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Energy metabolism - introduction

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Energy metabolism - introduction

- Animals need chemical energy to carry out their various functions, and their overall use of chemical energy is often referred to as their *energy metabolism*.
- Animals obtain energy mostly through the oxidation of foodstuffs, and their consumption of oxygen can therefore be used as measure of their energy metabolism.
- Some animals can live in the absence of free oxygen; they still utilize chemical energy for their energy needs, although the metabolic pathways are different.
- *anaerobic metabolism*



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Metabolism - introduction

Common source of energy, *adenosine triphosphate (ATP)*.

immediate source of chemical energy for processes such as muscle contraction, ciliary movement, firefly luminescence, discharge of electric fish, cellular transport processes, all sorts of synthetic reaction and so on.

ATP is a universal intermediate in the flow of the chemical energy of the food



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Metabolic rate

- Metabolic rate refers to the energy metabolism per unit time.
- metabolic rate is the amount of oxygen used in oxidation processes,
- The determination of oxygen consumption is technically easy and is so commonly used for estimation of metabolic rates
- The reason oxygen can be used as a practical measure of metabolic rate is that the amount of heat produced for each liter of oxygen used in metabolism remains nearly constant, irrespective of whether fat, carbohydrate, or protein is oxidized



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Respiratory quotient

The ratio between carbon dioxide formed and oxygen used is known as the respiratory quotient (RQ).

Food	a	b	c	d
	Kcal g ⁻¹	Liter O ₂ g ⁻¹	Kcal per liter O ₂	$\frac{\text{Co}_2 \text{ formed}}{\text{RQ} = \text{O}_2 \text{ used}}$
Carbohydrate	4.2	0.84	5.0	1.00
Fat	9.4	2.0	4.7	0.71
Protein (urea)	4.3	0.96	4.5	0.81
Protein (uric acid)	4.25	0.97	4.4	0.74



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Respiratory quotient

- The RQ gives information about the fuel used in metabolism
- Usually the RQ is between 0.7 and 1.0.
- An RQ near 0.7 suggests primarily fat metabolism; an RQ near 1.0 suggests primarily carbohydrate metabolism.
- From determinations of oxygen consumption, carbon dioxide elimination, and nitrogen excretion, it is thus possible to calculate the separate amounts of protein, fat and carbohydrate metabolized in a given period of time.



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Effect of oxygen concentration on metabolic rate

If the oxygen uptake is studied over a wider temperature range in an animal such as the goldfish,

At relatively high oxygen tension the oxygen uptake of goldfish is independent of the available oxygen, but at lower oxygen tensions there is a linear relationship



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Acclimation to low oxygen levels

Many fast-swimming, active fish are quite sensitive to low oxygen in the water.

If the fish has been kept in relatively oxygen-poor water, it becomes more tolerant to low levels of oxygen.

This improved tolerance is probably attributable to an enhancement of the ability to extract oxygen from the water.



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Acclimation to low oxygen levels

a fish acclimated to low levels of oxygen could be expected to survive longer than a nonacclimated fish

The improved oxygen extraction could result from increased volume of water pumped over the gills, increased ability to remove oxygen from the water flowing over the gills, improved oxygen transport capacity in the blood, improved function of the heart, or any combination of these



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Anaerobic metabolism

- Animals that tolerate prolonged exposure to zero oxygen must of necessity obtain their metabolic energy from nonoxidative reactions.
- Animals that can intermittently survive long periods of anoxic conditions are called facultative anaerobic organisms.
- An example is the sea anemone
- These sea anemones are often buried in the sand, and some are found under neath rocks where the sand is black from anaerobic sulfur bacteria.



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Anaerobic metabolism

- One common process for obtaining energy under anaerobic conditions is the breakdown of carbohydrate into lactic acid.
- This process, known as glycolysis, occurs commonly in vertebrate muscle when the energy demand in heavy exercise exceeds the available oxygen.
- ATP is the immediate source of energy for nearly every energy-requiring process in the living organism.



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Anaerobic metabolism

The tolerance to anoxic conditions sometimes is amazing. It has been reported that the crucian carp (*Carassius carassius*) can live for 5.5 months under the ice of a frozen lake when the water under the ice is oxygen-free because of fermentation of dead plant material and hydrogen sulfide is present (Blazka 1958).



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Anaerobic metabolism

- The anaerobic metabolism of fish has an interesting consequence that is related to the low carbon dioxide concentration in fish blood.
- The low carbon dioxide concentration means that the amount of sodium bicarbonate that serves as the main buffering substance in the blood is also very low.
- The addition of large amounts of lactic acid would therefore severely disturb the normal acid-base balance of the poorly buffered blood.



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The oxygen minimum layer

- Some of the animals, particularly the fish, make daily migrations to the surface, ascending at dusk and returning to depth before sunrise, in vertical movements that amount to 300 m or more.
- Paradoxically, the fish present in the low-oxygen region often have gas-filled swim bladders that contain a high percentage of oxygen.
- During the day, when the fish are at depth, it seems likely that they must obtain energy by anaerobic pathways.



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The oxygen minimum layer

Their blood has a low oxygen capacity and their hemoglobin such a strikingly low affinity for oxygen that no more than 1% of the hemoglobin would be oxygenated while the fish are at depth