Tishk International University
Faculty of Applied Science
Nutrition and Dietetics Department
2nd Grade

Metabolic Pathways and Biological Oxidation

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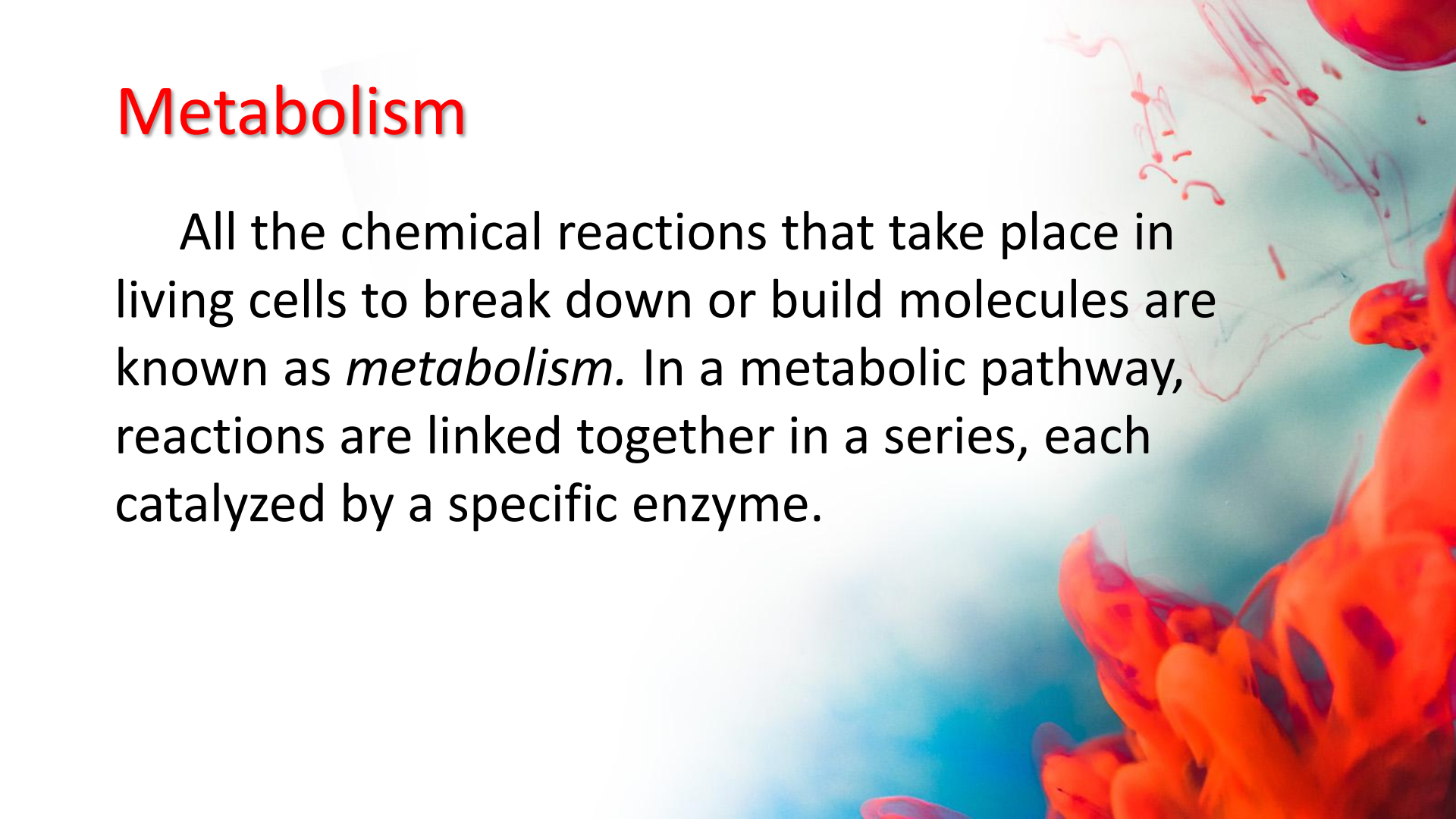
Objectives

- Metabolism
- Energy generation and Utilization
- Biological Oxidation
- Citric Acid Cycle
- Cellular Respiration

Metabolism

All the chemical reactions that take place in living cells to break down or build molecules are known as *metabolism.* In a metabolic pathway, reactions are linked together in a series, each catalyzed by a specific enzyme.



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- The term metabolism refers to all the chemical reactions that provide energy and the substances required for continued cell growth.
- There are two types of metabolic reactions: catabolic and anabolic.
- In catabolic reactions, complex molecules are broken down to simpler ones with an accompanying release of energy. Anabolic reactions utilize energy available in the cell to build large molecules from simple ones.

Energy generation and Utilization

- Energy is vital to life : growth, reproduction and tissue repair require energy.

- Most organisms obtain energy by oxidation of these fuel molecules (Carbohydrates, fats and amino acids).

- Synthesis of ATP (also known as bioenergetics) within mitochondria is essential for producing the energy needed for normal cellular processes.

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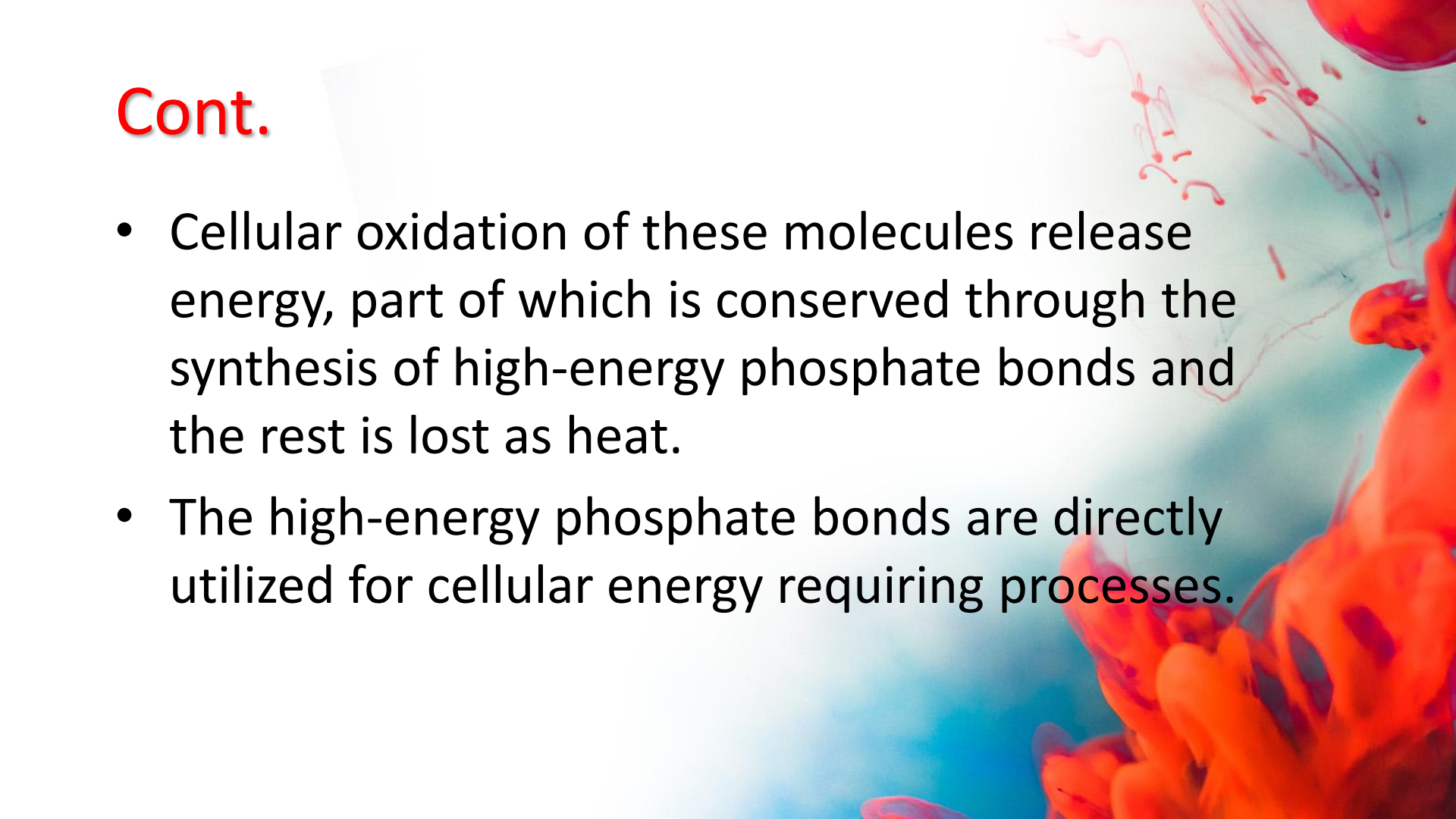
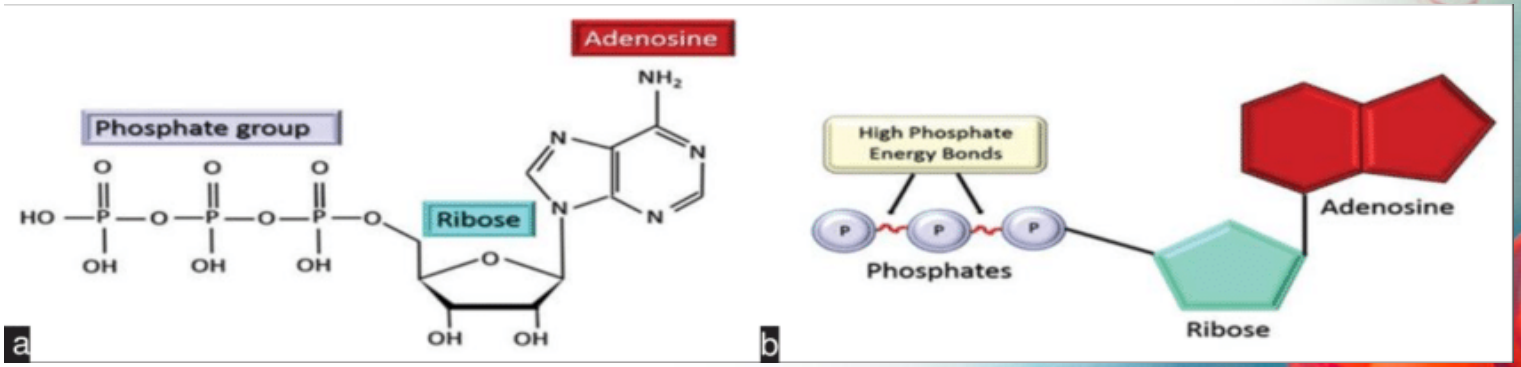
- Cellular oxidation of these molecules release energy, part of which is conserved through the synthesis of high-energy phosphate bonds and the rest is lost as heat.
- The high-energy phosphate bonds are directly utilized for cellular energy requiring processes.



ATP

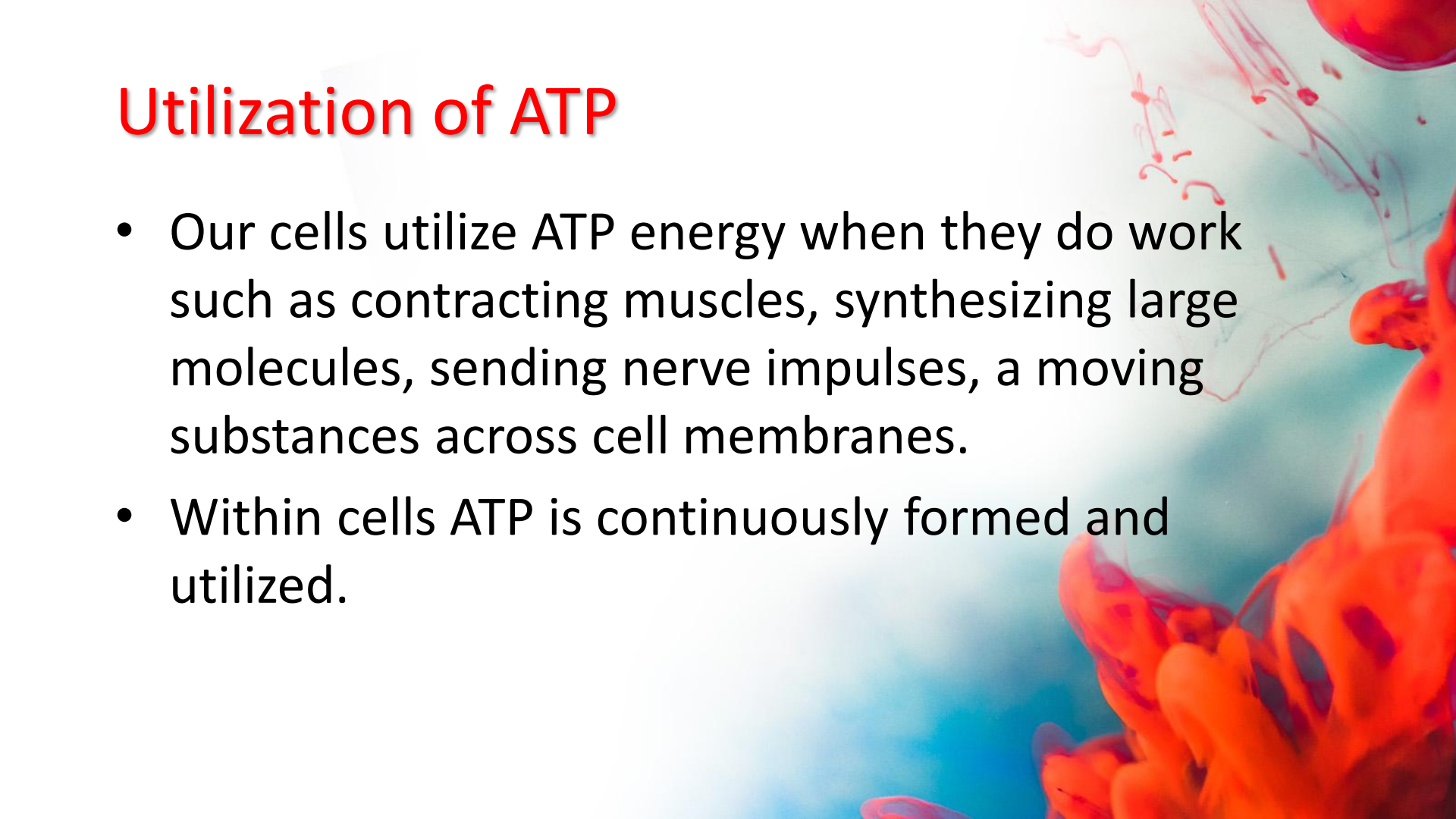
- ATP (Adenosine triphosphate) is the common high-energy phosphate bond that is formed during oxidative processes.
- It is the universal transfer agent of chemical energy between energy-yielding and energy-requiring cellular processes.



(a) Chemical structure of ATP; (b) The ATP molecule is composed of an adenosine ring and a ribose sugar with three phosphate groups. From the high energy bonds among the phosphate group, ATP is produced.

Utilization of ATP

- Our cells utilize ATP energy when they do work such as contracting muscles, synthesizing large molecules, sending nerve impulses, a moving substances across cell membranes.
- Within cells ATP is continuously formed and utilized.



Oxidation of Fuel molecules;

- Serve as the principal immediate donor of free energy in biological system.
- Catabolism of fuel molecules occurs stepwise each step releasing partial energy content of molecules.

The amount of total energy release depends upon the cellular conditions:

I. Presence or absence of oxygen (aerobic or anaerobic)

II. Presence or absence of specific organelles with oxidative functions (mitochondrial)

Biological Oxidation

The utilization of chemical energy in living system involves ***oxidation – reduction*** reactions. For example, the energy of chemical bonds of carbohydrates, lipids and proteins is released and captured in utilization form by processes involving oxidation- reductions.

I- Oxidation

- Removal of electron(s) from substance
- Usually accompanied by a decrease in energy content of oxidized substance

II-Reduction

- Addition of electron(s) to a substance
- Usually accompanied by an increase in energy content of reduced substance

Oxidation reduction reactions are coupled processes, usually occur together and they are frequently reversible .

Biological Oxidation

- Is the process of oxidation of diet in biological systems in the presence of intracellular enzymes .
- In human body the three principal components of the diet [carbohydrates, lipids, and proteins] undergo biologic oxidation in a series of biochemical reactions catalyzed by multiple enzyme systems to produce energy,CO_2 and H_2O .

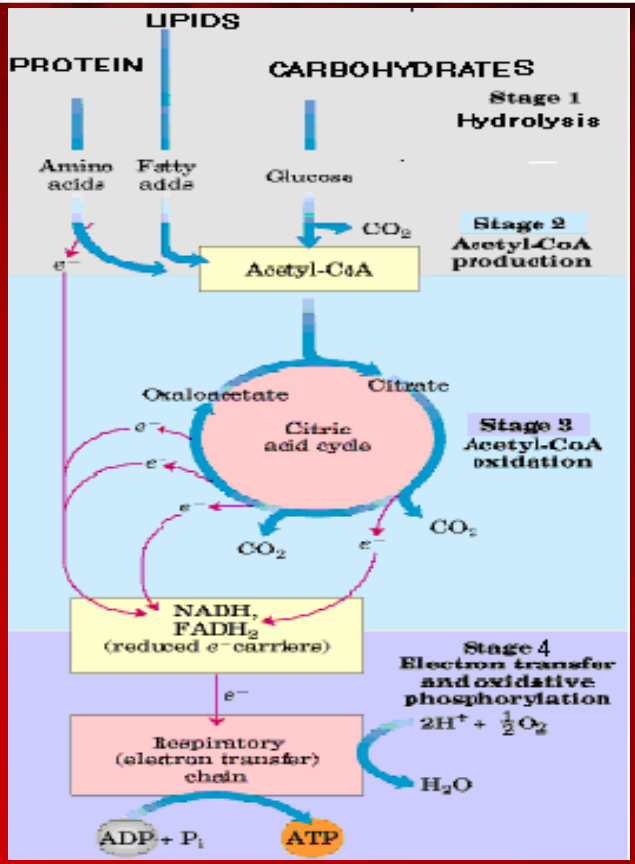
- The overall process of biologic oxidation of [carbohydrates ,lipids and proteins] includes four steps;

1) Hydrolysis of carbohydrates

2) Formation of acetyl CoA

3) TCA cycle

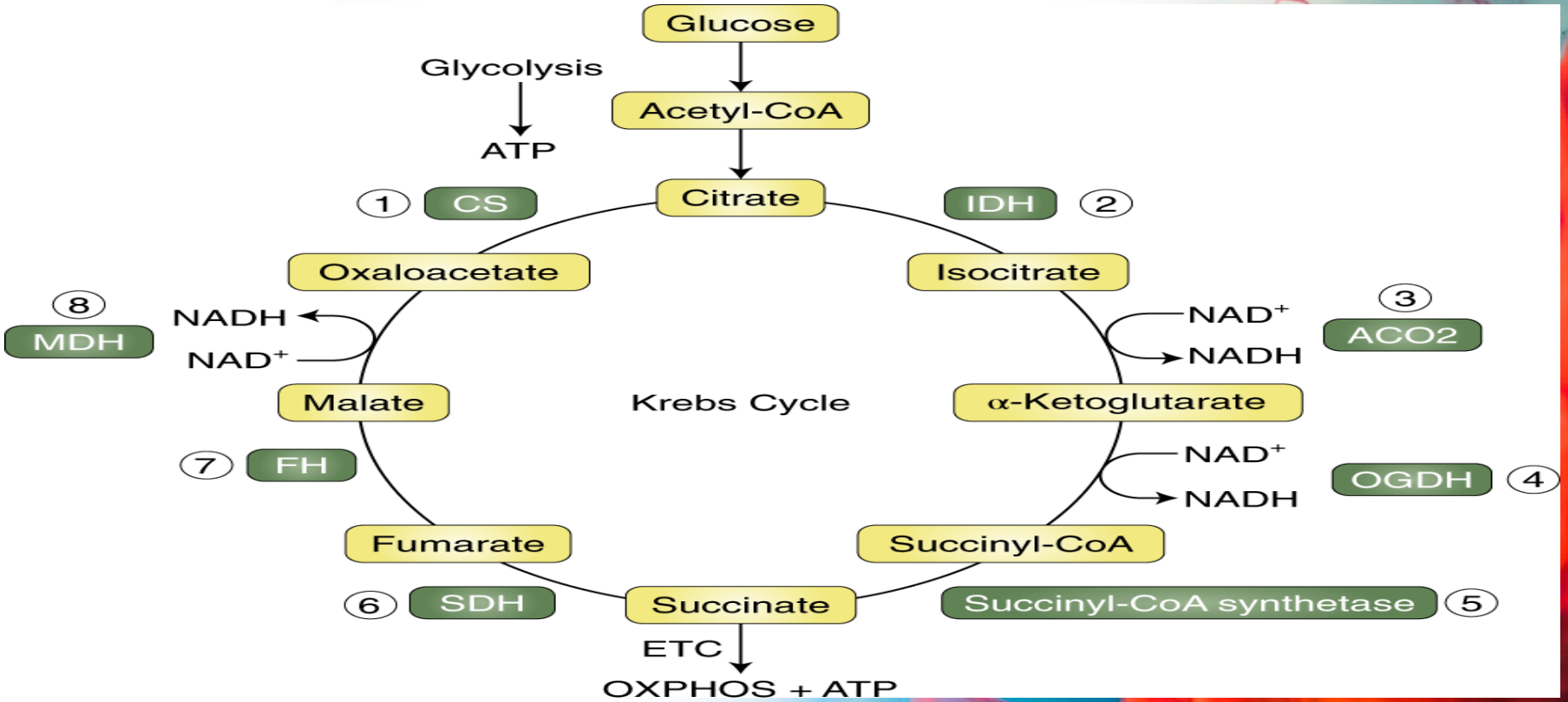
4) Respiratory Chain



TCA Cycle

- ✓ The three-stage process by which living cells break down organic fuel molecules in the presence of oxygen to harvest the energy they need to grow and divide.
- ✓ This metabolic process occurs in most plants, animals, fungi, and many bacteria. In all organisms except bacteria the TCA cycle is carried out in the matrix of intracellular structures called mitochondria.

Kreb's cycle or citric acid cycle or tricarboxylic acid (TCA) cycle:



Cellular Respiration

- Is a series of biochemical reactions within mitochondria that results in ATP production.
- Adenosine triphosphate is generated through a highly organized system embedded within the inner membrane.
- Cellular respiration involves three processes:

  (1) glycolysis;

  (2) the citric acid cycle, also known as the Krebs cycle; and

  (3) the electron transport chain, also referred to as oxidative phosphorylation.

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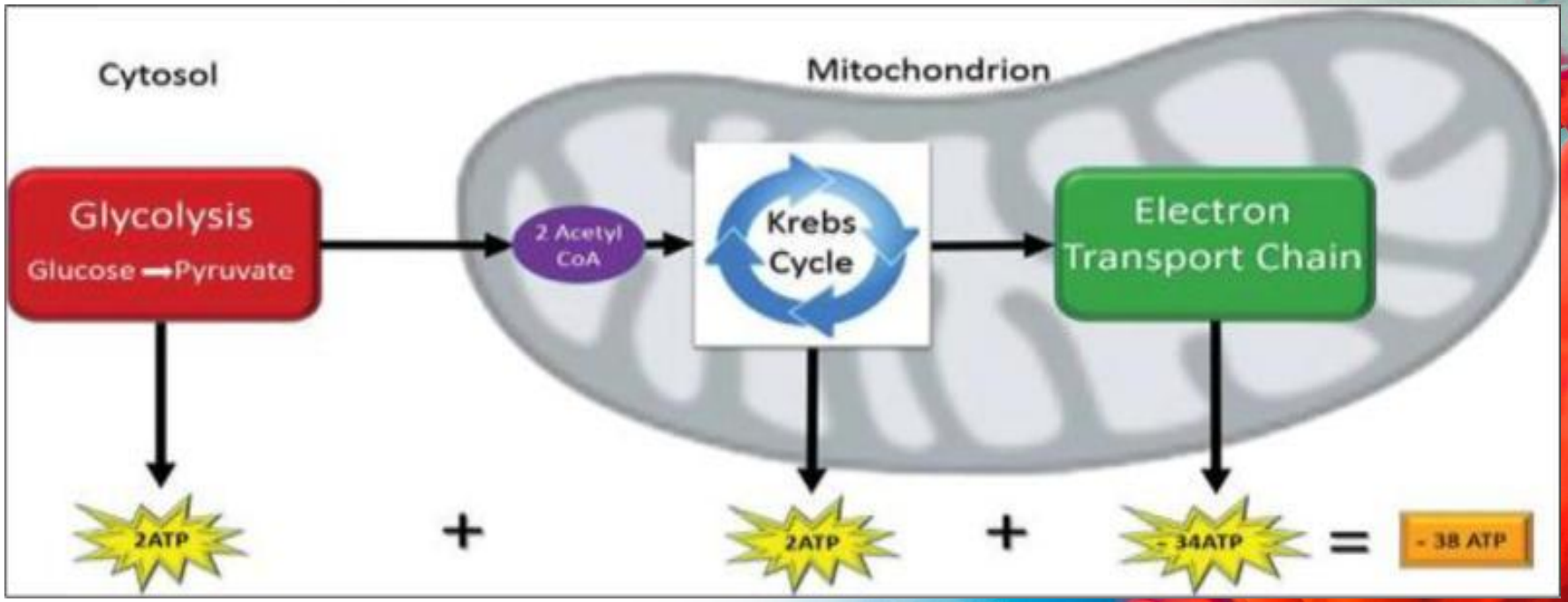
- Glycolysis is the anaerobic pathway within the cell cytoplasm in which glucose, a six carbon sugar, is converted into two molecules made of three carbons called pyruvate.

- From this pathway, one glucose molecule yields two ATP molecules.

- Following glycolysis, pyruvate enters the mitochondrion, and enzymatic systems in the mitochondrial matrix convert pyruvate into two carbon molecules called acetyl-CoA.

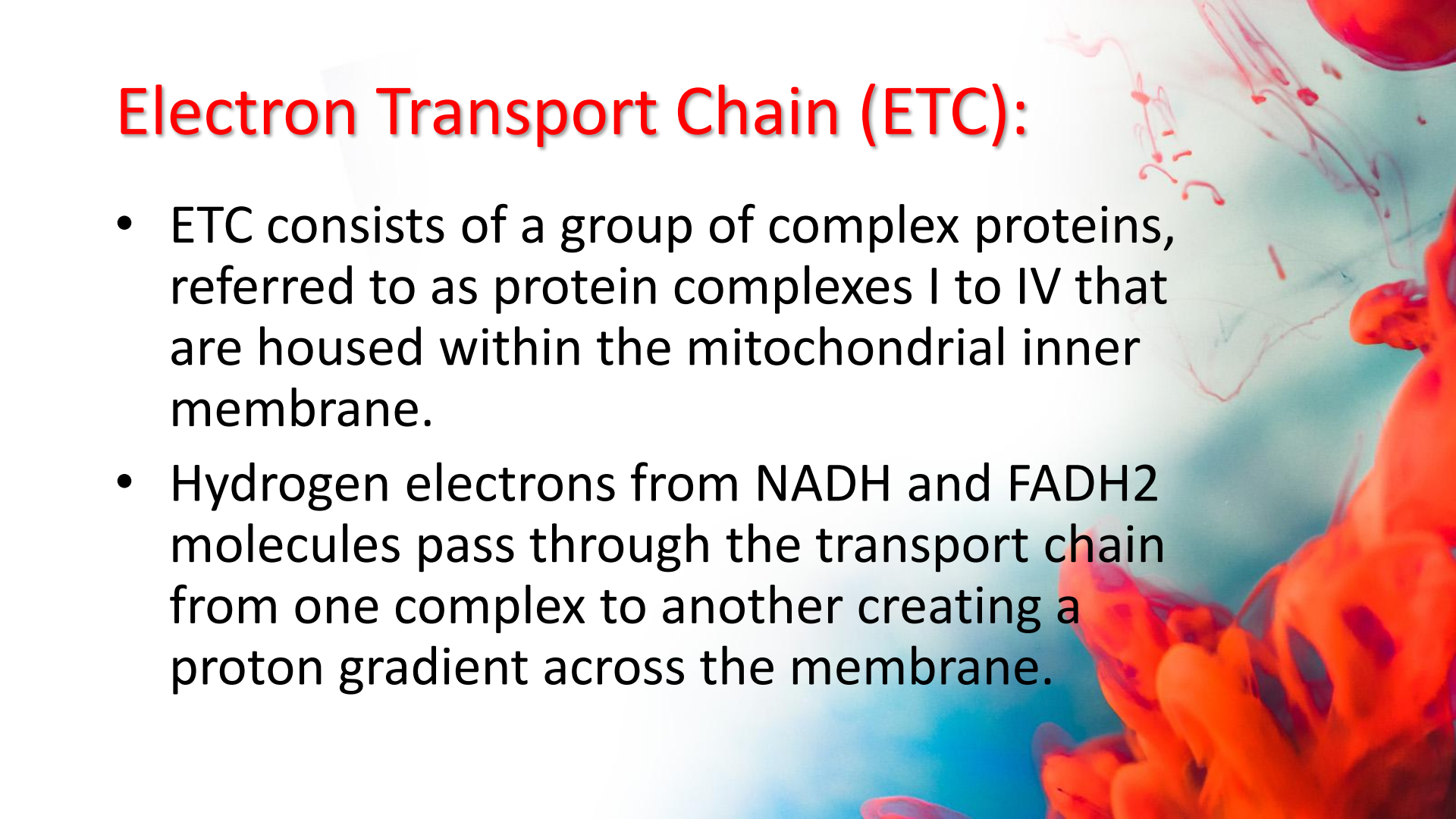
- Acetyl-CoA then enters the citric acid cycle and undergoes a series of biochemical reactions with enzymes that yield carbon dioxide and electron carrier molecules known as nicotinamide adenine dinucleotide (NADH) and flavinadenine dinucleotide (FADH2).
- There are two additional ATP molecules produced for each glucose molecule undergoing glycolysis.
- The majority of ATP is generated from the last phase of cellular respiration, an aerobic pathway known as the electron transport chain.

The stages of cellular respiration:



Electron Transport Chain (ETC):

- ETC consists of a group of complex proteins, referred to as protein complexes I to IV that are housed within the mitochondrial inner membrane.
- Hydrogen electrons from NADH and FADH2 molecules pass through the transport chain from one complex to another creating a proton gradient across the membrane.



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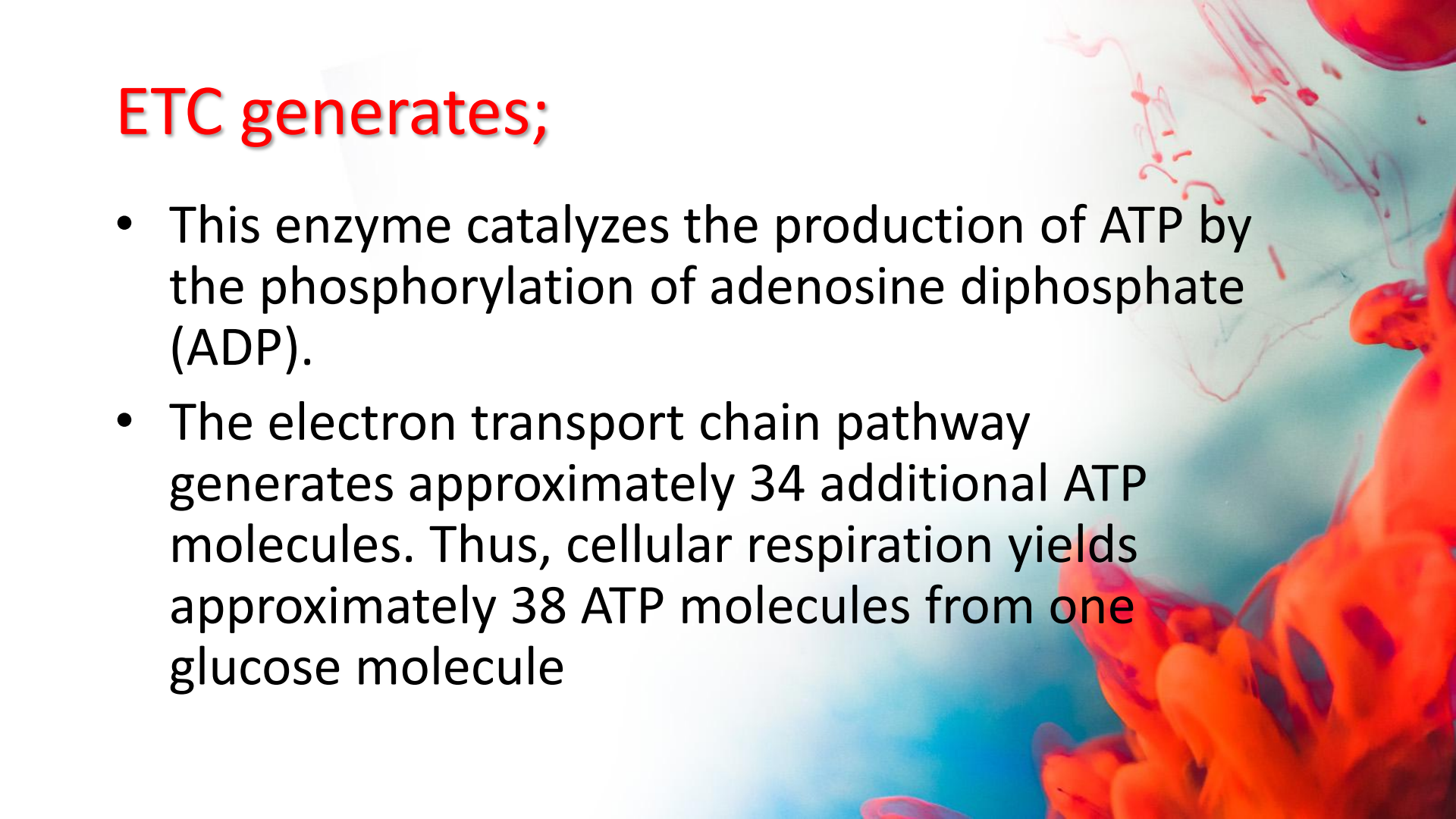
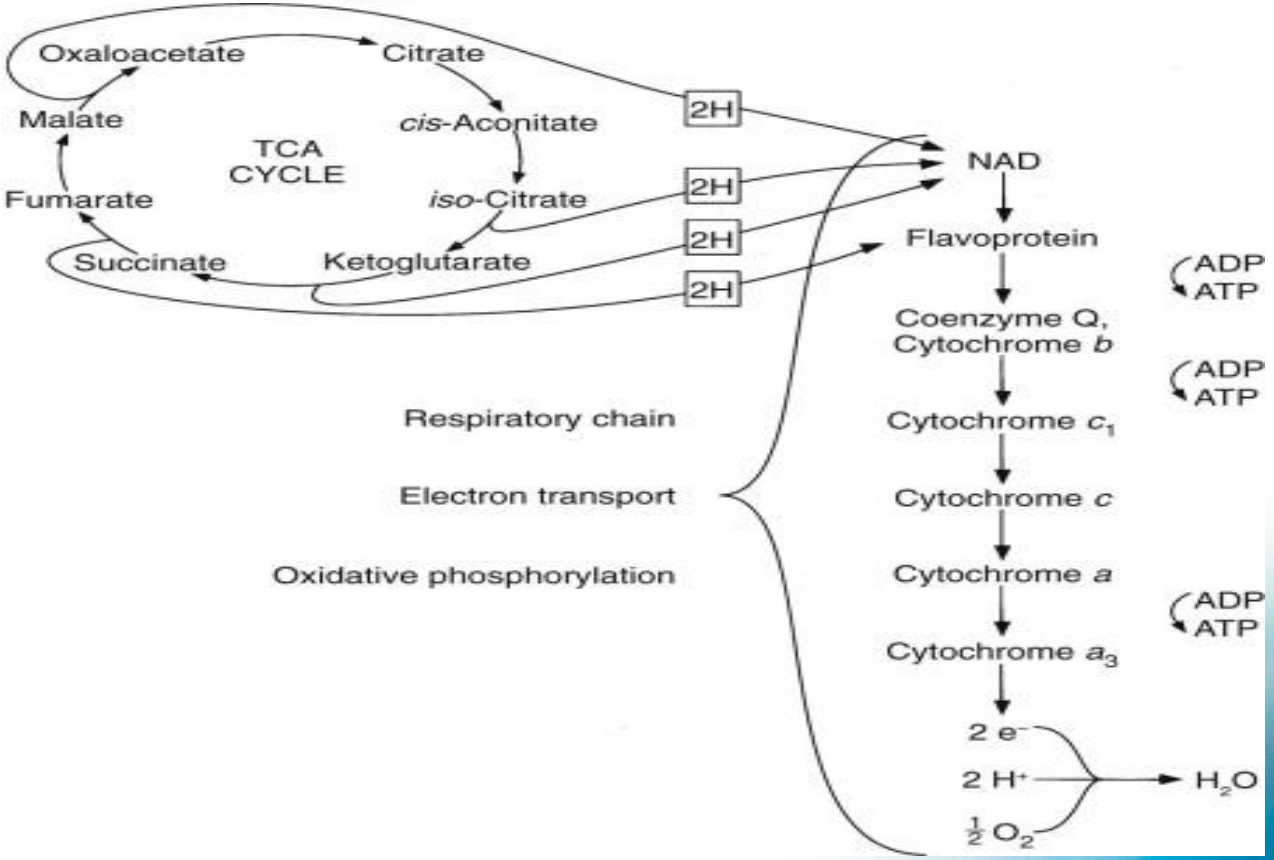
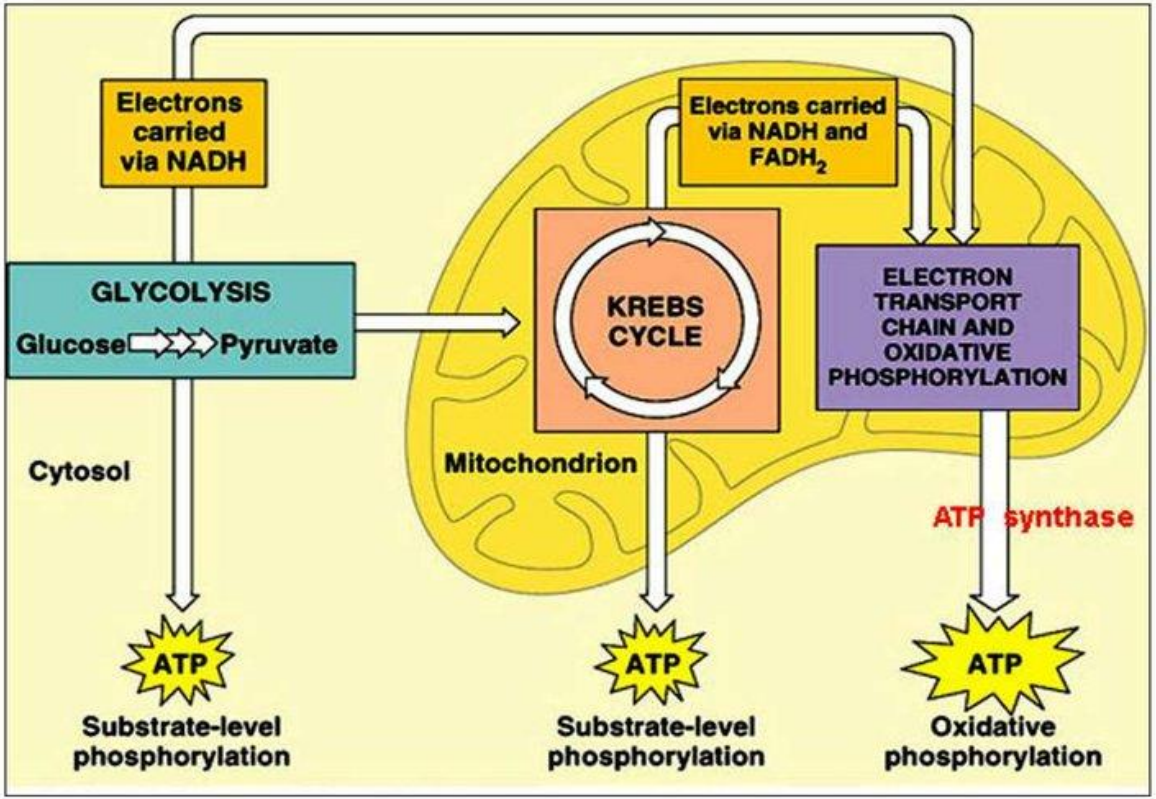
- Energy transfer from electrons is used to pump protons across the membrane space throughout the entire cristae surface.
- Once the concentration gradient of electrons becomes higher in the membrane space, protons migrate to the area of lower concentration in the mitochondrial matrix via an enzyme known as ATP synthase

ETC generates;

- This enzyme catalyzes the production of ATP by the phosphorylation of adenosine diphosphate (ADP).
- The electron transport chain pathway generates approximately 34 additional ATP molecules. Thus, cellular respiration yields approximately 38 ATP molecules from one glucose molecule




Oxaloacetate
Citrate
Malate
cis-Aconitate
TCA CYCLE
Fumarate
iso-Citrate
Succinate
Ketoglutarate
2H
2H
2H
2H
NAD
Flavoprotein
Coenzyme Q, Cytochrome b
Cytochrome c_1
Cytochrome c
Cytochrome a
Cytochrome a_3
ADP ATP
ADP ATP
ADP ATP
Respiratory chain
Electron transport
Oxidative phosphorylation
2 e^-
2 H^+
$\frac{1}{2}$ O_2
H_2O


Electrons carried via NADH
Electrons carried via NADH and $FADH_2$
GLYCOLYSIS
Glucose
Pyruvate
KREBS CYCLE
ELECTRON TRANSPORT CHAIN AND OXIDATIVE PHOSPHORYLATION
Cytosol
Mitochondrion
ATP synthase
ATP
Substrate-level phosphorylation
ATP
Substrate-level phosphorylation
ATP
Oxidative phosphorylation

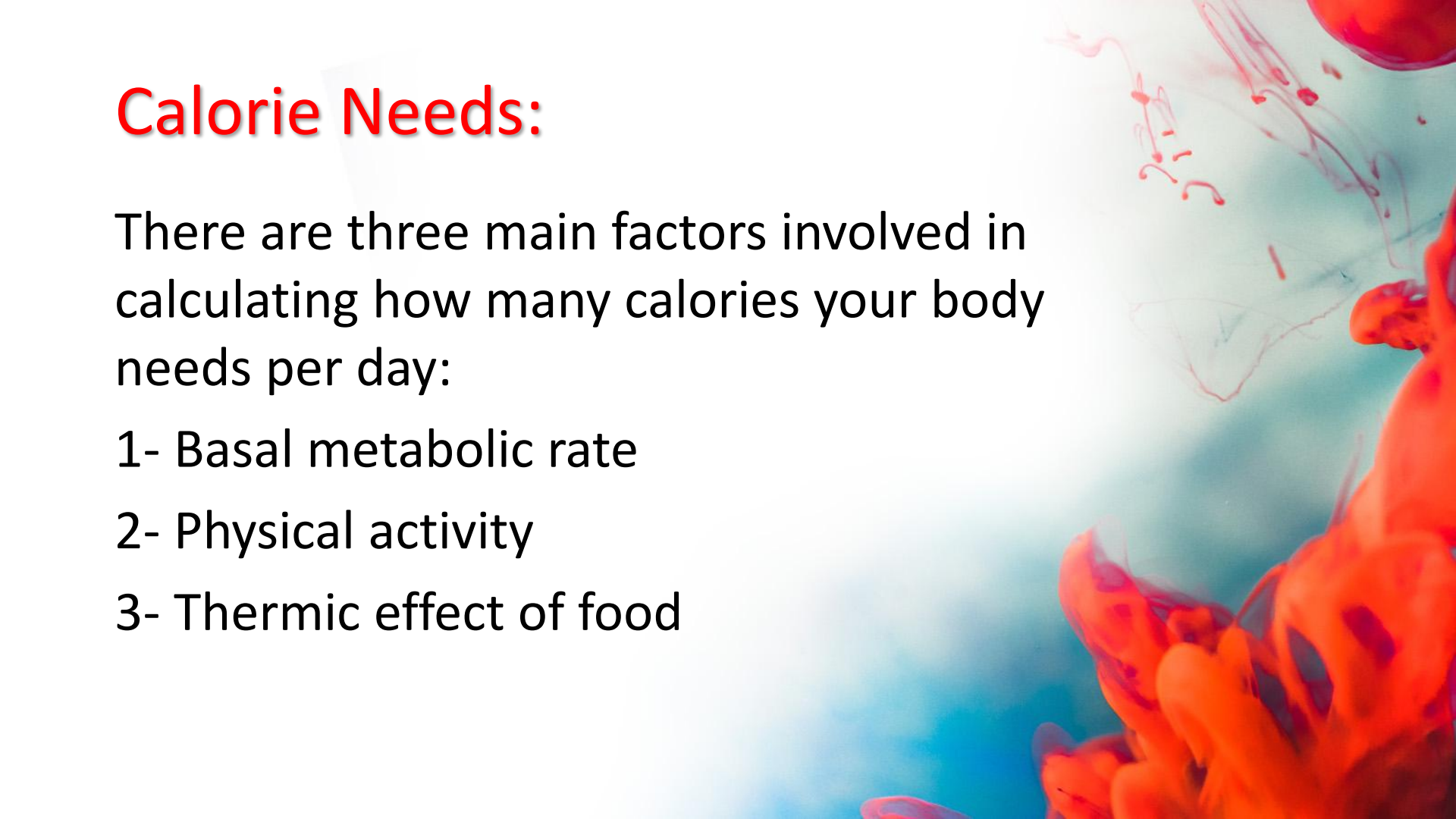
Calorie Needs:

There are three main factors involved in calculating how many calories your body needs per day:

1- Basal metabolic rate

2- Physical activity

3- Thermic effect of food

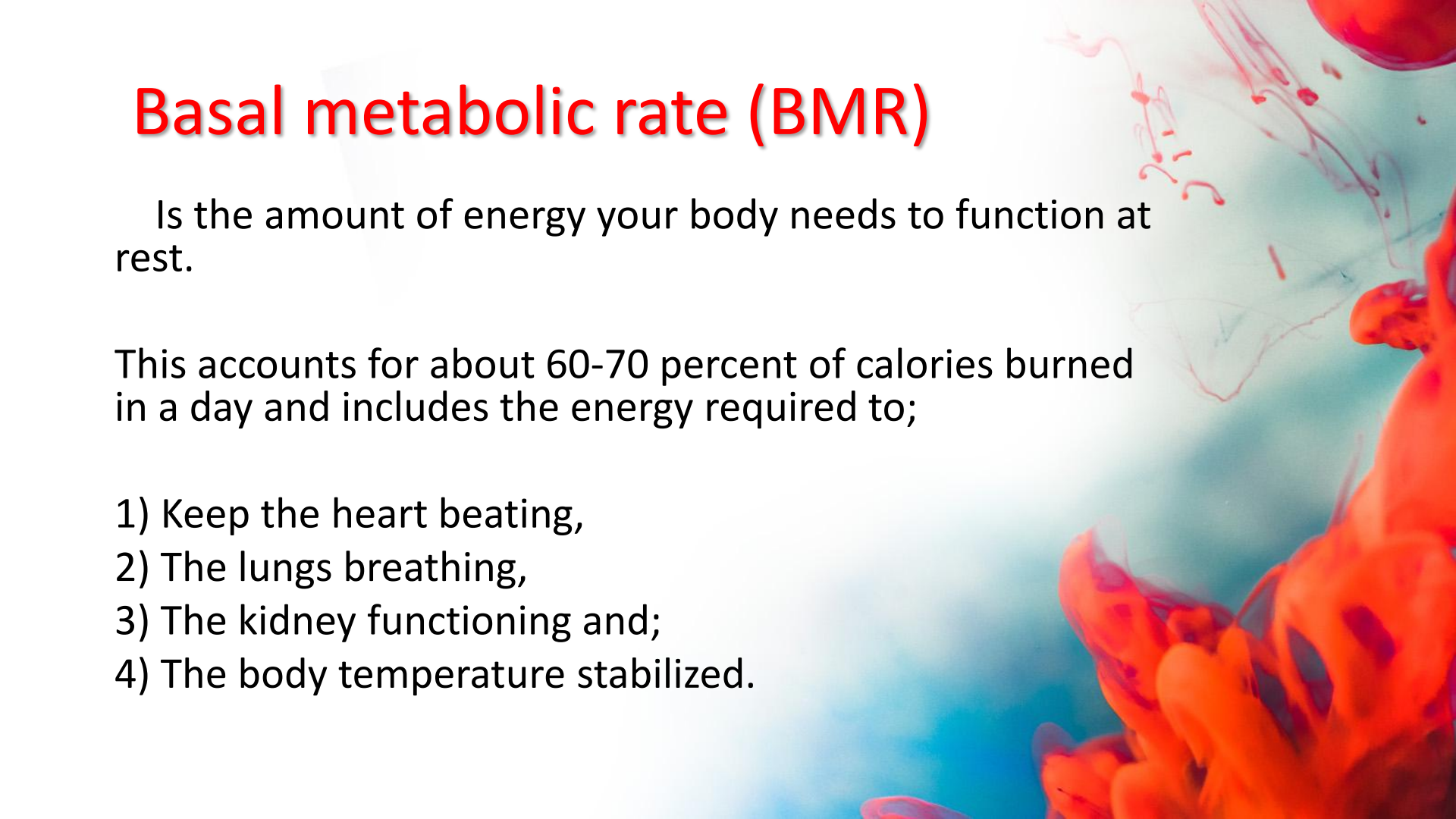


Basal metabolic rate (BMR)

Is the amount of energy your body needs to function at rest.

This accounts for about 60-70 percent of calories burned in a day and includes the energy required to;

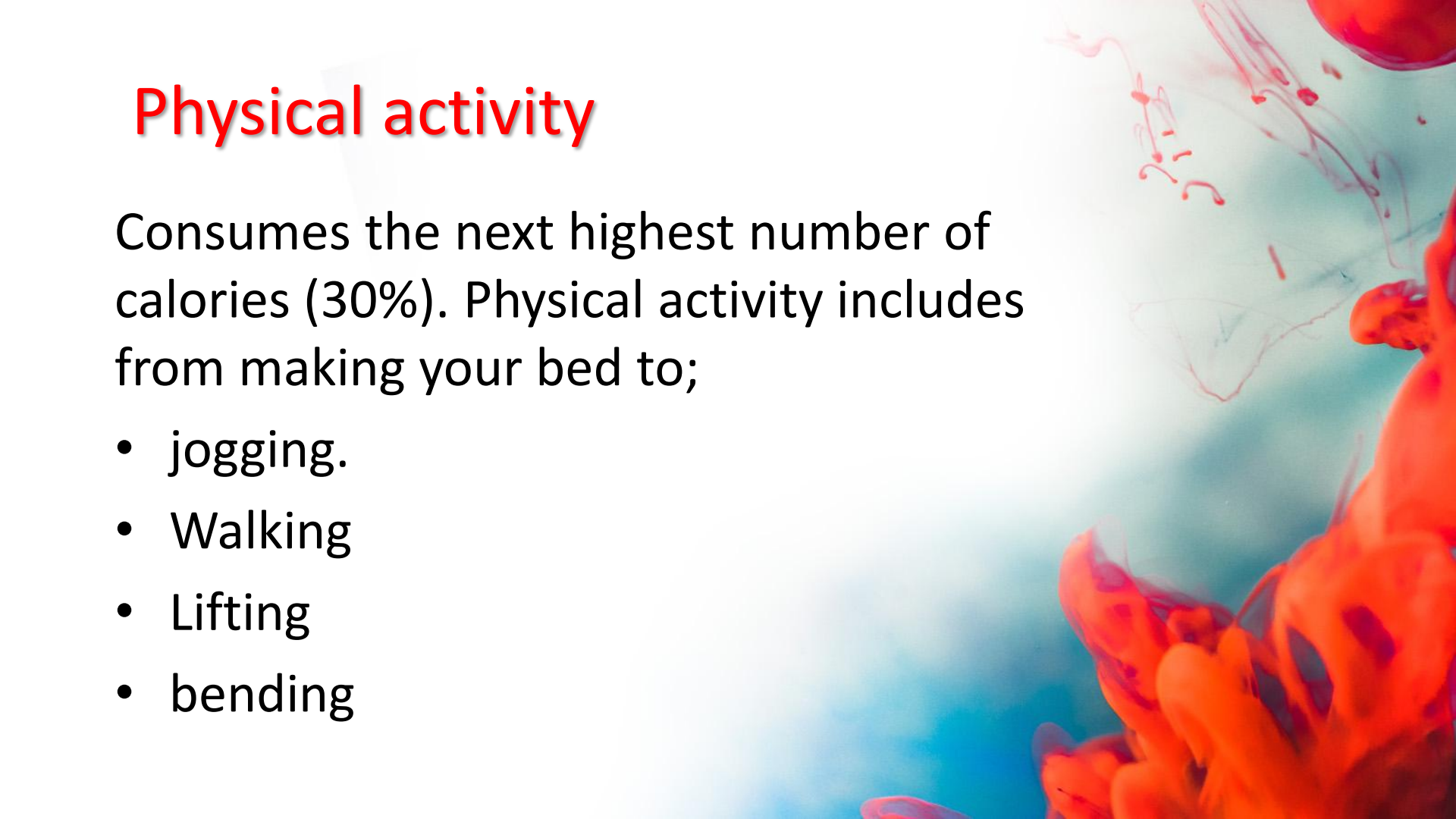
1) Keep the heart beating,
2) The lungs breathing,
3) The kidney functioning and;
4) The body temperature stabilized.



Physical activity

Consumes the next highest number of calories (30%). Physical activity includes from making your bed to;

- jogging.
- Walking
- Lifting
- bending



Thermic effect of food

The amount of energy your body uses to digest the food you eat (10%) .

Figure-1- **Metabolic Pathways and Energy Production**