Pasteur Effect

-Dr. Ekta Khare
Department of Microbiology
Institute of Biosciences & Biotechnology,
CSJM University, Kanpur

Pasteur effect

- The effect was discovered in 1857 by Louis Pasteur, who showed that aerating yeasted broth causes yeast cell growth to increase, while conversely, fermentation rate decreases.
- The effect can be explained; as the yeast being facultative anaerobes can produce energy using two different metabolic pathways.
- While the oxygen concentration is low, the product of glycolysis, pyruvate, is turned into ethanol and carbon dioxide, and the energy production efficiency is low (2 moles of ATP per mole of glucose).
- If the oxygen concentration grows, pyruvate is converted to acetyl CoA that can be used in the citric acid cycle, which increases the efficiency to 30-32 moles of ATP per mole of glucose (it depends on which shuttle is used for reducing the reducing equivalent, NADH, that is formed in the cytosol).
- Therefore, about 15 times as much glucose must be consumed anaerobically as aerobically to yield the same amount of ATP.
- Under anaerobic conditions, the rate of glucose metabolism is faster, but the amount of ATP produced (as already mentioned) is smaller

… Pasteur effect

- The maximum ATP yield in eucaryotes from glycolysis, the TCA cycle, and electron transport can be readily calculated.
- The conversion of glucose to two pyruvate molecules during glycolysis gives a net gain of two ATPs and two NADHs.
- 2NADH can yield a maximum of 5 or 3 ATPs during electron transport and oxidative phosphorylation, the total aerobic yield from the glycolytic pathway is 5 or 7 ATP molecules.
- Under anaerobic conditions, when the NADH is not oxidized by the electron transport chain, only two ATPs will be generated during the degradation of glucose to pyruvate.
- When O_2 is present and the electron transport chain is operating, pyruvate is next oxidized to acetyl-CoA, the substrate for the TCA cycle.
- This reaction yields 2 NADHs because 2 pyruvates arise from a glucose; therefore 5 more ATPs are formed.

ATP Yield from compete oxidation of glucose

- Oxidation of each acetyl-CoA in the TCA cycle will yield 1 GTP (or ATP), 3 NADHs, and a single FADH2 for a total of 2 GTPs (ATPs), 6 NADHs, and 2 FADH2s from two acetyl-CoA molecules.
- This amounts to 20 ATPs when NADH and FADH2 from the cycle are oxidized in the electron transport chain.
- Thus the aerobic oxidation of glucose to 6 CO_2 supplies a maximum of 32-30 ATPs.

Process	*Direct product*	*Final ATP*
Glycolysis	2 NADH (cytosolic)	3 or 5*
	2 ATP	2
Pyruvate oxidation (two per glucose)	2 NADH (mitochondrial matrix)	5
Acetyl-CoA oxidation in citric acid cycle (two per glucose)	6 NADH (mitochondrial matrix)	15
	2 $FADH_2$	3
	2 ATP or 2 GTP	2
Total yield per glucose		30 or 32

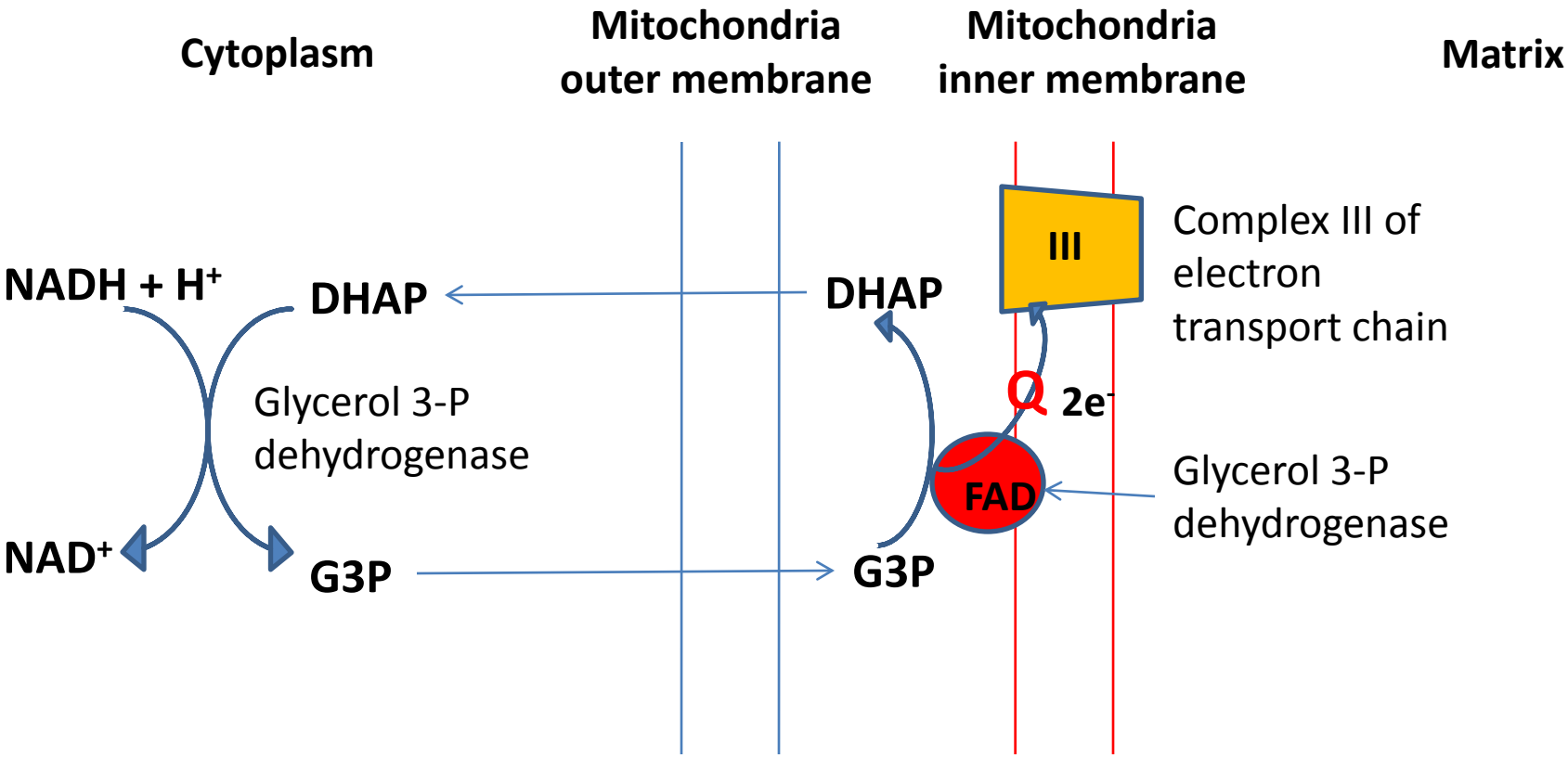
...Pasteur effect

- Bacterial electron transport systems often have lower P/O ratios than the eucaryotic system, bacterial aerobic ATP yields can be less.
- For example, *E. coli* with its truncated electron transport chains has a P/O ratio around 1.3 when using the cytochrome *bo path at high oxygen* levels and only a ratio of about 0.67 when employing the cytochrome *bd branch at low oxygen concentrations.*
- Clearly, aerobic respiration is much more effective than anaerobic processes not involving electron transport and oxidative phosphorylation.
- Many microorganisms, when moved from anaerobic to aerobic conditions, will drastically reduce their rate of sugar catabolism and switch to aerobic respiration, a regulatory phenomenon known as the **Pasteur effect.**
- This is of obvious advantage to the microorganism as less sugar must be degraded to obtain the same amount of ATP when the more efficient aerobic process can be employed.

Why by oxidation of glyceraldehyde 3-P to 1,3-bisphospho glycerate generate 2 NADH ultimately yield 3 or 5 ATP?

- NADH must pass into the mitochondria and after oxidation to NAD^+ should return to cytoplasm for use in glycolysis.
- However, mitochondria membrane is not readily permeable to NADH and NAD^+
- This complication is overcome by oxidizing NADH to NAD^+ at the expense of dihydroxyacetonephosphate (DHAP) which is reduced to glycerol 3-phosphate (G3P) **(glycerol phosphate shuttle)**.
- Glycerol-3-P then passes into the mitochondria where it is reoxidized to DHAP.
- The dehydrogenase which catalyses the conversion of G3P to DHAP in mitochondria is different from NAD^+ linked G3P dehydrogenase present in cytosol.
- It is linked to FAD instead of NAD^+ and transfer electrons to respiratory chain at the level of coenzyme Q.
- Consequently only 1.5 molecules of ATP instead of 2.5 are formed when cytoplasmic NADH is oxidized in this way.
- **In case of Malate-aspartate shuttle transferring hydrogen atoms from cytosolic NADH + H^+ to mitochondrial NAD^+** : 2 x 2.5 = 5 ATP generate

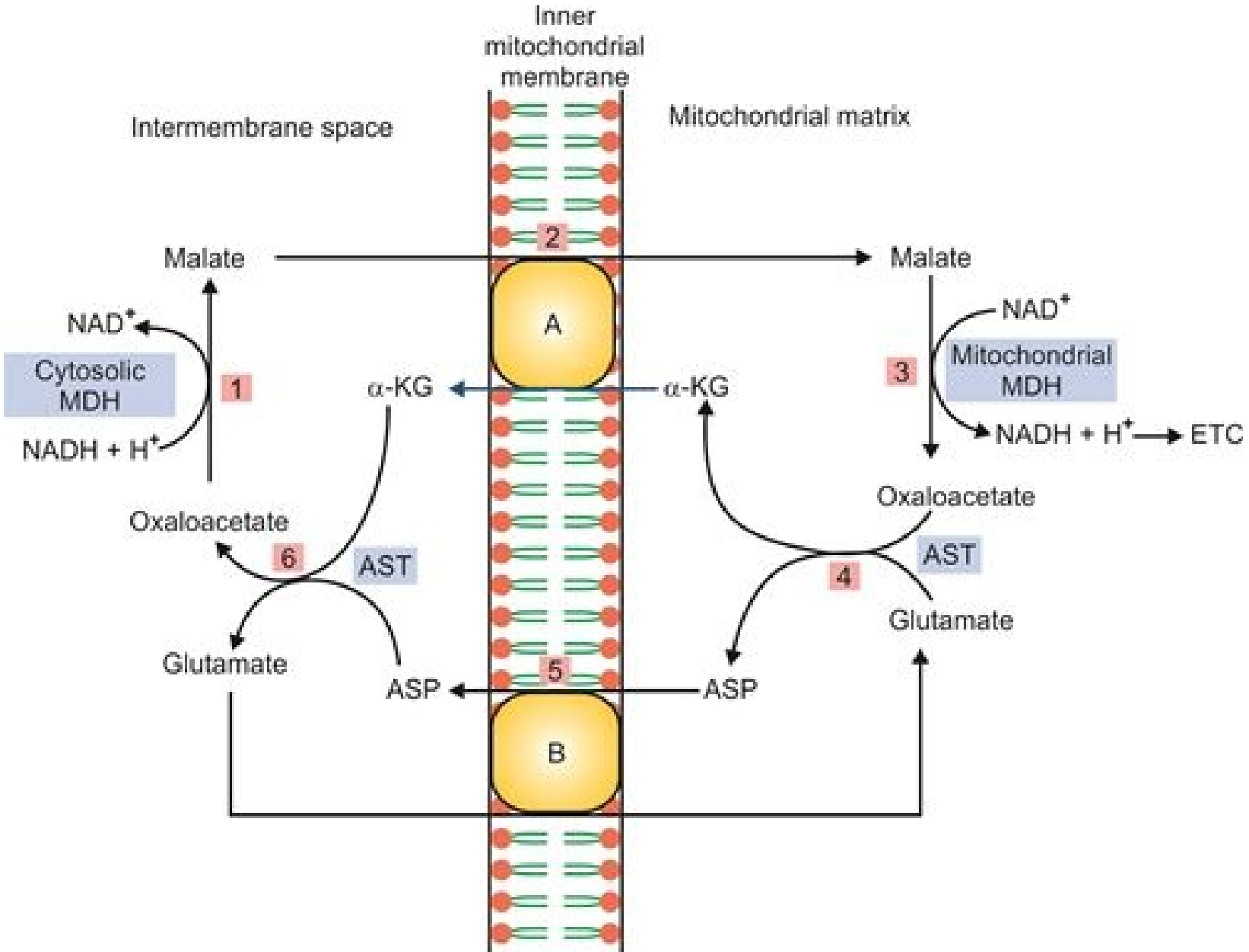
Why by oxidation of glyceraldehyde 3-P to 1,3-bisphospho glycerate generate 2 NADH ultimately yield 3 or 5 ATP?



Malate-aspartate shuttle

- First, in the cytosol, malate dehydrogenase catalyses the reaction of oxaloacetate and NADH to produce malate and NAD^+.
- Once malate is formed, the first antiporter (malate-alpha-ketoglutarate) imports the malate from the cytosol into the mitochondrial matrix and also exports alpha-ketoglutarate from the matrix into the cytosol simultaneously.
- After malate reaches the mitochondrial matrix, it is converted by mitochondrial malate dehydrogenase into oxaloacetate, during which NAD^+ is reduced with two electrons to form NADH.
- Oxaloacetate is then transformed into aspartate (since oxaloacetate cannot be transported into the cytosol) by mitochondrial aspartate aminotransferase.
- Since aspartate is an amino acid, an amino radical needs to be added to the oxaloacetate. This is supplied by glutamate, which in the process is transformed into alpha-ketoglutarate by the same enzyme.

Malate-aspartate shuttle



Questions

- What are the different components of various complexes involve in eukaryotic respiratory electron transport chain?
- Write a short note on Q-cycle.
- Write an essay on respiratory electron transport system of eucaryotes.
- Explain respiratory electron transport process of bacteria.
  - *E. coli*
  - *Paracoccus denitrificans*
- What do you mean by oxidative phosphorylation? What are the steps of oxidative synthesis?
- Explain chemiosmotic model of ATP synthesis.
- Explain structure of ATP synthase.
- Explain binding change mechanism of ATP synthesis given by Paul D. Boyer.
- Differentiate between oxidative and substrate level phosphorylation.
- What is Pasteur effect? Briefly discuss.