

Introduction to Exercise Physiology

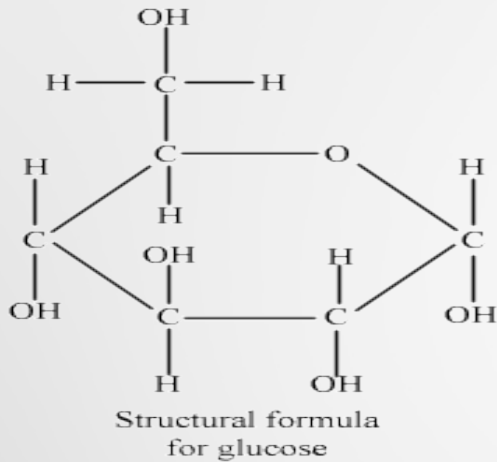
- Energy Systems



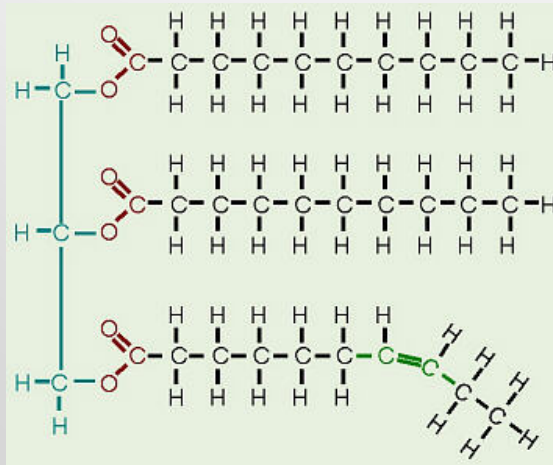
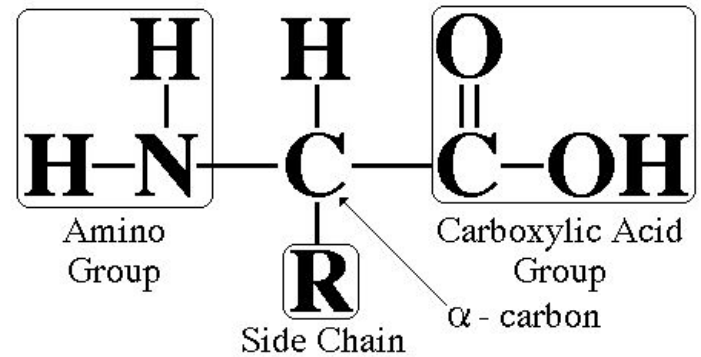
Learning Objectives

- Understand the terms associated with energy systems
- Be aware of the processes involved in aerobic respiration and anaerobic respiration at a cellular level
- To know how glucose is used to produce energy and how much energy is produced through a glucose molecule

Energy Metabolism

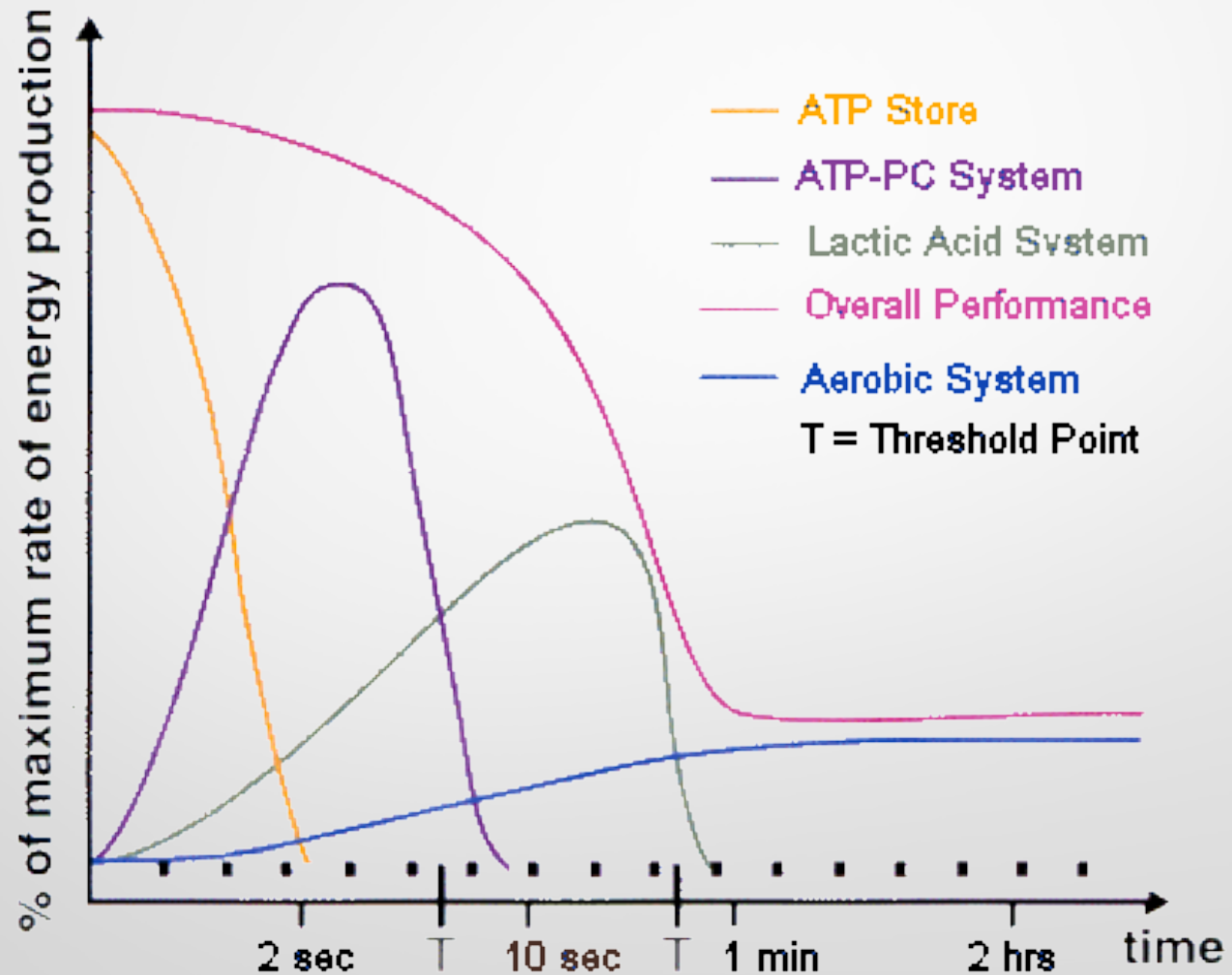


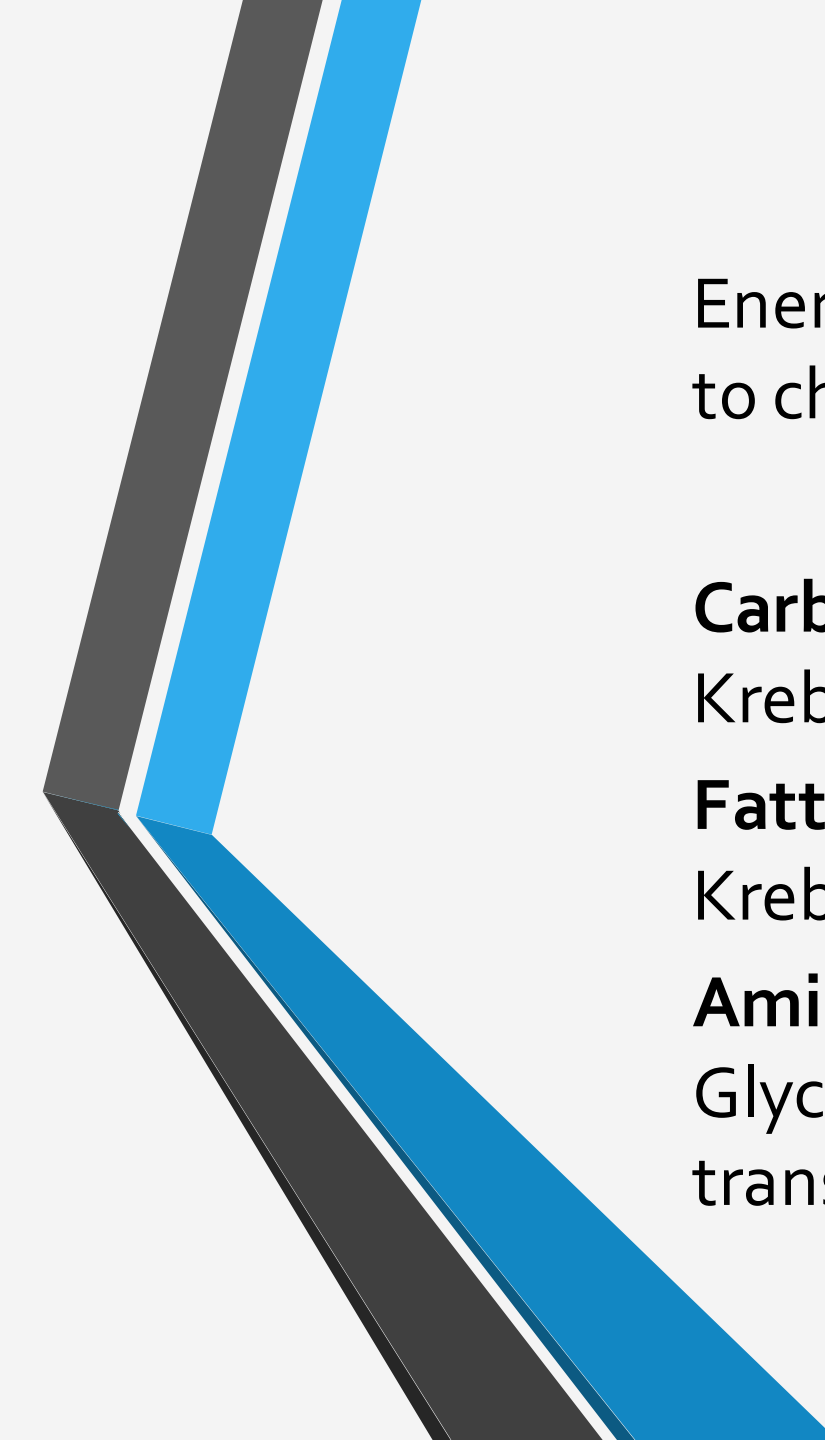
Amino Acid Structure



Stearic acid

Energy Requirements during exercise





Energy Systems

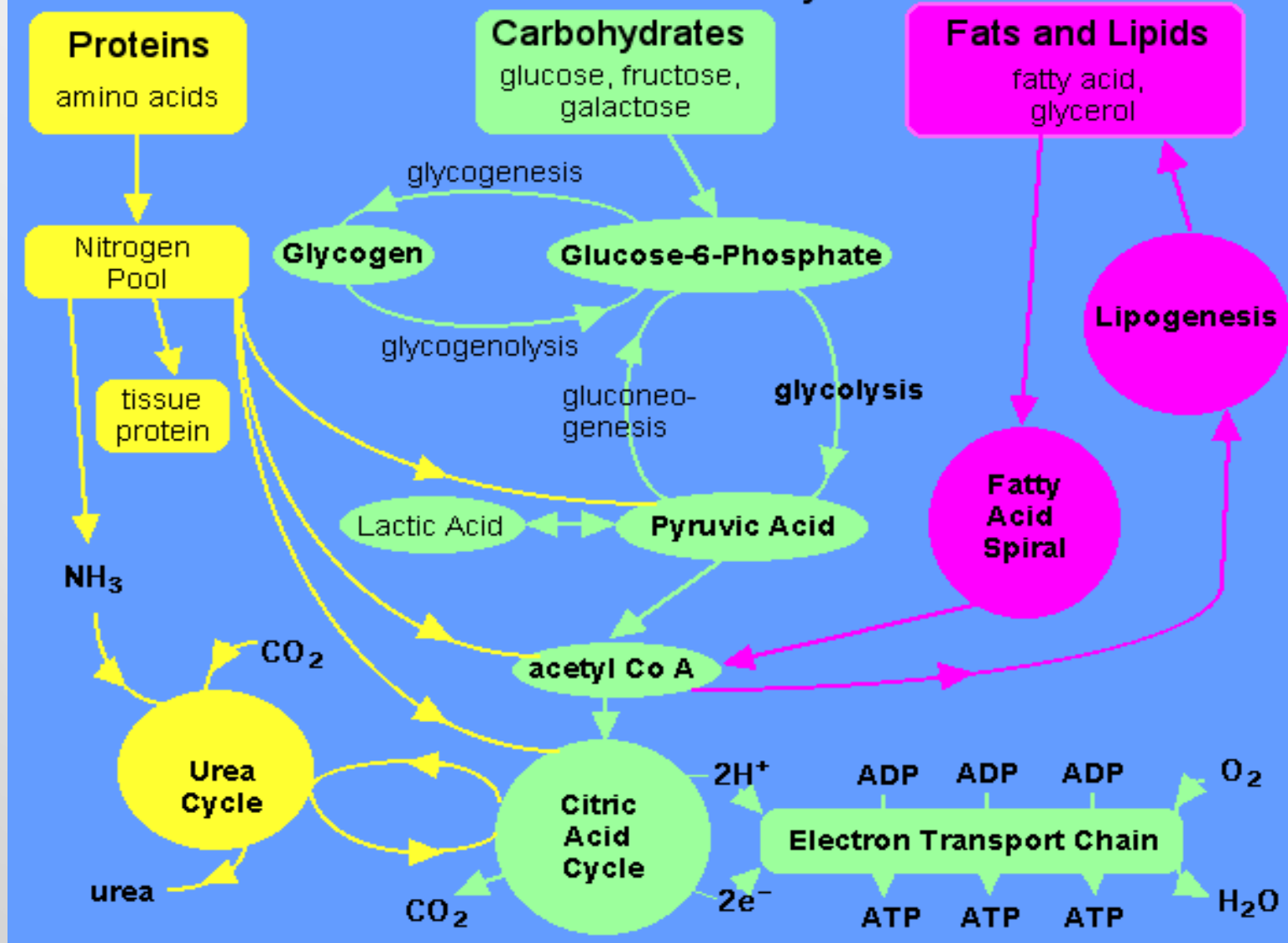
Energy stored in food converted to chemical energy stored in ATP.

Carbohydrates – Glycolysis,
Kreb's Cycle, Electron transport.

Fatty acids – beta oxidation,
Kreb's Cycle, Electron transport.

Amino acids – deamination,
Glycolysis, Kreb's Cycle, Electron transport.

Metabolism Summary

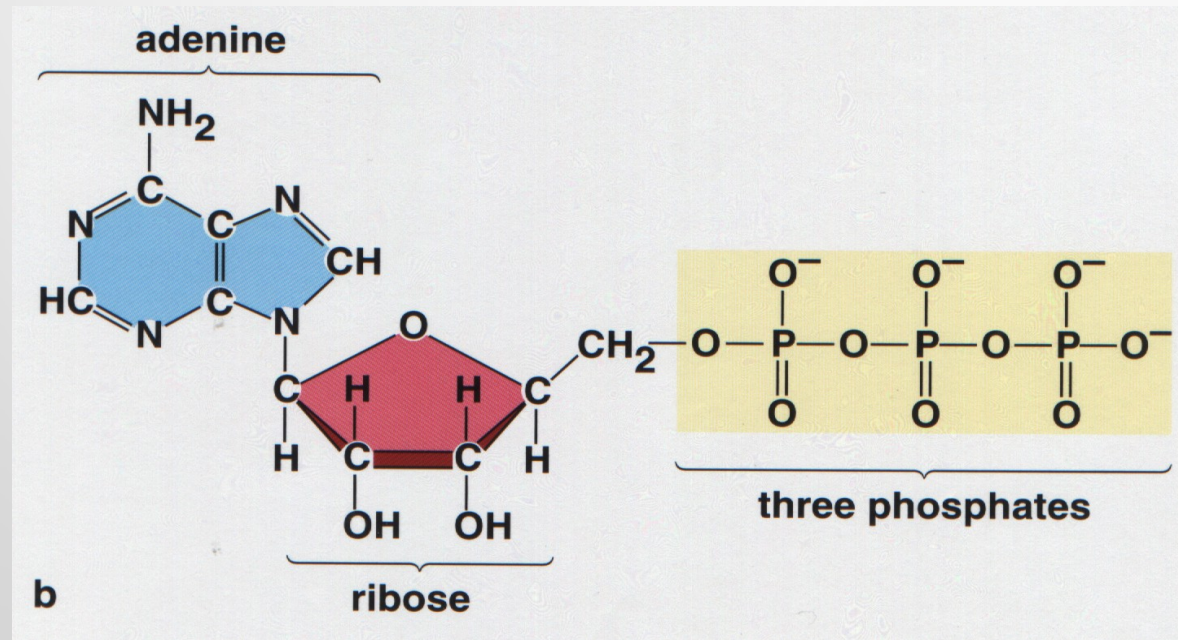


Terminology

- ATP
- ADP
- NAD
- FAD
- PCr
- Cytochrome
- Creatine kinase
- phosphofructokinase
- Glycolysis
- Krebs Cycle
- Electron transport
- Beta oxidation
- Cori Cycle
- Deamination
- Cytochrome oxidase

ATP

ATP - Adenosine Triphosphate



Aerobic V Anaerobic

- Anaerobic – no oxygen involved
- Aerobic - involves oxygen

Both systems convert the energy stored in food to chemical energy stored in adenosine triphosphate at a rate required to maintain activity.

Aerobic V Anaerobic



Anaerobic ATP synthesis

Anaerobic ATP synthesis does not involve oxygen.

ATP

Phosphocreatine

Glycolysis

ATP Stores

- Approx. 1 second worth of maximal effort stored as ATP.

$\text{ATP} \longrightarrow \text{ADP} + \text{P} + \text{Energy (muscle contraction)}$

- Phosphate and adenosine diphosphate rephosphorylated aerobically.

$\text{ADP} + \text{P} + \text{Energy (food, PCr)} \longrightarrow \text{ATP}$

“Anaerobic” Glycolysis

Anaerobic Glycolysis or Lactic Acid Cycle

Glucose $\longrightarrow$ Lactic acid + 2 ATP

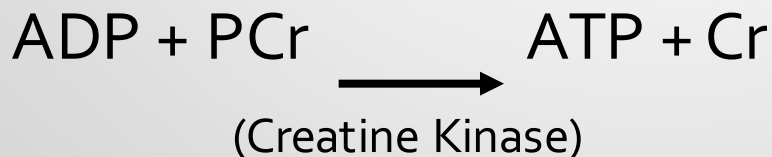
Glycogen $\longrightarrow$ Lactic Acid + 3 ATP

ATP / PCr

- ATP stores last for about 1 second
- Resynthesis from P.Cr. lasts 6-10 seconds
- Anaerobic glycolysis and subsequent formation of lactic acid can sustain maximal effort for about 40 seconds then lactate accumulation affect performance

Creatine Phosphate

- 6-10 seconds worth of maximal energy store in this form.
- Phosphate taken from creatine to rephosphorylate ADP under the control of creatine kinase.

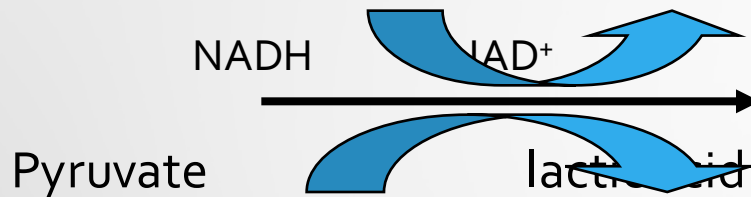


- Creatine rephosphorylated using aerobic energy

Glycolysis

- Occurs in cytoplasm of cell
- 3 ATP formed from 1 glucose molecule
- Only glucose / glycogen used
- Fast so near maximal effort sustained
- Limited supply lasting about 40 seconds
- 200m - 400m sprints
- Lactic acid as end product
 - Used by skeletal, cardiac muscles, kidneys, gluconeogenesis
 - 65% of lactic acid is converted to carbon dioxide and water, 20% into glycogen, 10% into protein and 5% into glucose.

Pyruvate to lactic acid



lactate dehydrogenase

- Transported out of the cell by assisted diffusion i.e. bound to a protein carrier.
- Used by cardiac muscles, kidneys, gluconeogenesis
- 65% of lactic acid is converted to carbon dioxide and water, 20% into glycogen, 10% into protein and 5% into glucose.

Lactic Acid

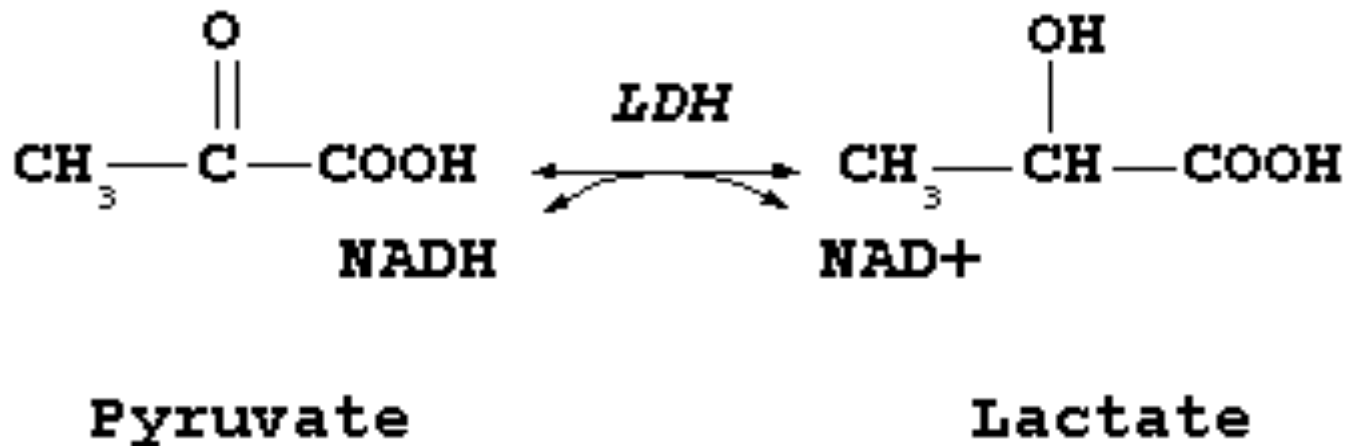
- The lactic acid system is capable of releasing energy to resynthesise ATP without the involvement of oxygen and is called anaerobic glycolysis.
- Glycolysis (breakdown of carbohydrates) results in the formation of pyruvic acid and hydrogens ions (H^+).
- A build up of H^+ will make the muscle cells acidic and interfere with their operation so carrier molecules, called nicotinamide adenine dinucleotide (NAD^+), remove the H^+ .

Lactic Acid

- The NAD^+ is reduced to NADH which deposit the H^+ at the electron transport gate (ETC) in the mitochondria to be combined with oxygen to form water (H_2O).
- If there is insufficient oxygen then NADH cannot release the H^+ and they build up in the cell. To prevent the rise in acidity pyruvic acid accepts H^+ forming lactic acid which then dissociates into lactate and H^+ . Some of the lactate diffuses into the blood stream and takes some H^+ with it as a way of reducing the H^+ concentration in the muscle cell.

Formation of Lactic acid

- The formation of Lactic acid is controlled by the enzyme lactate dehydrogenase.
- This combines the hydrogen from an NADH_2 with the pyruvate from the end of glycolysis and forms lactic acid.
- The LA subsequently dissociates a hydrogen forming lactate



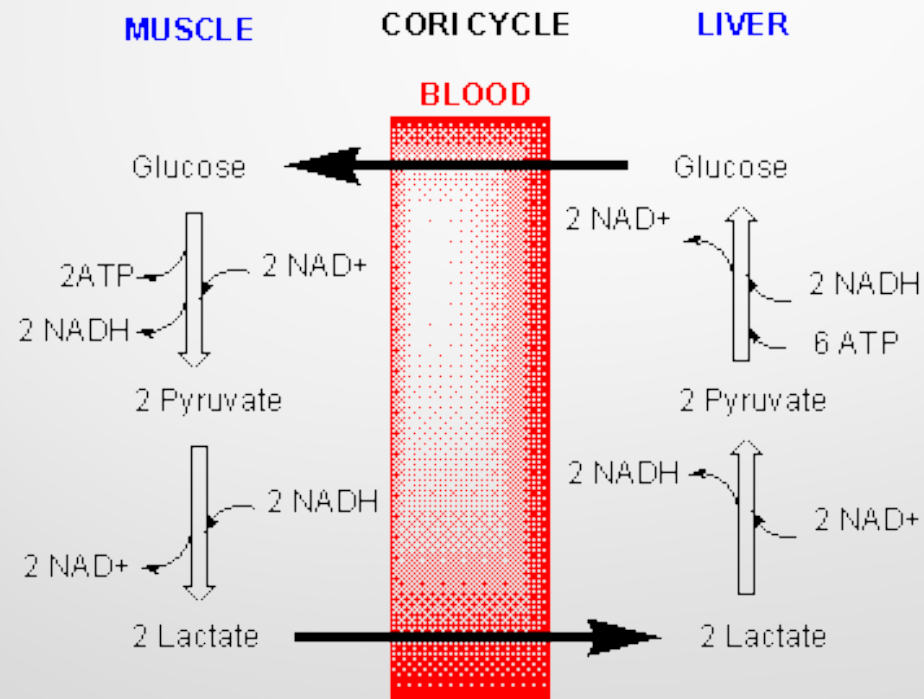
Fate of Lactate

- Cori Cycle
- Lactate shuttle

Lactate Shuttle

- Lactate enters the surrounding muscle cells, tissue and blood
- The muscle cells and tissues receiving the lactate either breakdown the lactate to fuel (ATP) for immediate use or use it in the creation of glycogen
- The glycogen then remains in the cells until energy is required
- 65% of lactic acid is converted to carbon dioxide and water, 20% into glycogen, 10% into protein and 5% into glucose.

Cori Cycle

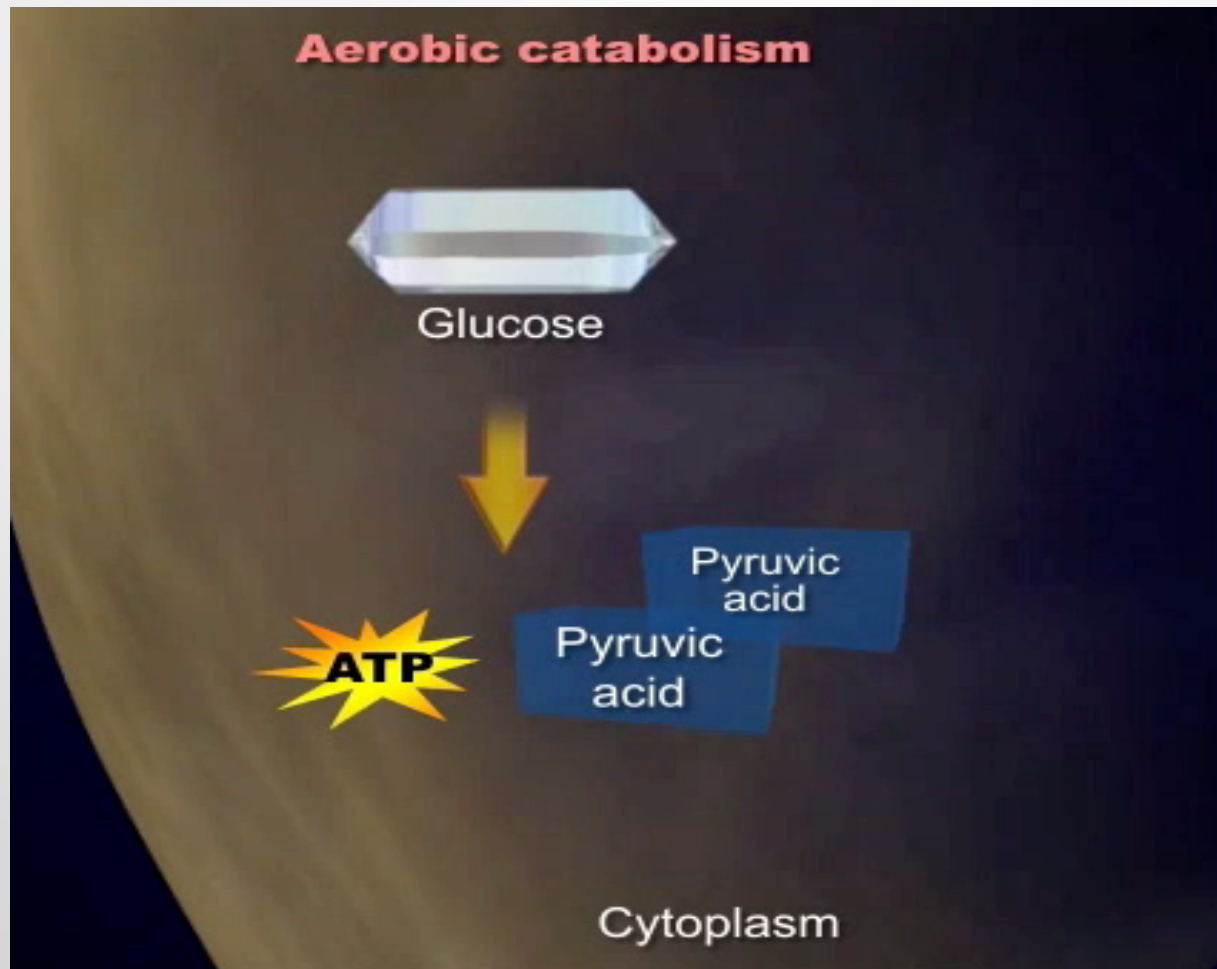


Anaerobic Metabolism of Carbohydrate

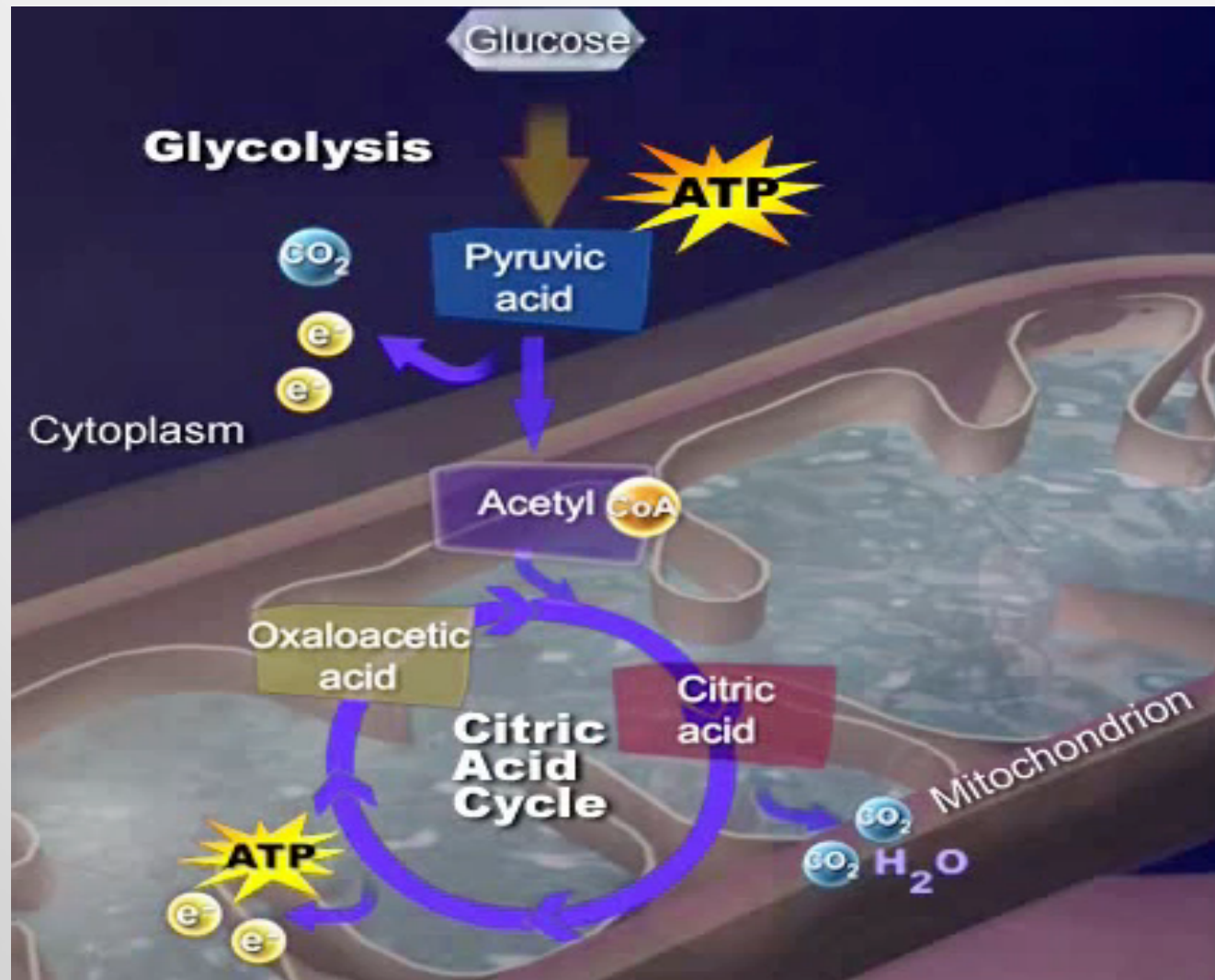
- Equation 1 – Aerobic metabolism of glucose



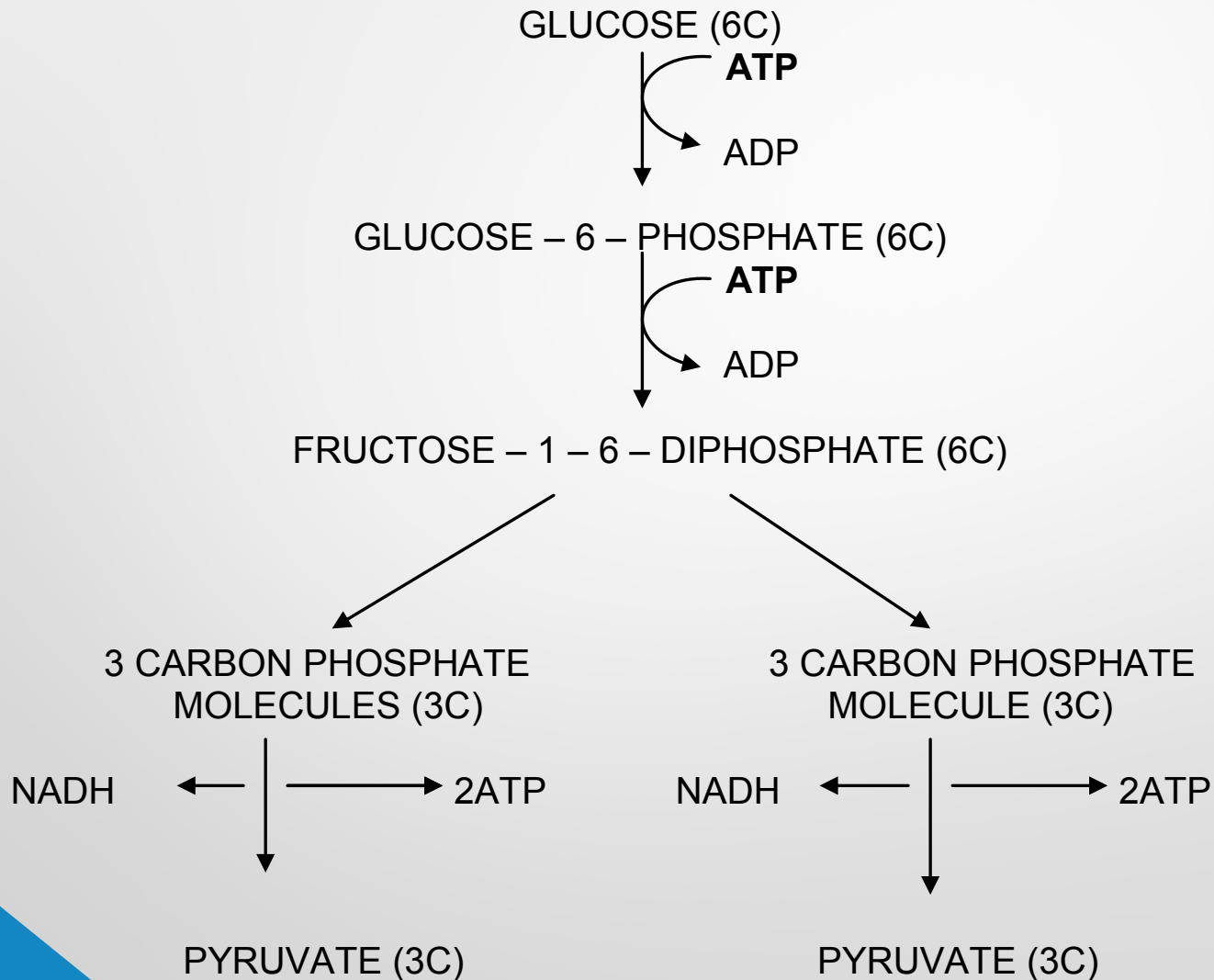
TCA or Krebs Cycle



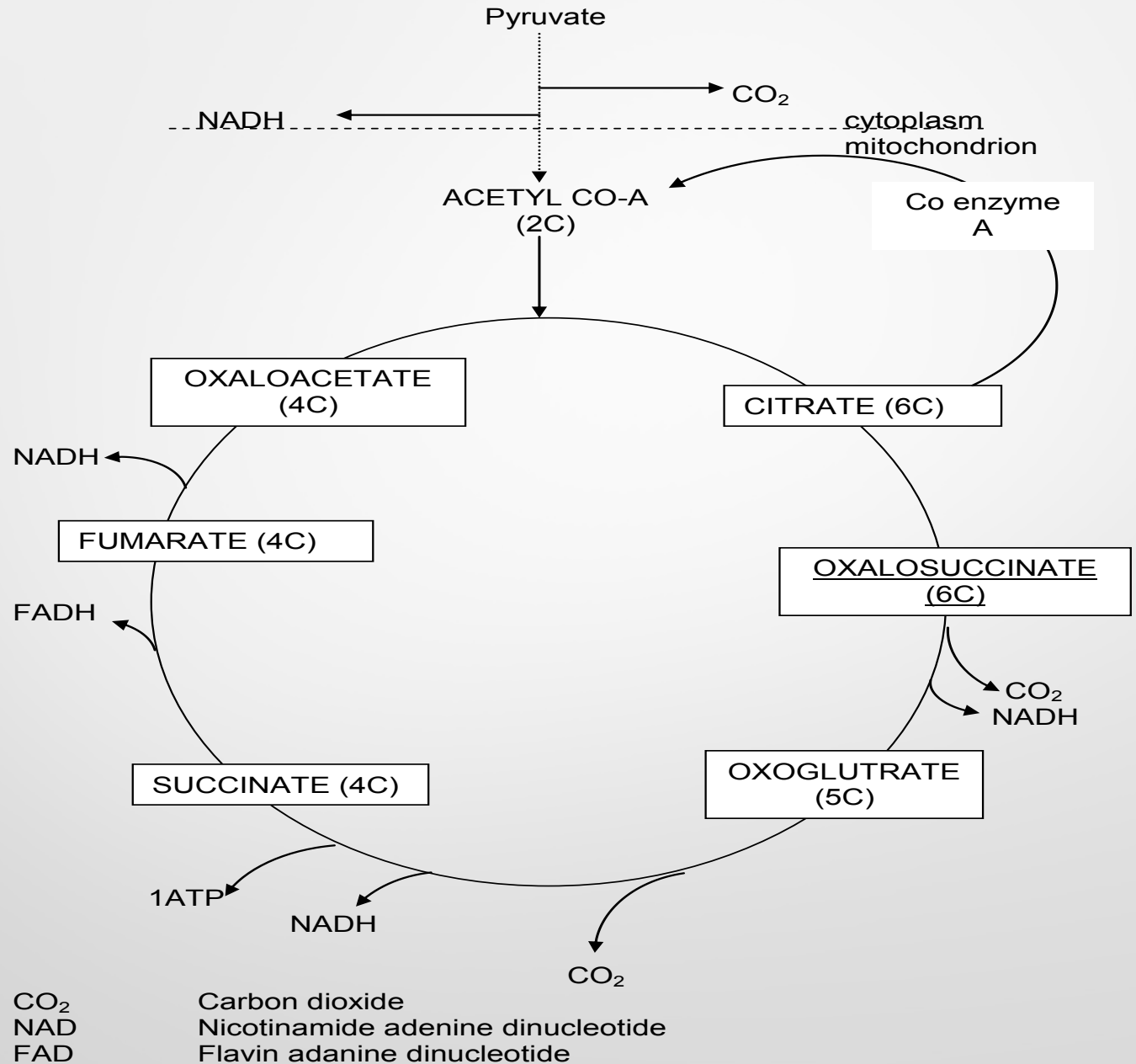
Electron Transport Chain



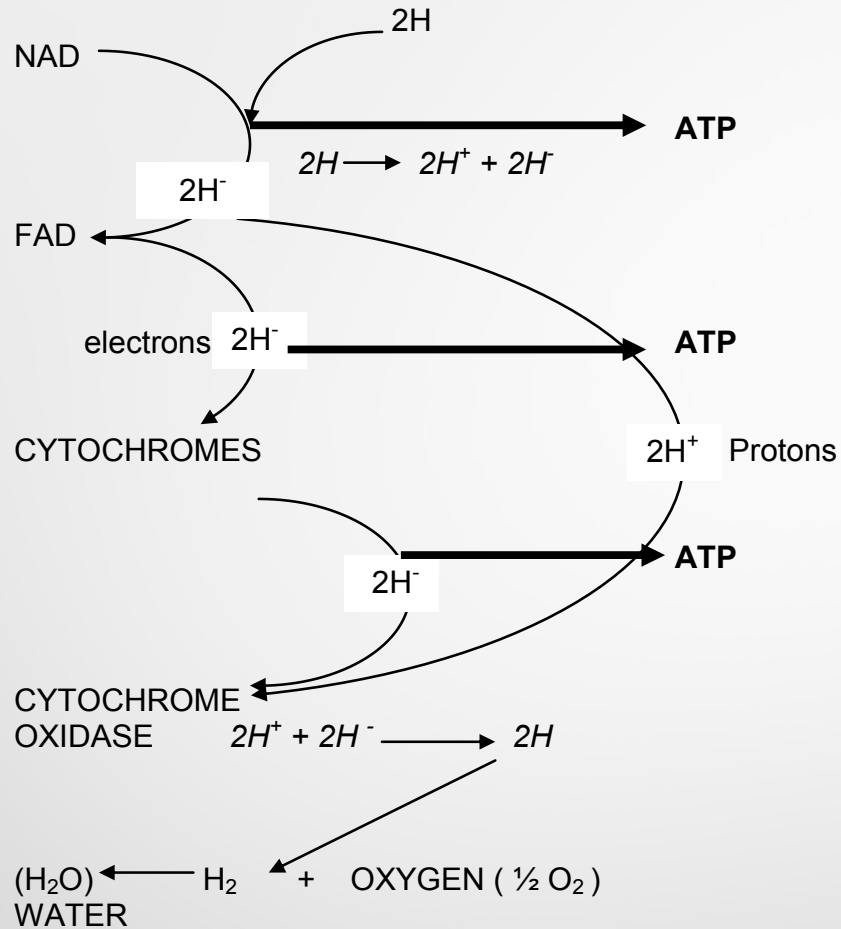
Simplified Glycolysis



Simplified Krebs Cycle



Simplified Electron Transport



Each NADH molecule synthesises 3 ATP whilst FADH results in 2 ATP

Task

Draw out the Energy Pathways on A3 paper?

Show for each molecule of glucose how much ATP can be produced?

Resources

<https://www.youtube.com/watch?v=q-fKQuZ8dco>

https://www.youtube.com/watch?v=_zR5BaeJd3k

Moof University youtube