are hydrolyzed to their 20 kinds of constituent amino acids, polysaccharides are hydrolyzed to simple sugars such as glucose, and fats are hydrolyzed to glycerol and fatty acids.
- **In the second stage**, these numerous small molecules are degraded to a few simple units that play a central role in metabolism. In fact, most of them sugars, fatty acids, glycerol, and several amino acids are converted into the acetyl unit of acetyl CoA.
- **In the third stage**, ATP is produced from the complete oxidation of the acetyl unit of acetyl CoA. The third stage consists of the citric acid cycle and oxidative phosphorylation, which are the final common pathways in the oxidation of fuel molecules. Four pairs of electrons are transferred (three to NAD+ and one to FAD) for each acetyl group that is oxidized. Then, a proton gradient is generated as electrons flow from the reduced forms of these carriers to O2, and this gradient is used to synthesize ATP

Breakdown of energy molecules into smaller unit



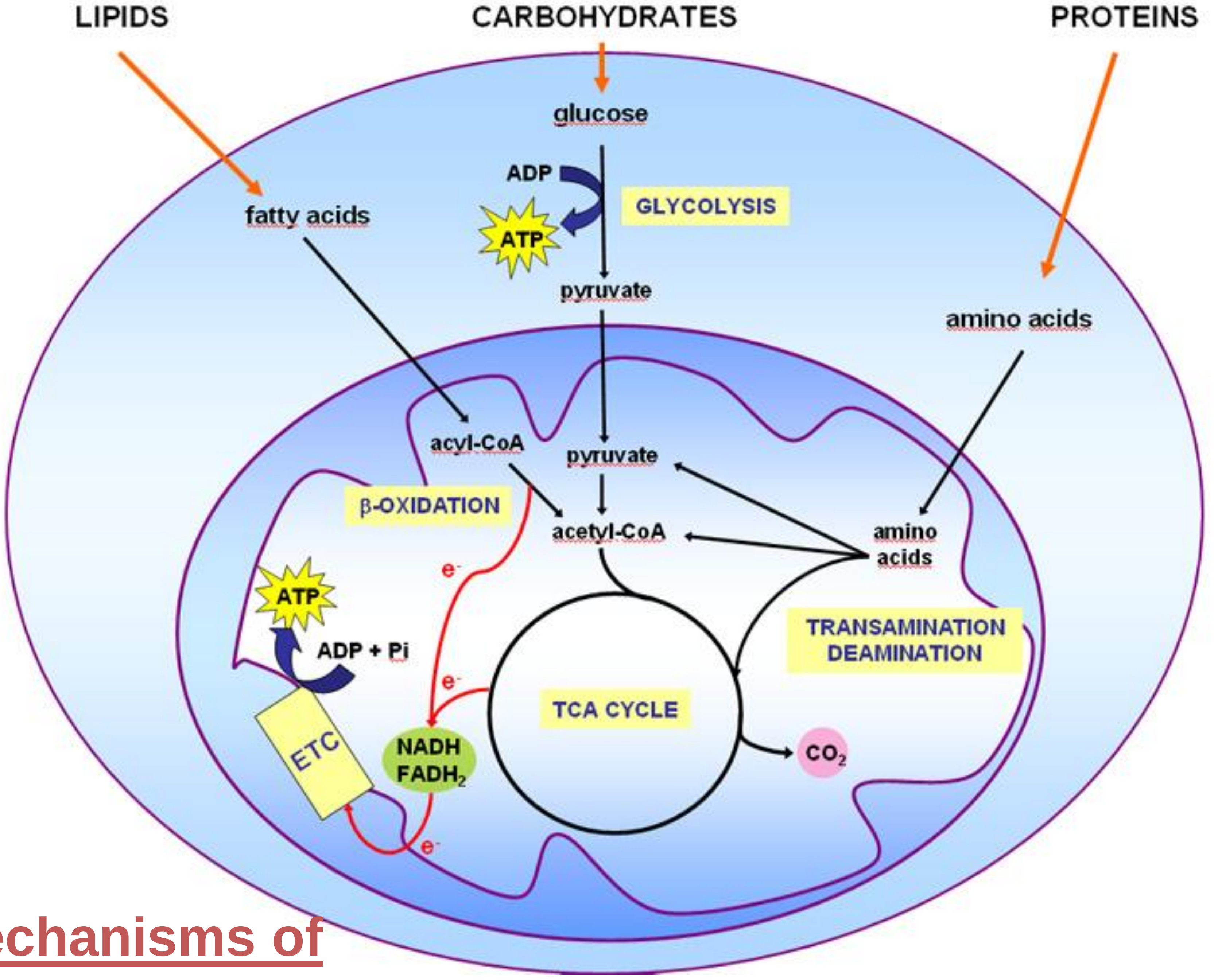

acetyl-CoA
H2O
CoA-SH
oxaloacetate
citrate synthase
citrate
aconitase
isocitrate
NAD+
isocitrate dehydrogenase
CO2
NADH
CoA-SH
α-ketoglutarate
CO2
NAD+
α-ketoglutarate dehydrogenase
NADH
succinyl-CoA
CoA-SH
GTP
GDP + Pi
succinyl-CoA synthetase
succinate
FAD
FADH2
succinate dehydrogenase
fumarate
H2O
fumarase
malate
NAD+
NADH
malate dehydrogenase

Mechanisms of ATP Synthesis

- There are two mechanisms of ATP synthesis:

- 1. **oxidative phosphorylation**, the process by which ATP is synthesized from ADP and inorganic phosphate (Pi) that takes place in mitochondrion.

- 2. **substrate-level phosphorylation**, in which ATP is synthesized through the transfer of high-energy phosphoryl groups from high-energy compounds to ADP. It occurs in both the mitochondrion, during the tricarboxylic acid (TCA) cycle, and in the cytoplasm, during glycolysis.



Mechanisms of ATP Synthesis

Energy balance and dietary requirement

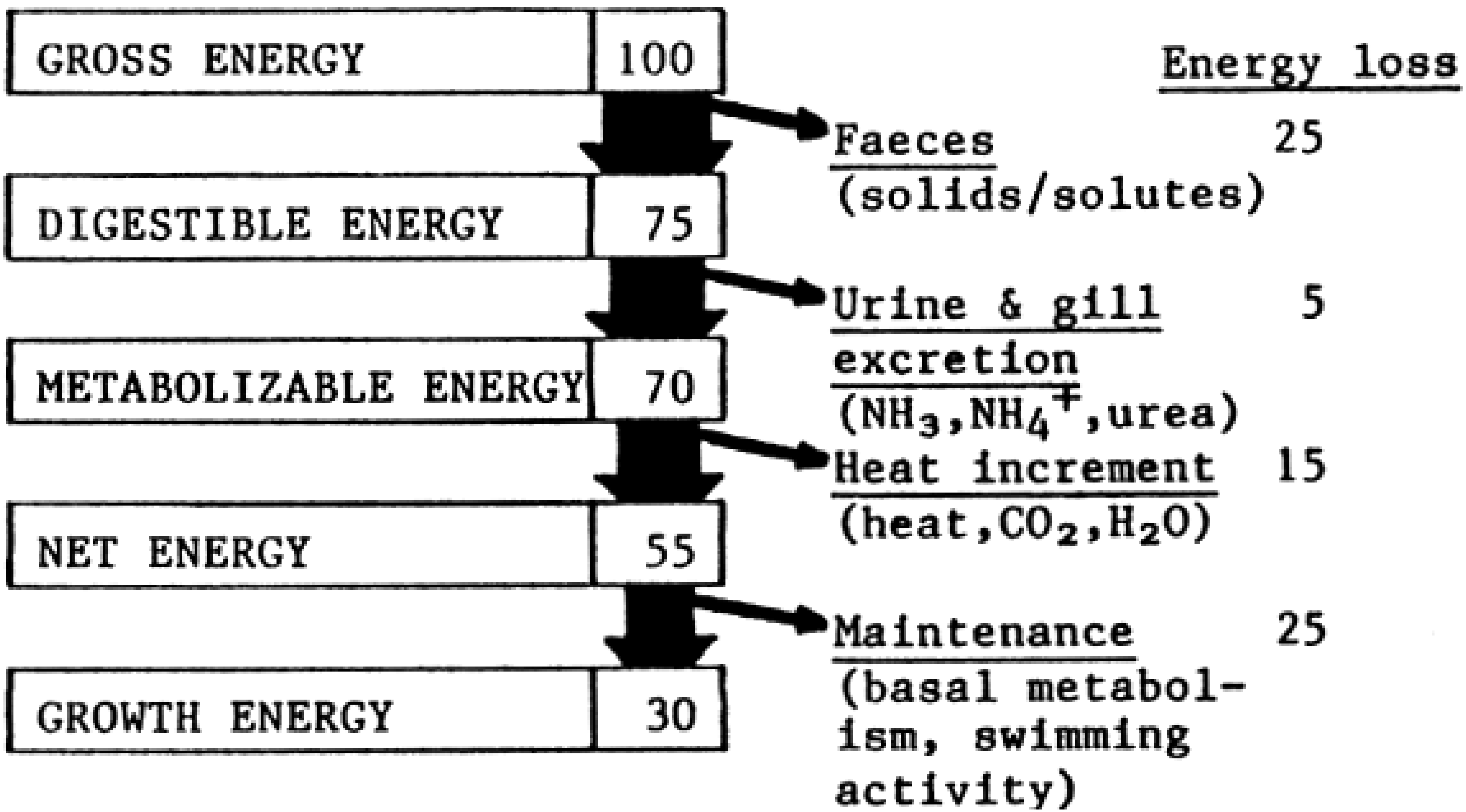
- Only a portion of the total chemical energy contained within the food ingested is available to the animal (ie. net energy) for maintenance, activity and growth; 45% of the ingested food energy being lost as undigested food (faeces), metabolic excretion and as heat.

- The energy balance equation

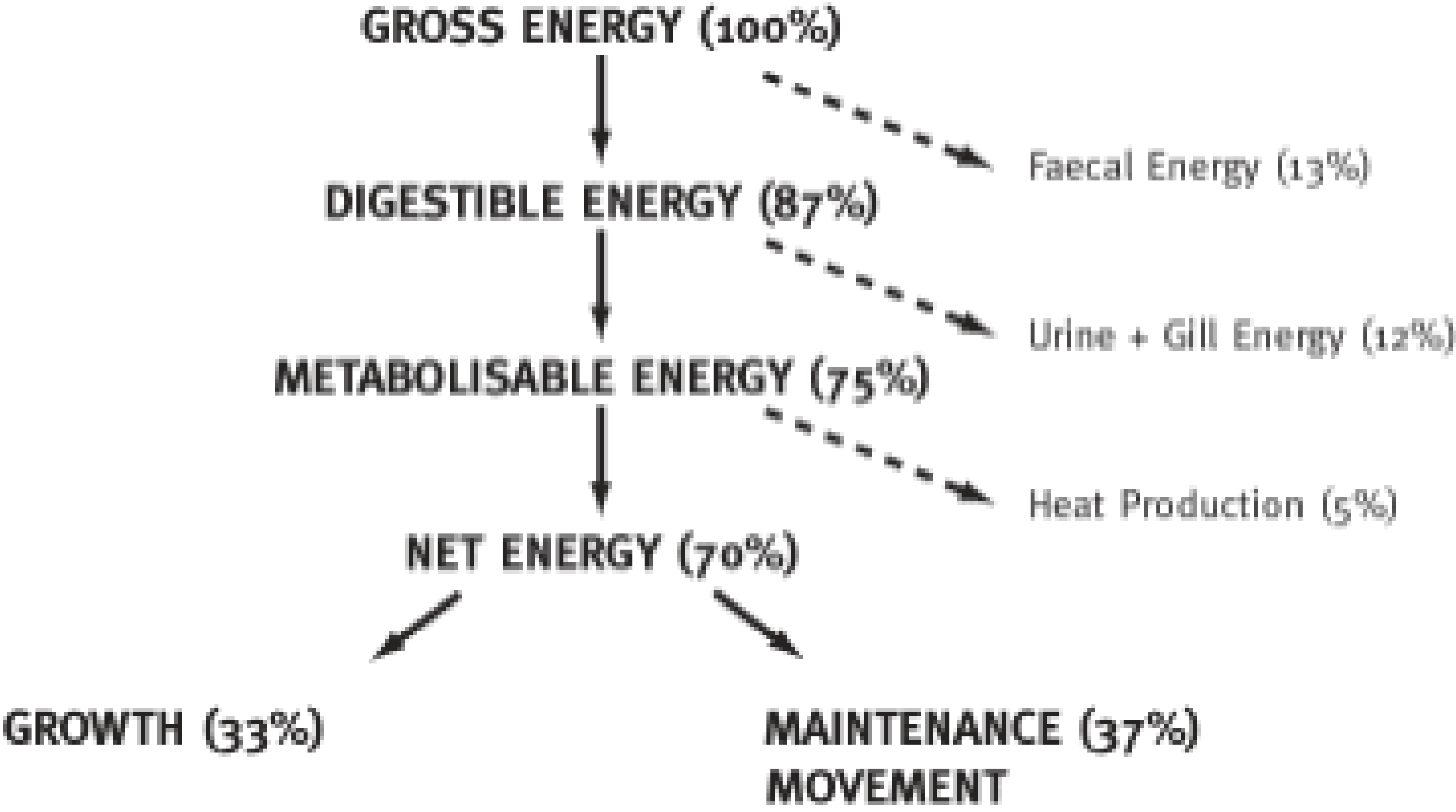
$$\mathbf{C = P + R + U + F}$$

where C (for consumption) is the gross energy content of the food ingested, P the energy utilized in growth materials (production), R the net loss of energy as heat (R standing for respiration), U (urinary loss) the energy lost in nitrogenous excretory products, and F the energy lost in the faeces.

Utilization of dietary energy in fish



Energy Distribution



Factors that Alter Energy Needs

- **Temperature:** As Most freshwater fish do not attempt to maintain a body temperature which is different from the environment. As water temperature declines, body temperature of the fish declines and metabolic rate is reduced.
- **Water Flow:** Energy which is used for physical activity is not available for growth. Fish which are forced to swim against a strong current are expending energy which would otherwise be used for growth
- **Body Size**. Small animals produce more heat per unit weight than do large animals. Small fish should be fed a higher percentage of body weight than large fish
- **Level of Feeding.** The level of feeding also has an effect on the energy expenditure of fish. The oxygen consumption increases shortly after feeding due to the physical activity of feeding and the heat of nutrient metabolism
- **Other Factors.** Several other factors can contribute to high energy requirements. Anything which makes the fish uncomfortable increases physical activity and reduces growth. Crowding, low oxygen and waste accumulation are some of these factors

Metabolic rate

- **Standard Metabolic Rate: is required for maintaining the critical physiological functions. it is minimal or resting metabolic rate of unfed fish performing no swimming activity.**

- **Active Metabolic Rate: the upper limit of aerobic metabolic rate with maximum sustained swimming is known as active metabolic rate.**