enzyme-driven reactions

break down food to produce energy (catabolism), stored as ATP & electron carriers: NADH, NADPH2, FADH2

build up from biomolecules (anabolism), requiring energy in form of phosphoryl group transfer from ATP & reducing power of NADH & NADPH

eliminate waste

grow & reproduce, maintain structures & respond to environment

drive desirable energy-requiring reactions by coupling them to spontaneous energy-releasing reactions

glycolysis

cytoplasm

1. phosphate group transferred from ATP to glucose-6-phosphate. Catalysed by hexokinase. 1 molecule of ATP used

2. Glucose-6-phosphate converted to isomer fructose-6-phosphate by phosphoglucose isomerase enzyme

3. second ATP molecule used to phosphorylate fructose-6-phosphate to produce fructose-1,6-bisphosphate. catalysed by phosphofructokinase.

4. fructose 1,6-bisphosphate is split into 2x 3C sugars by adolase. these are glyceraldehyde-3-phosphate & dihydroxyacetone phosphate

5. DHAP converted to GAP by triose phosphate isomerase

6. G3P dehydrogenase enzyme catalyses two processes: it oxidises GAP, & at the same time NAD+ is reduced to NADH + H+. overall reaction releases energy that is used to phosphorylate GAP, creating 2 x 1,3-bisphosphoglycerate molecules.

7. each of the two BPG molecules donate a phosphate group to an ADP, forming 2 x ATP & two molecules of 3-phosphoglycerate. catalysed by phosphoglycerate kinase.

8. phosphoglyceromutase converts two 3 PGA into 2 molecules of 2-phosphoglycerate (isomers)

9. enolase removes a water molecule from each of 2PGA, creating two molecules of phosphoenolpyruvate

10. phosphate group transferred from PEP to ADP, creating 2 x ATP & 2x pyruvate. catalysed by pyruvate kinase.

glycosis notes

1. 6th c is phosphorylated as it is the most exposed. neg charge addition of phosphate prevents g6p from leaving cytosol. Delta g negative & irreversible.
2. isomerisation rearranges atoms to present another C for phosphorylation. delta g 0, reversible.
3. delta g negative & irreversible.
4. lysis. previous phosphates added makes fructose easier to break due to charge redistribution. products used up quickly, pushing equil to right. delta g positive & irreversible.
5. isomerisation moves carbonyl to generate g3p which is more reactive. delta g positive & reversible.
6. redox generates highly reactive acyl phosphate intermediate & NADH. enzyme is dehydrogenase because it takes H off first C. Delta g 0, reversible.
7. sub-level phosphorylation. delta g large, neg & irreversible.
8. isomerisation moves phosphate from 3rd to 2nd position to make molecule more reactive, delta g 0, reversible.
9. dehydration. delta g 0, reversible.

glycosis notes (cont)

10. sub-level phosphorylation. delta g negative & irreversible.

anaerobic reduction of pyruvate to lactate

during vigorous exercise, pyuvate production > pyruvate oxidation (by citric acid cycle)

red blood cells lack mitochondria, produce lactate

the 2x NADH are oxidised to 2x NAD+ by lactate dehydrogenase to regenerate NAD+ & maintain redox balance

Gibbs free energy

amount of free energy available is related to the difference in energy levels between products & reactions

if +/- 10 kj/mol = at equil

if over 10 kj/mol = favours substrate, little product

if under - 10 kj/mol = favours product, little substrate

TCA cycle

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Link: pyruvate from glycolysis is decarboxylated to form acetyl-CoA by pyruvate dehydrogenase.

1. (condensation), acetyl-CoA (2C) joins oxalocetate (4C) to form citrate (6c) + CoA. catalysed by citrate synthase. delta G neg & irr.

2. citrate converted to isocitrate isomer. catalysed by aconitase. dehydration & hydration step alter position of H/OH. delta G positive & irr.

3. isocitrate oxidised to alpha-ketoglutarate (5C) resulting in release of CO2. 1 x NADH2 molecule formed. catalysed by isocitrate dehydrogenase.

4. alpha-ketoglutarate oxidised to form 4C molecule succinate that binds to CoA forming succinal CoA. catalysed by alpha-ketoglutarate dehydrogenase complex. 2nd NADH produced & 2nd O2. delta G = neg & irr.

5. succinyl coA to succinate (4C) & one GTP produced. catalysed by succinylchlorine-CoA synthetase. delta g = 0 & rev

6. succinate to fumerate (4C) & molecule of FADH2 produced. delta G = 0 & rev. catalysed by succinate dehydrogenase.

7. fumarate to malate (4C). hydration, catalysed by fumerase. delta G =0, reversible.

8. malate to oxaloacetate, 3rd NADH produced. dehydrogenation to make oxaloacetate to keep cycle going. catalysed by malate dehydrogenase. delta G = pos & irr.

cycle occurs twice - one for each pyruvate

oxidative phosphorylation: e- transport chain

NADH, FADH2 have electrons in high energy states that move from NADH, FADH2, reducing O2 to H2O & energy is transferred to protein complexes

Energy from oxidising NADH, FADH2 used to pump H+s into intermembrane space

oxidative phosphorylation: e- transport chain (cont)

Intermembrane space more acidic than matrix – creates electrochemical gradient

Flow of H+s down electrochemical gradient used to generate ATP

electron transfer with transfer of H+ protons across inner mitochondria membrane used to create electrochemical gradient & generate ATP

end products

Cellular respiration:

1. Glycolysis
2. TCA Cycle
3. Electron transport/oxidative phosphorylation

- Glycolysis: glucose → 2 pyruvate + 2 ATP net
- TCA cycle: each turn oxidizes 1 pyruvate, so it takes 2 turns to completely oxidize 1 glucose
- Prep step + two turns TCA: 8 NADH, 2 $FADH_2$ and 2 ATP

- NADH and $FADH_2$ oxidatively phosphorylated: up to 34 more ATP
- **The 3 stages together produce up to 38 ATP**

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