METABOLISM

Metabolism:

Metabolism is the means of providing the energy essential to normal life processes, to compensate for losses caused by wear and tear or excretion and to ensure the further development and growth of Organism.

Or

The chemical processes occurring within a living cell or organism that are necessary for the maintenance of life. In metabolism some substances are broken down to yield energy for vital processes while other substances, necessary for life, are synthesized.

METABOLISM

Functions of Metabolism:

1. To obtain chemical energy from the degradation of energy rich nutrients.

2. To convert nutrient molecules in to the building block precursors of cell macro molecules.

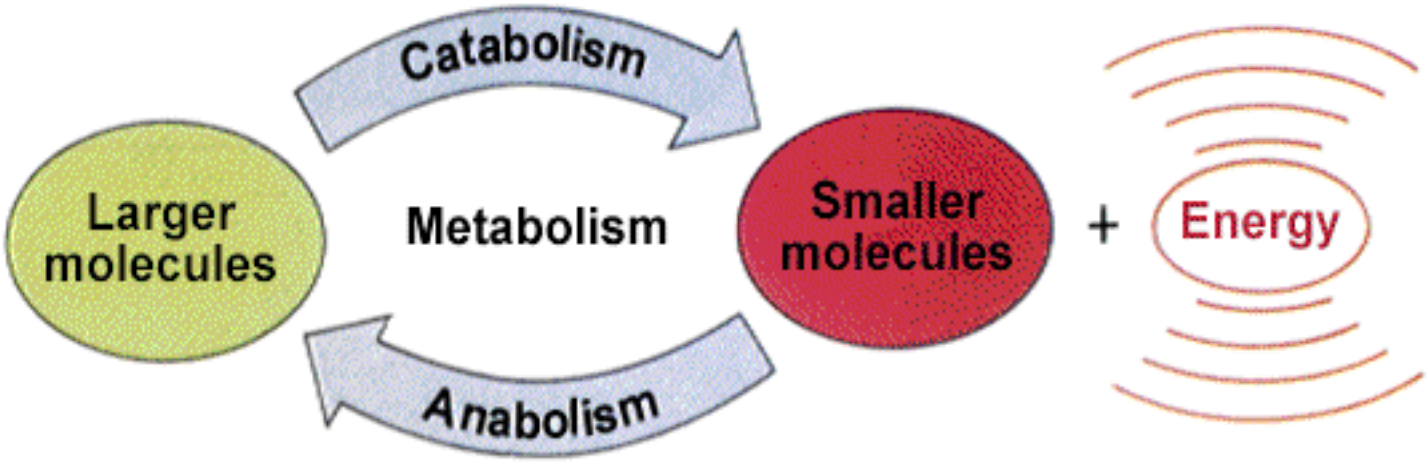
3. To assemble these , building blocks into protein, nucleic acid, lipid, Polysaccharides and other cell components.

4. To formed degrade biomolecules required in specialized function of cell.

Phases of metabolism

Metabolism has two phases:

1. **Catabolism**
2. **Anabolism**



Proteins to Amino Acids, Starch to Glucose

Synthesis
Amino Acids to Proteins, Glucose to Starch

Catabolism:

The catabolism is the degradation process in which the relatively large molecules of nutrients (eg., Carbohydrate, Lipids and Proteins) coming either from environment or from the cells own nutrient stores are degraded by stepwise reactions into smaller simpler compounds (Lactic acids, CO_2 and NH_3) with concomittent (relation) release of chemical free energy. This energy is then used for maintainance, growth, replications etc.

Anabolism:
Anabolism is the biosynthesis of molecular component of the cell such as nucleic acids, proteins, polysaccharides and lipids from their simple building block precursors.

Two stages of catabolism

Catabolism is done in two stages:

1. **Transformation/breakdown of large molecules into a limited number of intermediate compounds of relatively smaller molecular weight, releasing about one-third of the energy in the nutrient as free energy. These intermediate products are as follows:**

   for Carbohydrates, trios phosphate and /or pyruvate
   for Fats, acetyl CoA, propionyl CoA and glycerol
   for Proteins, acetyl CoA, oxaloacetate, alfa-ketoglutarate, fumerate and succinate

2. **Final oxidation of the intermediate compounds to CO_2 and water, releasing the remaining two thirds of the energy**

Link between anabolism and catabolism

1. On the level of carbon sources: The product of catabolism through intervention of the central routes, become the substrates of anabolism

2. On the level of energy supply: Catabolism produces metabolic energy in the form of ATP or of compounds easily convertible to ATP; anabolism requires energy and consumes ATP

3. On the level of reducing power: Catabolism is essentially oxidative; it therefore consumes oxidizing power and produces reducing power. The reverse is true for anabolism

Metabolic activity on fish

1. **Maintenance metabolism**
2. **Basal or standard metabolism**
3. **Routine metabolism**
4. **Active metabolism**

1. Maintenance metabolism: For maintaining the normal life processes such as a) respiration, b) blood circulation, c) excretion, osmoregulation, d) digestion and movement, the animal require energy. These physiological processes and the energy required to maintain them are referred to as maintenance metabolism.

2. Basal or standard metabolism: Basal metabolism reflects the energy Requirements of those cellular and tissue processes due to continue the activities of the organism (in the fasting and resting stage), eg., metabolic activit Of muscle, brain, kidney, liver and other cells.

3. Routine metabolism:

When animals are permitted to move normally and spontaneously during metabolism determination, the resulting value is called routine metabolism.

The level of metabolic activity shown by a fish when it is under normal condition in the absence of food or stress

4. Active metabolism: two states

The metabolism of animals stimulated to maximum sustained activity is active metabolism.

1. **AM level 1: this relates to normal conditions of metabolism of fish digesting food and engaged in free-swimming motion**

2. AM level 2: The highest level of metabolic activity with great exertion

Metabolic rate:

The metabolic rate should be measured in terms of calorific output. These Require determination of a) Oxygen intake, b) CO_2 output and c) Nitrogen excretion together with an estimate of the calorific value of the excreta. Thus the metabolic rate has almost universally been measured by determining O_2 consumption (mg O_2/h).

Equations:

$Q = aw^b$

$Q = aW^b t^c$…….by Liao

Q = Metabolic rate

a = specific metabolism

w/W = body weight

t = Water temperature

b and c are the regression coefficien of body weight and temperature, respectively.

Metabolism

Factors affecting metabolism

- Activity level
- Temperature
- Body mass
- Feeding level

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy (ATP \& heat)}$$

Factors affecting metabolism

The rate of metabolism depends on the following factors:

1. **Intrinsic factors**
2. **Extrinsic factors**

1. Intrinsic factors

- it includes genetic and hereditary factors.

Metabolism is completely an enzymatic process. The synthesis of enzymes is almost entirely depending on gene.

Besides there are many examples of metabolic diseases which are due to genetic disorder and are hereditary

2. Extrinsic factors

Physiological factors

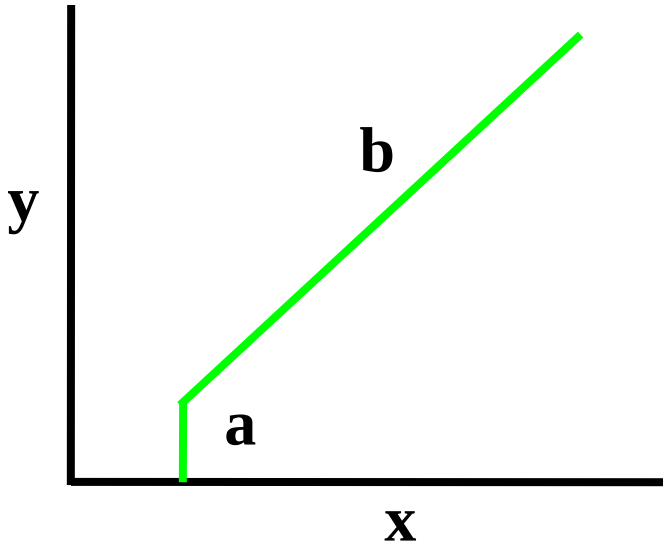
i) Size and weight of fish
ii) Activity and food intake
iii) Starvation

Environmental factors

i) Temperature
ii) Oxygen
iii) Salinity
iv) Light
v) Pollution

i) Size and weight of fish

$$Q = aW^b$$



Q = total metabolism

a = a co-efficient

W = weight of the specimen

b = an exponent which determines the change in the metabolic rate as a function of body weight

- **the value of the b generally 0.75-0.8;**
  for fish 0.8, indicates an inverse relation between metabolism and weight of the animal

ii) Activity and food intake

- With increase in activity, metabolic rate increase (expressed as O_2 consumption/mg/kg/h)

-e.g. when activate or swim against current O_2 consumption increases

- For rainbow trout an increase in swimming speed from 20 m/s to 30 m/s caused as increase O_2 consumption from 100mg/kg/h to 500 mg/kg/h

- For rainbow trout food intake and digestion can increase O_2 consumption by 15-40%

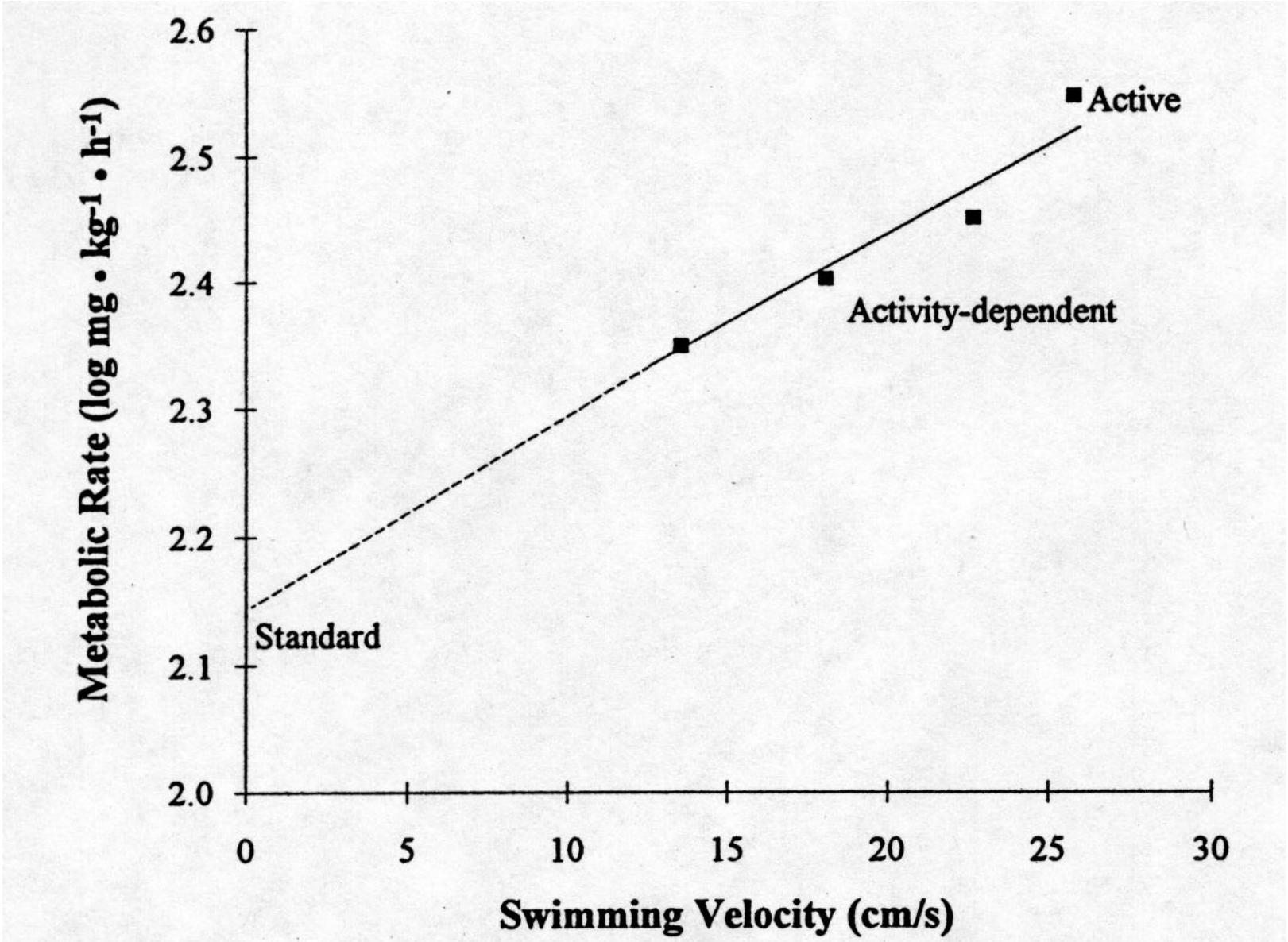


Figure 3-3. *The relationship between metabolic rate and swimming speed of a 150-g largemouth bass at 20 C. Redrawn from Beamish (1970).*

iii) Starvation

- **Leads to reduction in metabolic rate and energy requirement must be met from body reservoirs**

- **For brook trout standard metabolism during starvation fell to a loweric limit within 3 days but remained static thereafter**

- **Routine metabolism falls down even lower 3 days compared to standard metabolism**

Environmental factors

i) Temperature

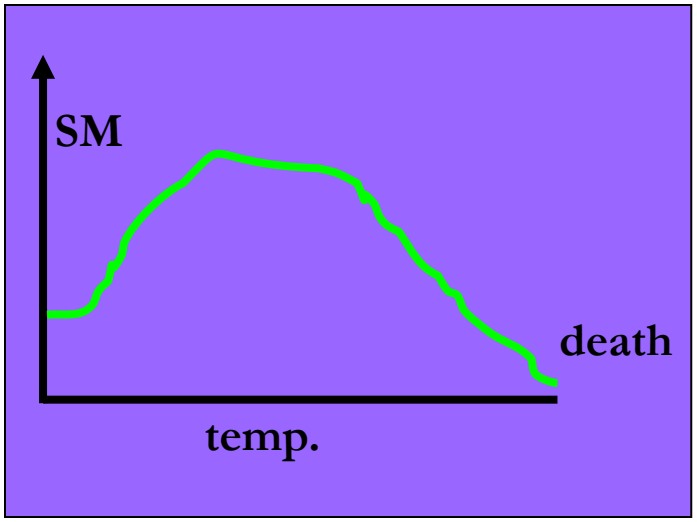
- **Specially important for poikilothermic animals**

- **Generally the Van't Hoff's rule is applicable which states that**

"for every temperature rise of 10 ^{0}C, rate of biochemical reactions (most body functions) doubles, up to a point (when proteins break down)"

- **Standard metabolism raises with temperature increase and reaches a peak at certain temperature.**

- **Standard metabolism decreases sharply ultimately resulting in death**



- **Active metabolism does not necessarily follow the same pattern as SM.**

-e.g.

in rainbow trout, SM increases from 5 °C to 25 °C, after 25 °C death occurs due to cardiac disorder.

AM increases from 5 °C to 15 °C, remains static or diminution

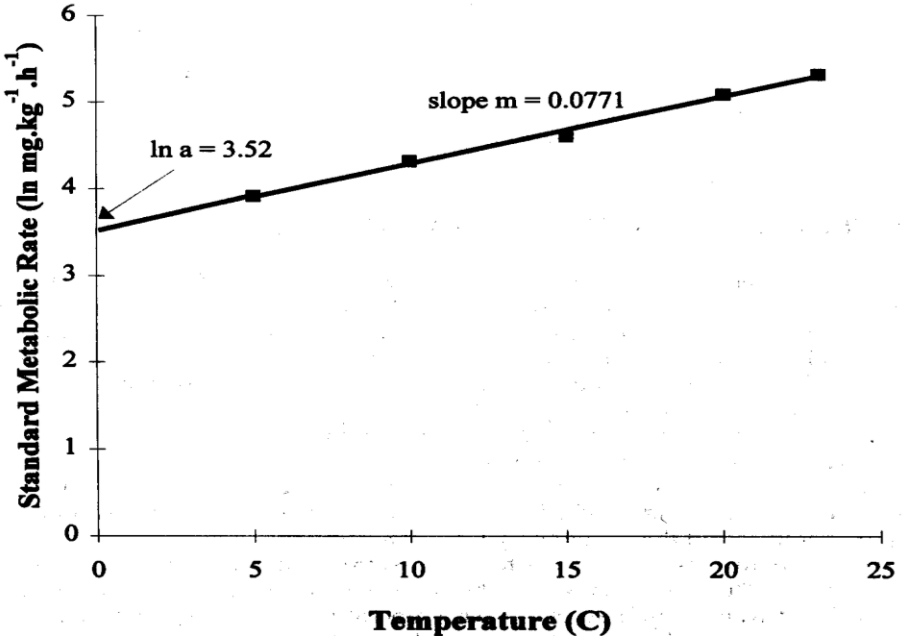


Fig. Relationship between SM and temp.

Temperature & Metabolism

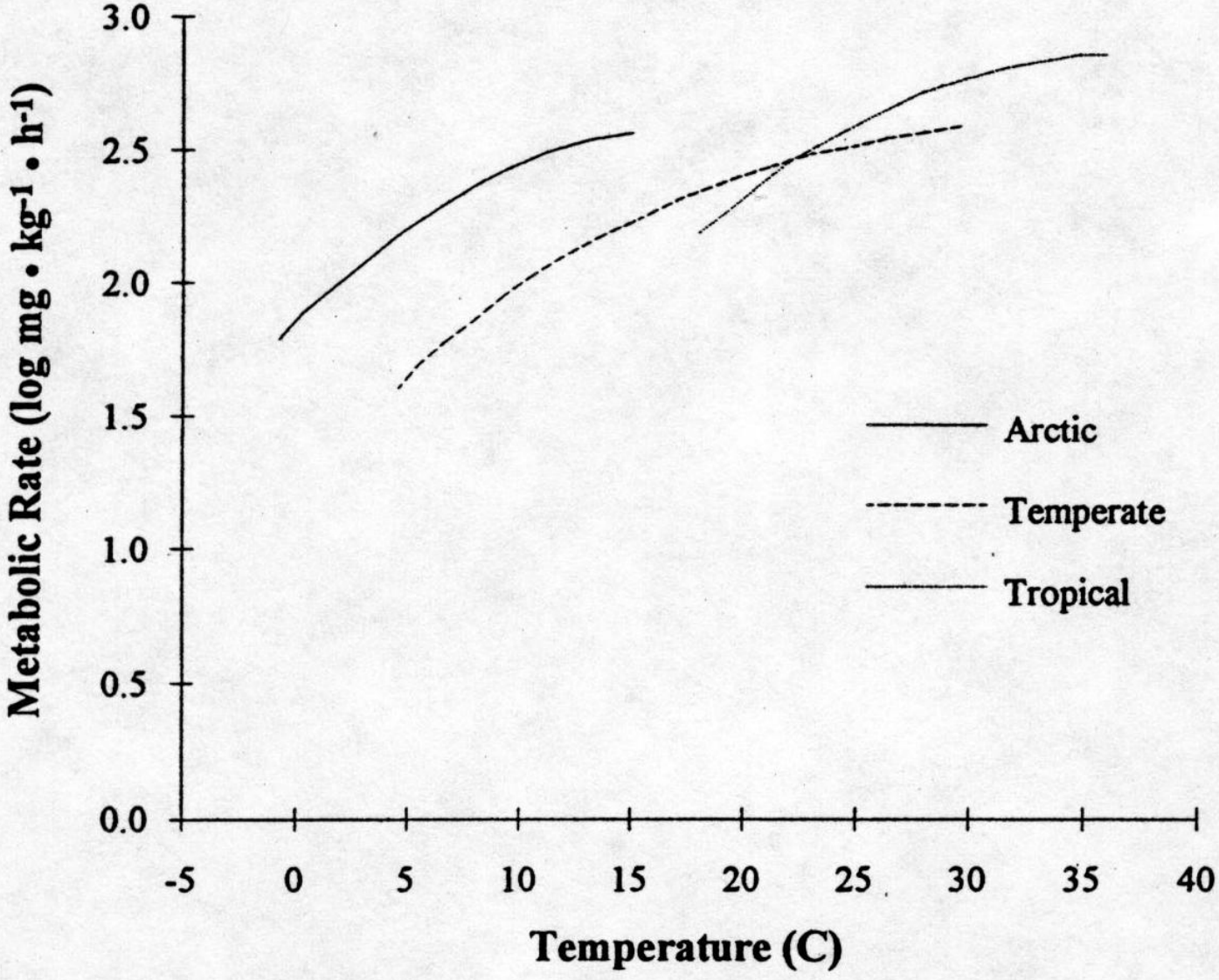


Figure 3-7. *Standard metabolic rate at various temperatures for Arctic, temperate, and tropical fish (modified from Brett and Groves 1979).*

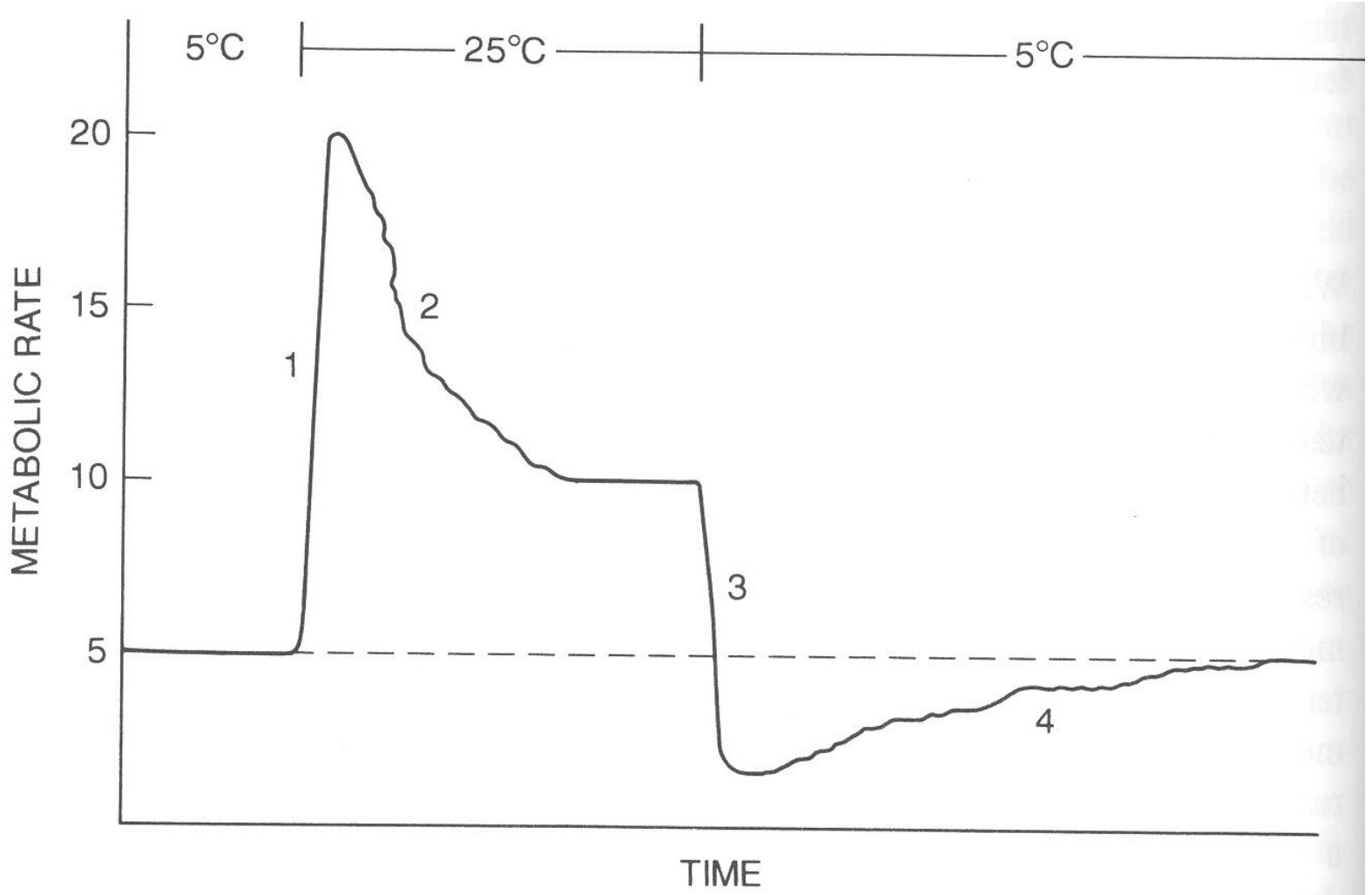


Fig. 8.1 Schematic figure showing the time course of thermal acclimation and metabolic compensation following transfer between different temperature conditions. (1) 'Acute' response following temperature increase; (2) acclimation to new temperature conditions resulting in a partial compensation of metabolic rate; (3) 'acute' response following return of acclimated fish to low-temperature conditions; (4) re-acclimation of fish to low temperature accompanied by an increase in metabolic rate.

ii) O_2

Active metabolism increases with increasing O_2 content

- But this occurs within a certain limit which is known as range of dependence. This is quite species specific

- SM is almost independent of O_2 content of water except when it become low to cause death

iii) Salinity

It is important in case of diadromous fishes (eg. Rainbow trout)

- **Both SM & AM were found to be the lowest at 7.5 ppt and at 15 ppt, respectively**

- **In freshwater there are slight elevation in metabolic rate**

  - **Maximum value of 30 ppt because of the increased demand of energy for osmoregulation**

  - **At 7.5 ppt this energy requirement is taken as zero**

Specific Dynamic Action (SDA)

- **Comprises the energetic costs of processing and assimilating food, such as**
  - **deamination of proteins, and**
  - **transport and deposition of lipids**

- Affected by:
  - Size of meal
  - Composition of food

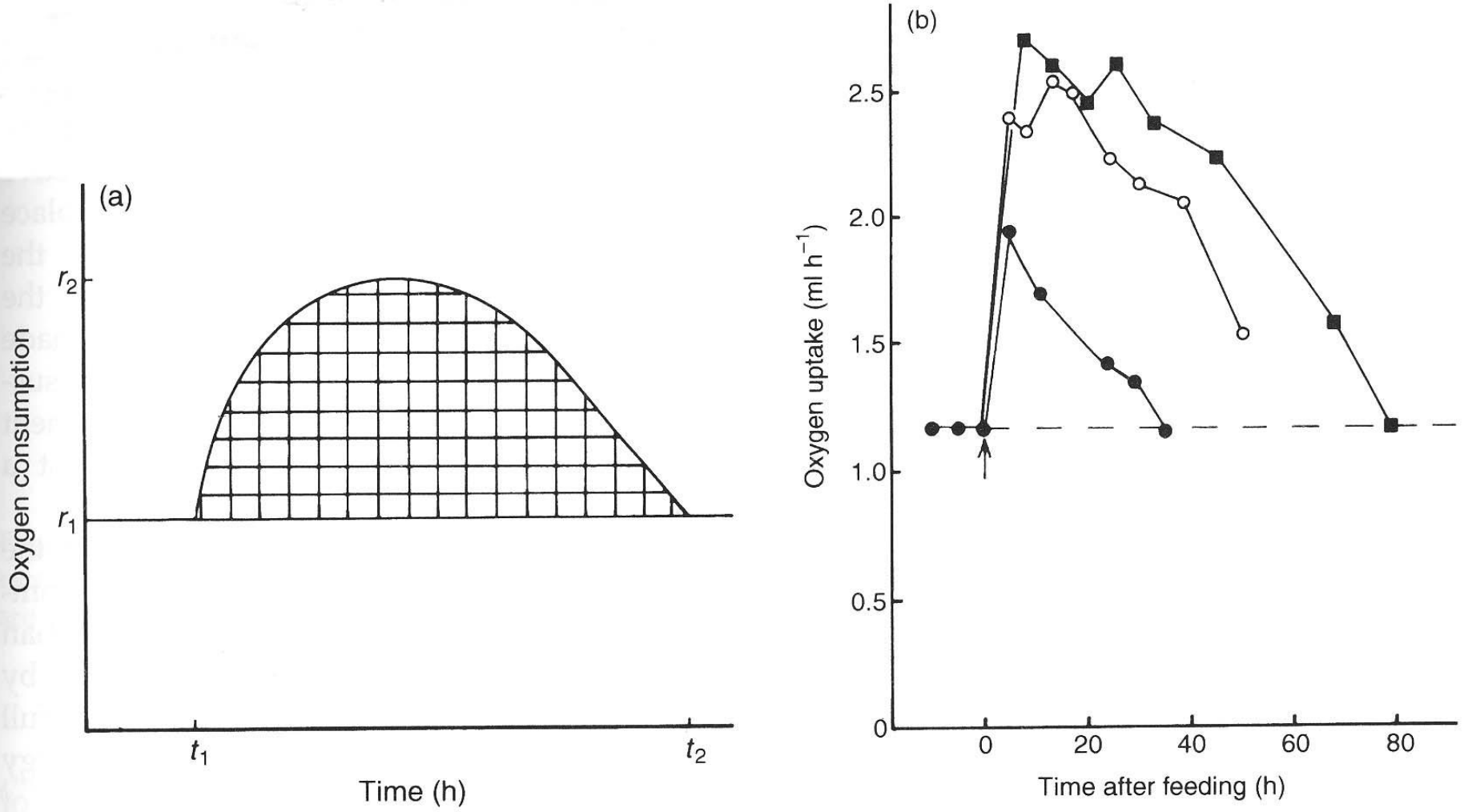
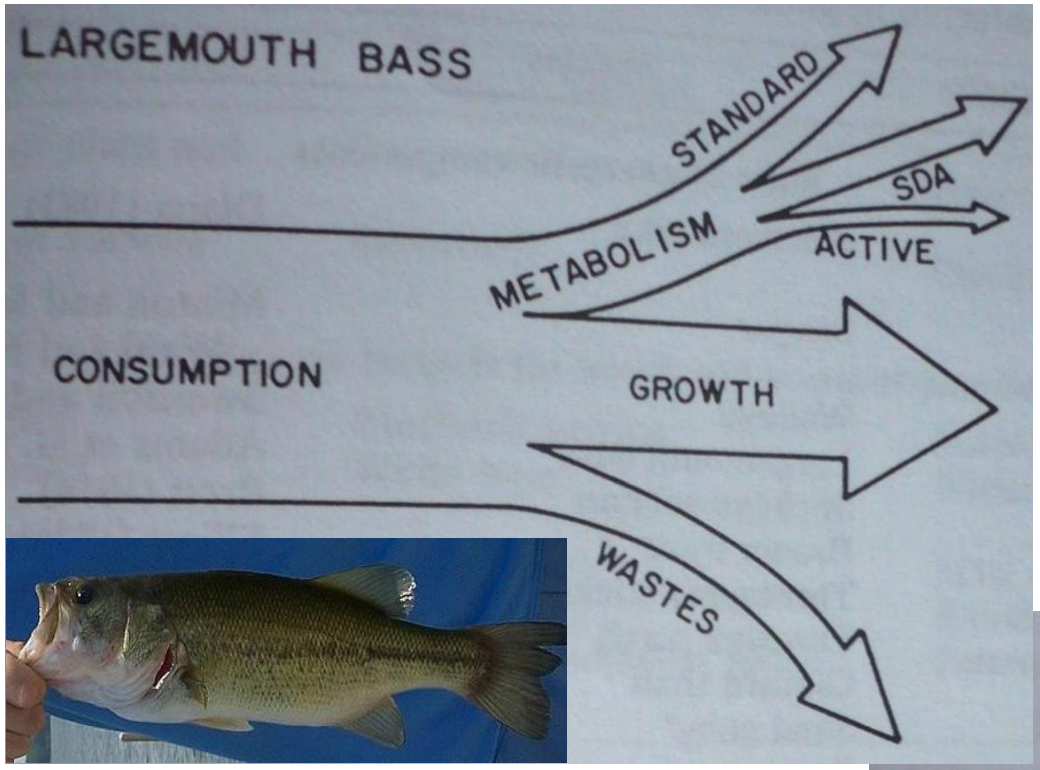
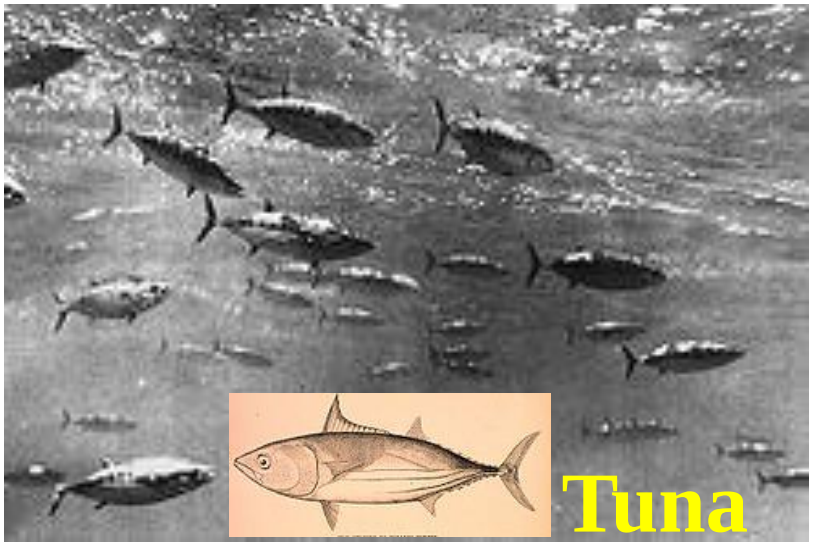


Fig. 4.2 Apparent specific dynamic action (heat increment of feeding). (a) Schematic diagram showing the rise in oxygen consumption after a meal. Apparent SDA is measured by shaded area. r_1, routine rate; r_2, peak rate; t_1, time of feeding; t_2, termination of SDA. Redrawn from Jobling (1981). (b) Effect of meal size on mean apparent SDA in plaice, *Pleuronectes platessa*, fed white fish paste. ●, 0.25 ml paste (N = 1); ○, 0.5 ml paste (N = 7); ■ 1.0 ml paste (N = 5); arrow, time of meal. Broken line indicates the routine rate. Redrawn from Jobling and Spencer Davies (1980).





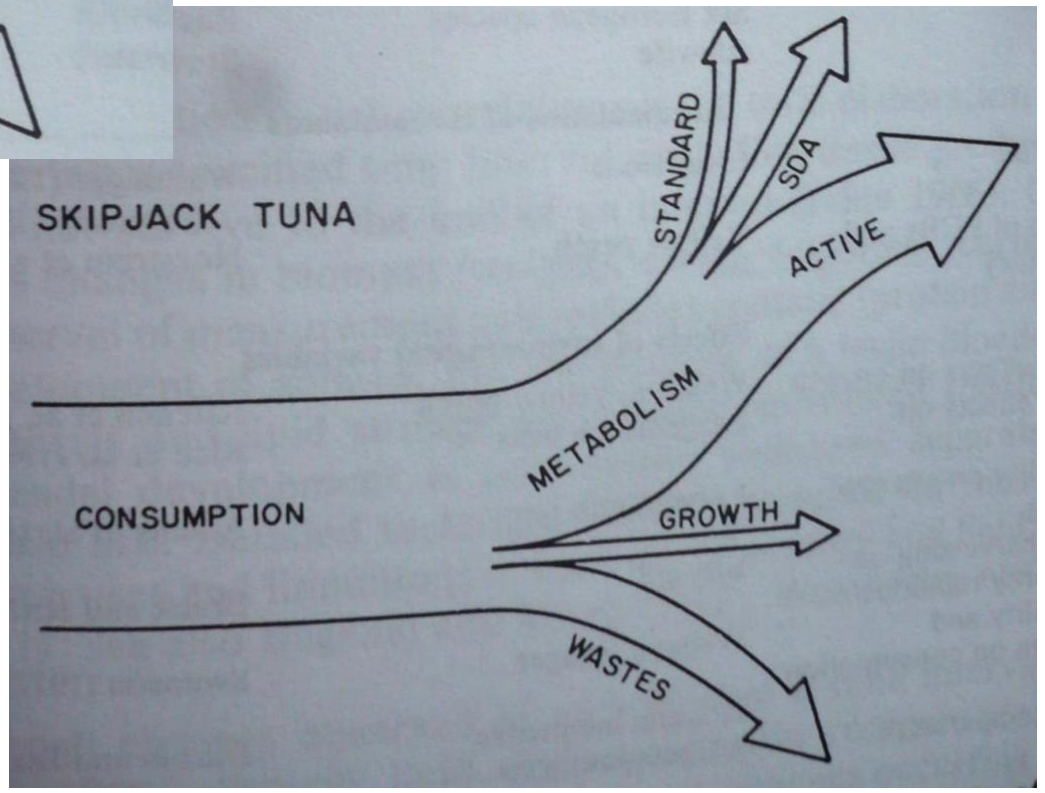
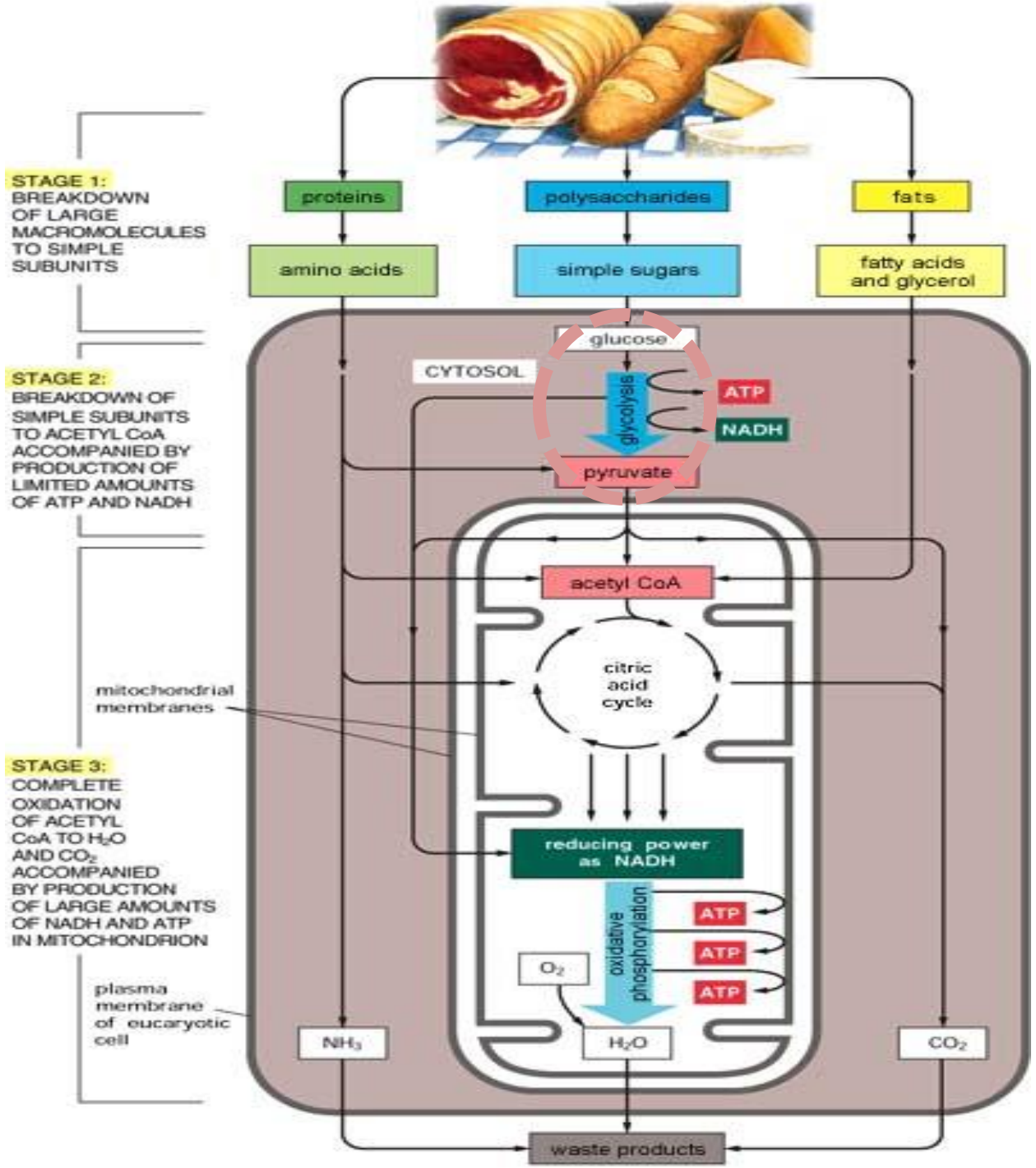


Fig. Allocation of consumed energy into the major components of the bioenergetics budget at maximum rations in the relatively sedentary largemouth bass and the actively foraging skipjack tuna.



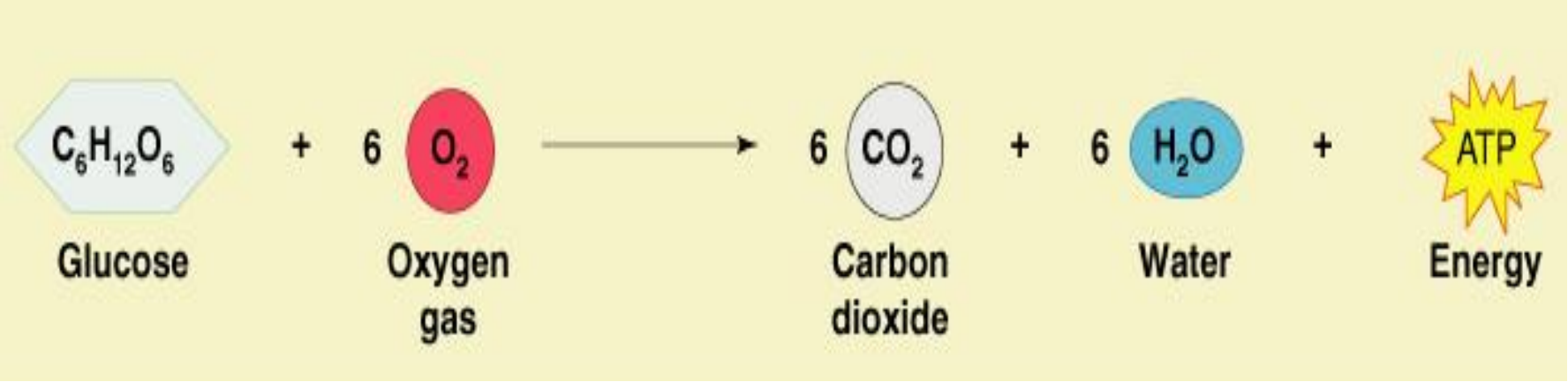
Identify if there are genetic differences in fish that utilize alternative dietary sources more or less efficiently.

What specific metabolic pathways and enzymes are involved and how the expression or activity of these genes modulate utilization.

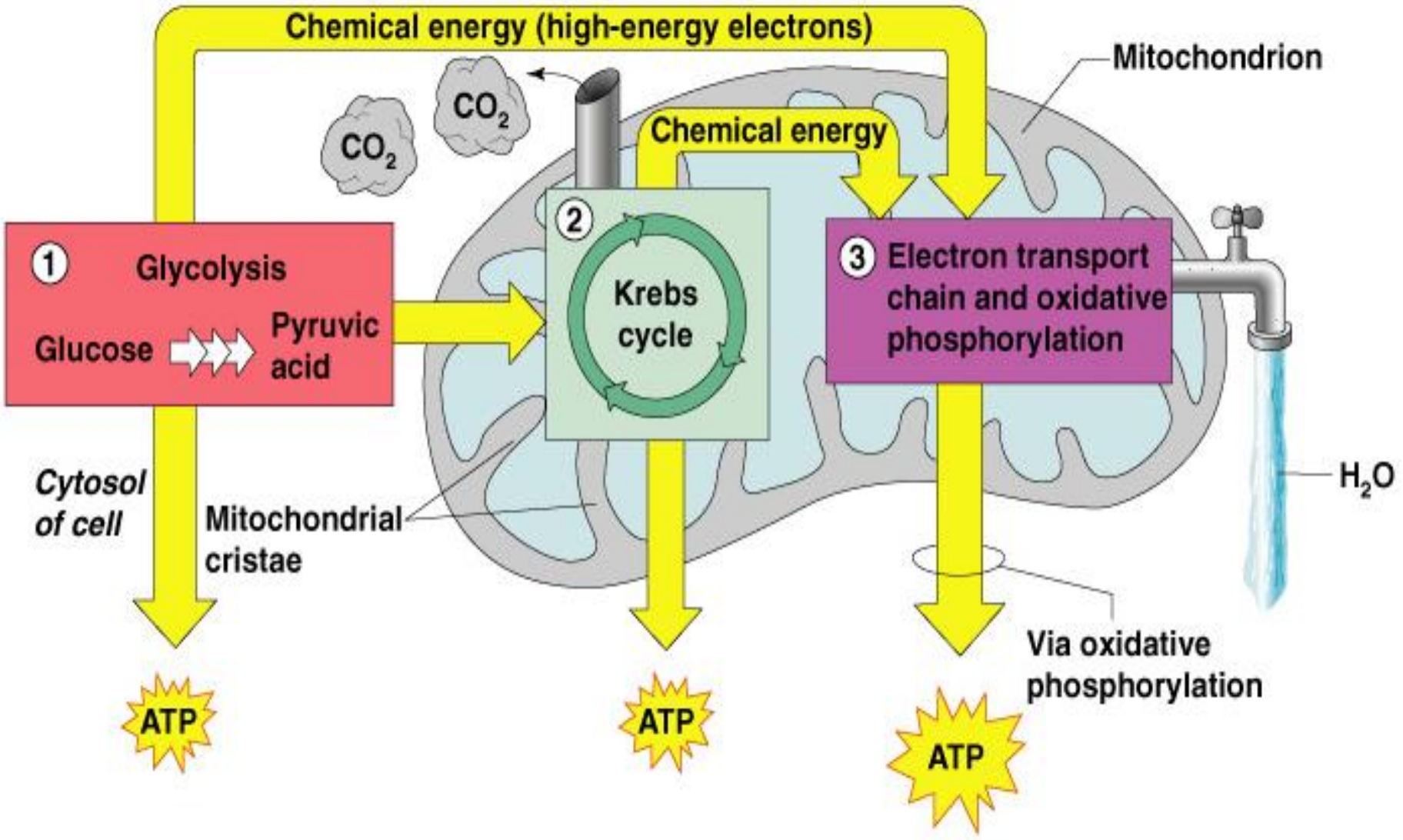
Carbohydrate Metabolism

- The body's preferred source to produce cellular energy (ATP)

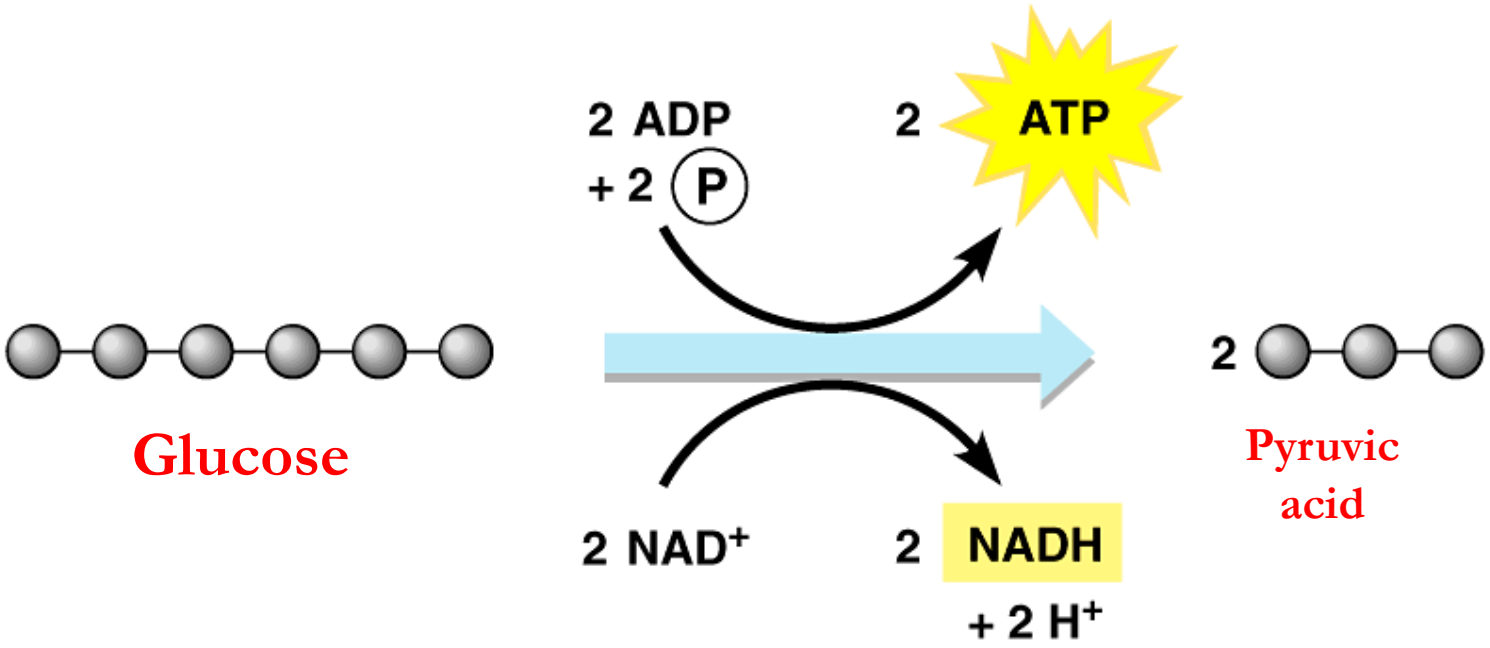
- Glucose (blood sugar) is the major digestive product and serves as fuel to make ATP



Metabolic Pathways Involved in Cellular Respiration



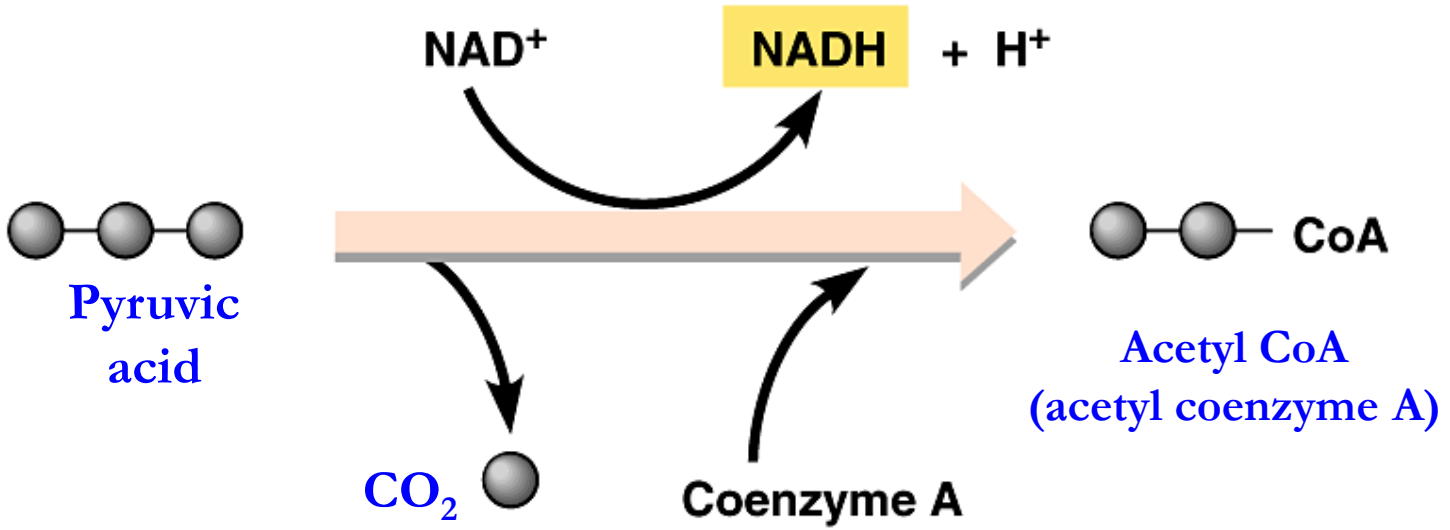
Glycolysis harvests chemical energy by oxidizing glucose to pyruvic acid



Energy yield:

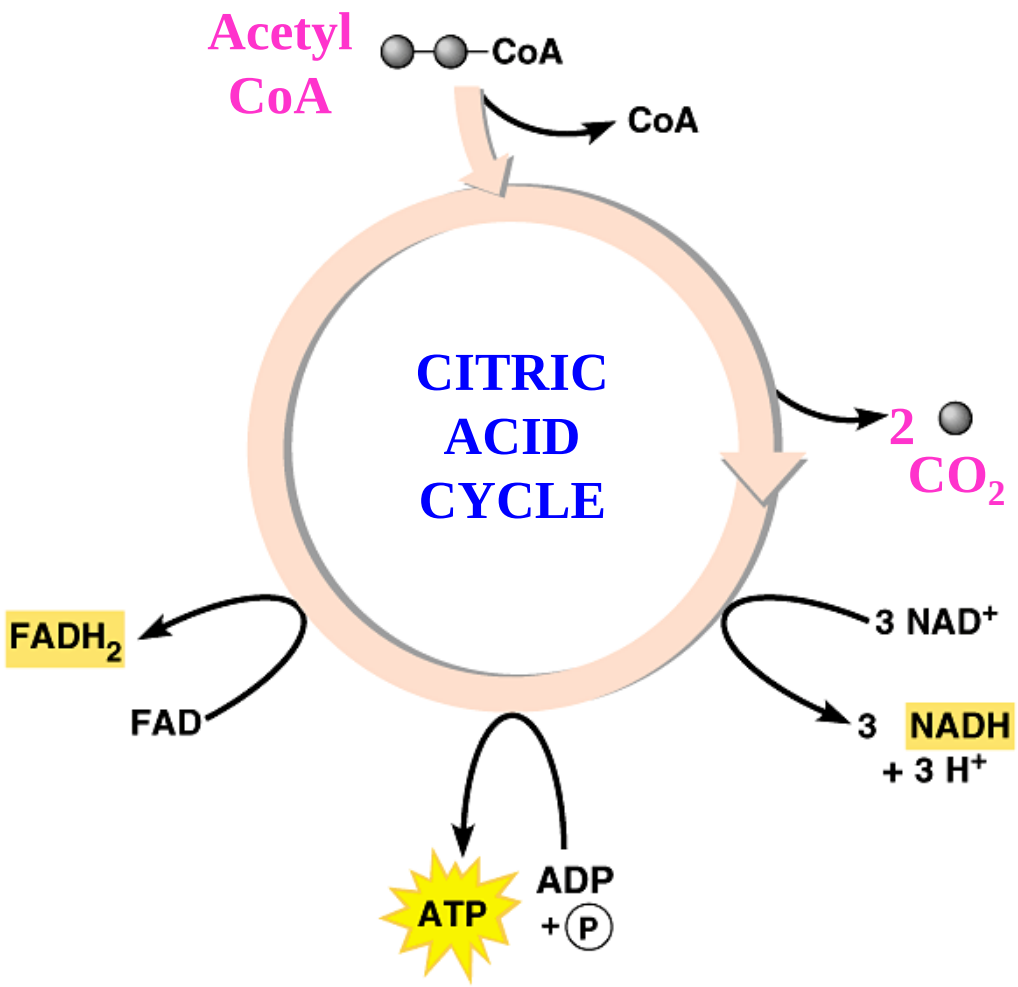
2 ATP and 2 NADH

Pyruvic acid is altered for the citric acid cycle



The citric acid cycle completes the oxidation of organic fuel

- enzymes convert acetyl to CO_2 and generate NADH and $FADH_2$ molecules



Energy in the Diet

Component	Heat of combustion / 1 gram component	Metabolizable energy
Carbohydrates $(CH_2O)_n$	4.1 kcal	1.6 kcal
Protein $(CH_2O)_n + N_2$	5.66 kcal	4.23 kcal
Lipids $(CH_2O)_n$ + OH	9.45 kcal	8.0 kcal

- Carbohydrates readily breakdown into CO_2 + H_2O & provide little energy.
- Proteins supply the greatest energy (45-60% of fish's diet).
- Lipids are complex and require energy to digest; not soluble in water.

Chemical Composition of Fish Foodstuffs

	Percentage composition				
Prey type	**Water**	**Protein**	**Lipid**	**Carbohydr-ate**	**Energy content ($kJ*g^{-1}$)**
Algae	**92**	**2.5**	**0.3**	**4.4**	**1**
Worms	**85**	**11**	**1**	**1**	**3**
Zooplankton	**80**	**13**	**3.5**	**1**	**4.5**
Insects	**75-80**	**10-16**	**1-5**	**2**	**3-6**
Fish	**72**	**14.5**	**10**	**trace**	**7.5**