Class: M.Sc.
Semester :IV (Parasitology)
Course : XV A Physiology & Biochemistry of Parasites
Unit : 2a
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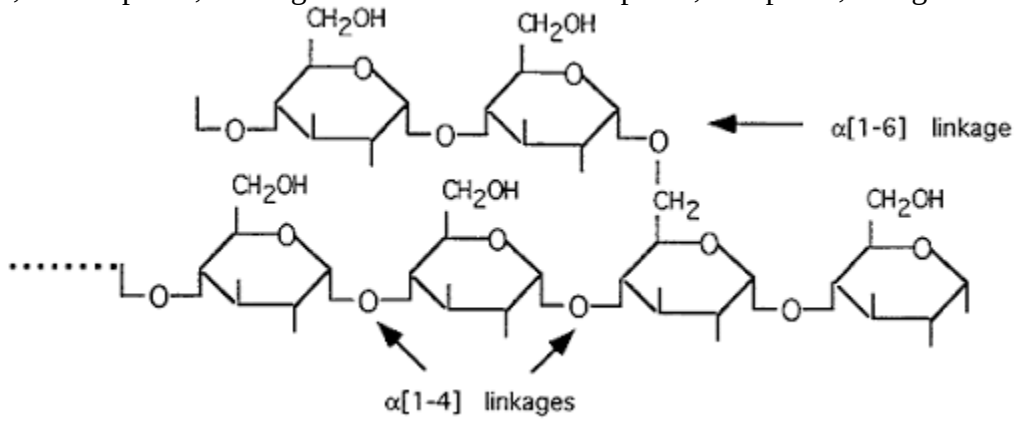
Carbohydrate metabolism and Energy

Although parasites use to live inside / on the body of other organism and they need not to work hard and their energy requirements are quite low but they do need energy for various purposes like- to fix them selves, to anchor, to migrate etc etc. Like other animals parasites also depend upon the universal energy giving substrate, the carbohydrate. An almost universal feature of endoparasitic organisms their dependence upon anaerobic carbohydrate metabolism to obtain energy, regardless the amount of oxygen available.

Carbohydrate Reserve

For energy most of the parasites store polysaccharide to yield energy (ATP). Glycogen is reported to be the polysaccharide reserve of most of the helminths. It is a homopolysaccardide (made up of similar type of monomeric units, glucose). These units are polymarized by alapha-1,4 and alpha-1,6 linkages. The ratio between Alpha-1,4 : alpha-1,6 ranges from 12:1 to 15:1.



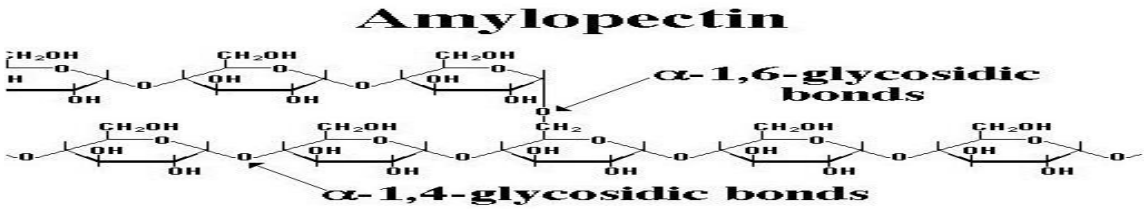
Von Brand (1973) studies the amount of glycogen in different parasites and it was observed that amount of plysaccharide –

1. Monogenea 1% of dry weight
2. Digenea 2-30% of dry weight
3. Cestodes 20-60%
4. Nematodes and acanthocephalan 10-70%

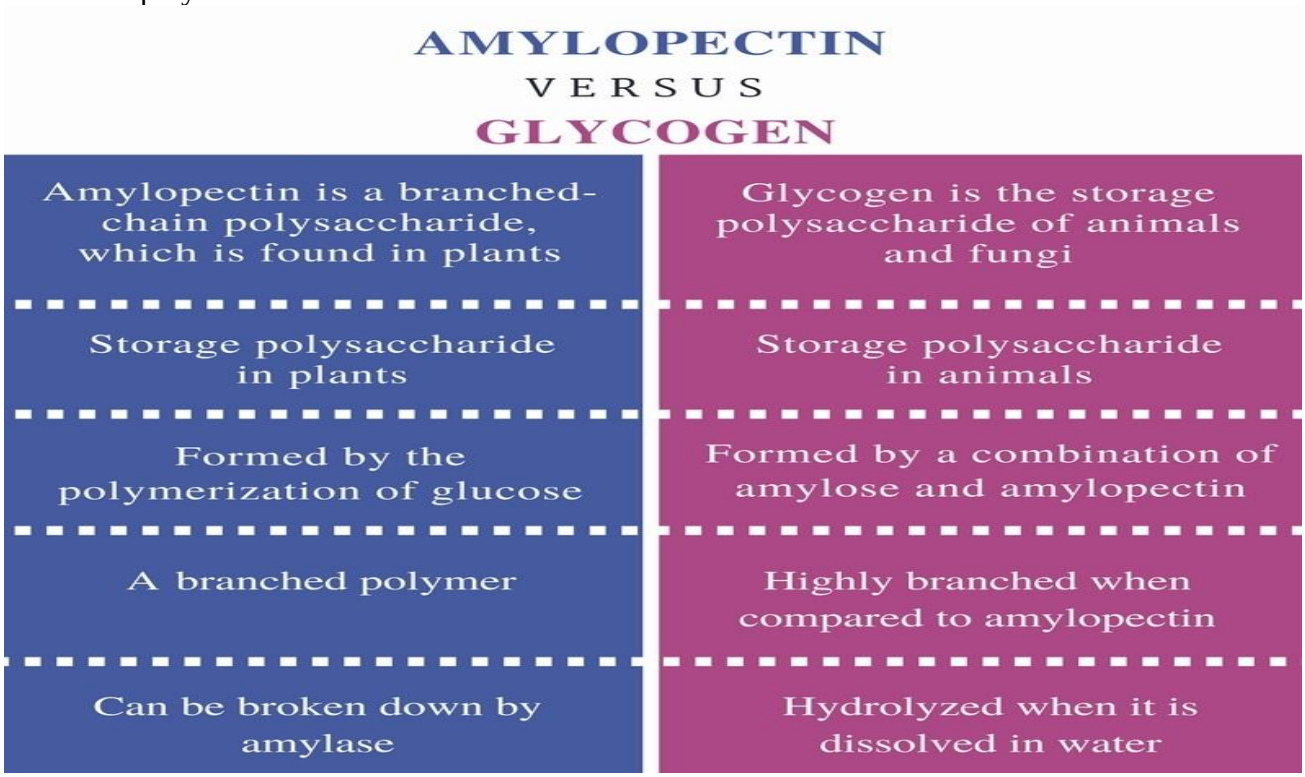
These concentration although appear as figure but in fact they are adapatations for parasitic mode of life. Lowest concentrations in ectoparasitic monogenea is on accpunt of the fact they are ectoparasites and are capable of performing TCA cycle and electron transport system and they

require less molecules of carbohydrate as compared to endoparasite which performs only glycolyis.

Major site for the storage of glycogen is parenchyma cells however significant amount of glycogen is stored in the muscles also. Some times in a few parasites, specially small protozoans alternate polysaccharide reserve in the form of amylopectin – a highly branched polymer is found as reserve.



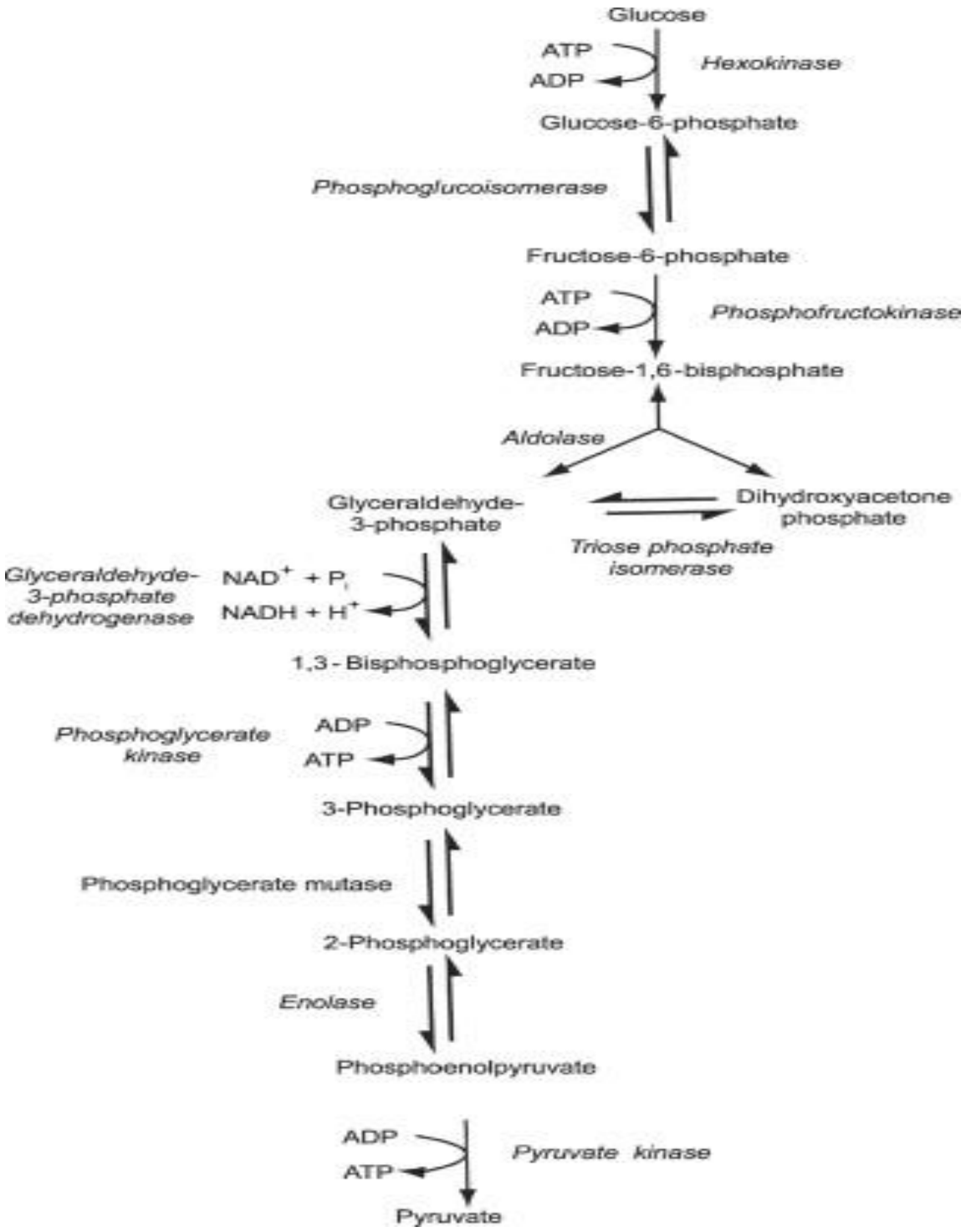
These two polysaccharide reserves differs from other –



Glycolysis

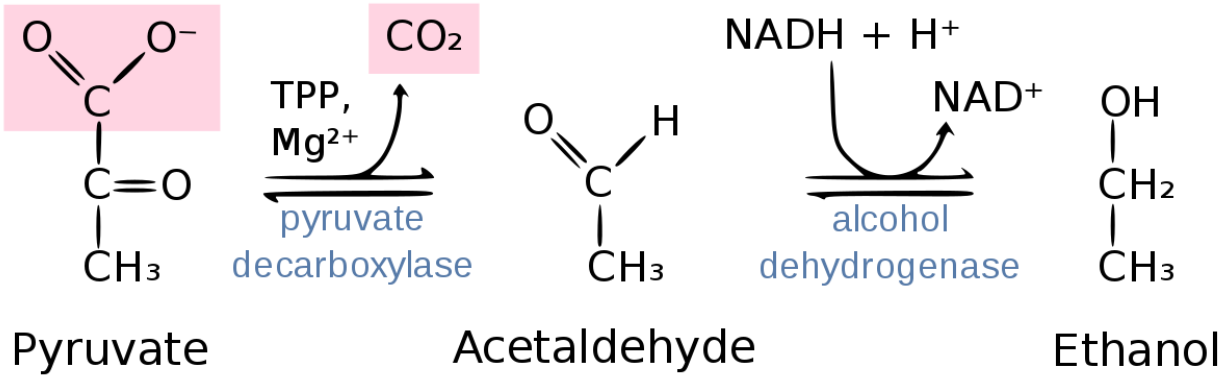
Glycoslysis is most basic and fundamental pathway (Fig. 1) of carbohydrate metabolism in almost all animal tissues it is also known as EMP pathway after the discoverer. During this catabolic pathway break down of glucose into pyruvic acid takes palace. Free living animals use to use this pathway as rapid means of obtaining energy like running, strenuous exercise etc. Due to which oxygen debt is created under anerobic condition. In order to oxidise reduced products of glycolysis pyruvic acid is converted into lactic acid(Fig 2). Besides this there are more ways –

1. Pyruvate is converted into acetaldehyde (look at reaction)
2. Puuruvate can also be converted into acetyl CoA and in etneters into motocondria for aerobic break down. (Reaction)

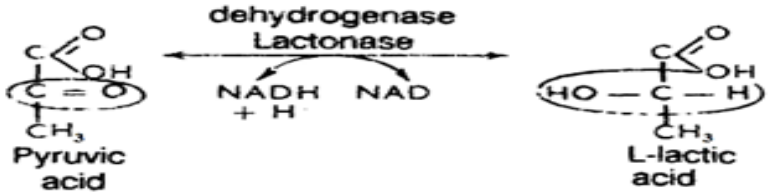


In case of parasite pyruvate produced after glycolysis has three fates-

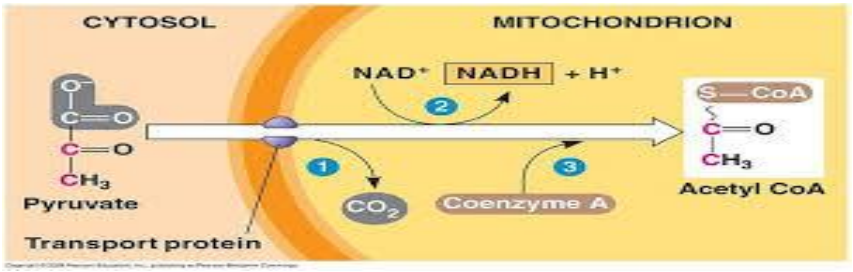
1. It is converted into acetaldehyde in presence of enzyme pyruvate decarbpxylase. This inturn is converted into ethanol in presence of alcpholic dehydrogenase



2. Pyuruvate is converted in Lactate in presence of lactate dehydrogenase. This is importent step in order to continue the glycolytic pathway and reduced coenzyme NADH+H is regenerated. Another important fact is that in case of reaction lating place in vertebratae muscle it is mostly L form but in case of parasites it may be L or D form.



3. The third fate is conversion of Pyruvate into acetyl CoA after that it enters into TCA cycle with in the miochondria



Net reaction of the glycolysis use to yield-

Glucose +2P + 2ADP = 2 Lactate + 2ATP

The glycolytic pathway has been examine d in wide variety of parasites and it was found that-

A. In most of the cases typical array of various glycolytic enzymes and their intermediate are are present in parasites which proves that parasites use glycolyis.
B. In some parasites some of the enzymes and intermediate are absent but even in them lactate is formed which has been explained by workers that these enzymes and the reaction are either mediated by some other enzymes or reactions are short circuited.

End product of Carbohydrate catabolism

Lactic acid is found to be the typical end product of glycolysis.As told earliar, reduction of pyruvate to lactic acid serves to reoxidise the reduced co factor NADH +H produced by glyceraldehydes 3 phosphate dehydrogenase.

Moreover there are certain parasites which are homolactic fermenters like *S.mansoni,Brugia,Diplectanum* etc use to excrete lactic acid exclusively both in aerobic and anaerobic conditions. But many other excrete different substances given in the table

Table 3.1 The end-products of carbohydrate catabolism in selected parasites.

Species	Conditions	End-products
Protozoa		
Crithidia fasciculata	aerobic	pyruvate, succinate, ethanol, CO_2.
	anaerobic	lactate, succinate, ethanol, CO_2.
Trypanosoma brucei	aerobic	pyruvate, acetate, succinate, glycerol, CO_2.
Trypanosoma lewisi	aerobic	lactate, pyruvate, acetate, succinate, glycerol, ethanol.
	anaerobic	lactate, pyruvate, acetate, succinate, ethanol.
Trypanosoma gambiense	aerobic	acetate, pyruvate, CO_2.
	anaerobic	lactate, pyruvate, acetate, succinate, CO_2.
Plasmodium berghei	aerobic	lactate, pyruvate, acetate, succinate, CO_2.
Digenea		
Fasciola hepatica	aerobic	lactate, acetate, propionate, α-methylbutyrate, α-methylvalerate.
	anaerobic	lactate, acetate, propionate, α-methylbutyrate, α-methylvalerate, succinate.
Cestoda		
Hymenolepis diminuta	aerobic	lactate, acetate, succinate.
	anaerobic	lactate.
Acanthocephala		
Moniliformis dubius	aerobic	lactate, formate, acetate, propionate, α-methylbutyrate, succinate, ethanol.
Nematoda		
Ascaris lumbricoides	aerobic	lactate, formate, α-methylbutyrate, α-methylvalerate, C6 acids, succinate.
	anaerobic	lactate, formate, acetate, propionate, α-methylbutyrate, succinate, acetone.

Data from Von Brand, (1973)

Carbon dioxide fixation

Many endoparasites in general and gut dwellers in particular inhibit an environment which is rich in carbon dioxide. They have adapted themselves to use this carbon dioxide with the help of specific enzyme systems for biosynthetic and energetic functions. There are two such well studied pathways –

1. Malic enzyme system (ME)
2. Phosphoenolpyruvate carboxykinase (PECPK)

This fixation has been studied in great detail by Braynt (1975) in a nematode Ascaris. This worker found that ME is found in mitochondria and PECPK in the cytoplasm. During this pathway malate is formed from oxaloacetatae (catalized by dependent NADH malate

dehydrogenase) and diffuses from the mitochondria. In the cytoplasm it undergoes dismutataion reaction resulting in the cleavage ofmalate to pyruvate and fumarate. The NADH generated by ME is re-oxidised during reducation of fumarate to succinate at which step a molecule of ATP is produced from each molecule of fumerate reduced. The details are given in the figure.

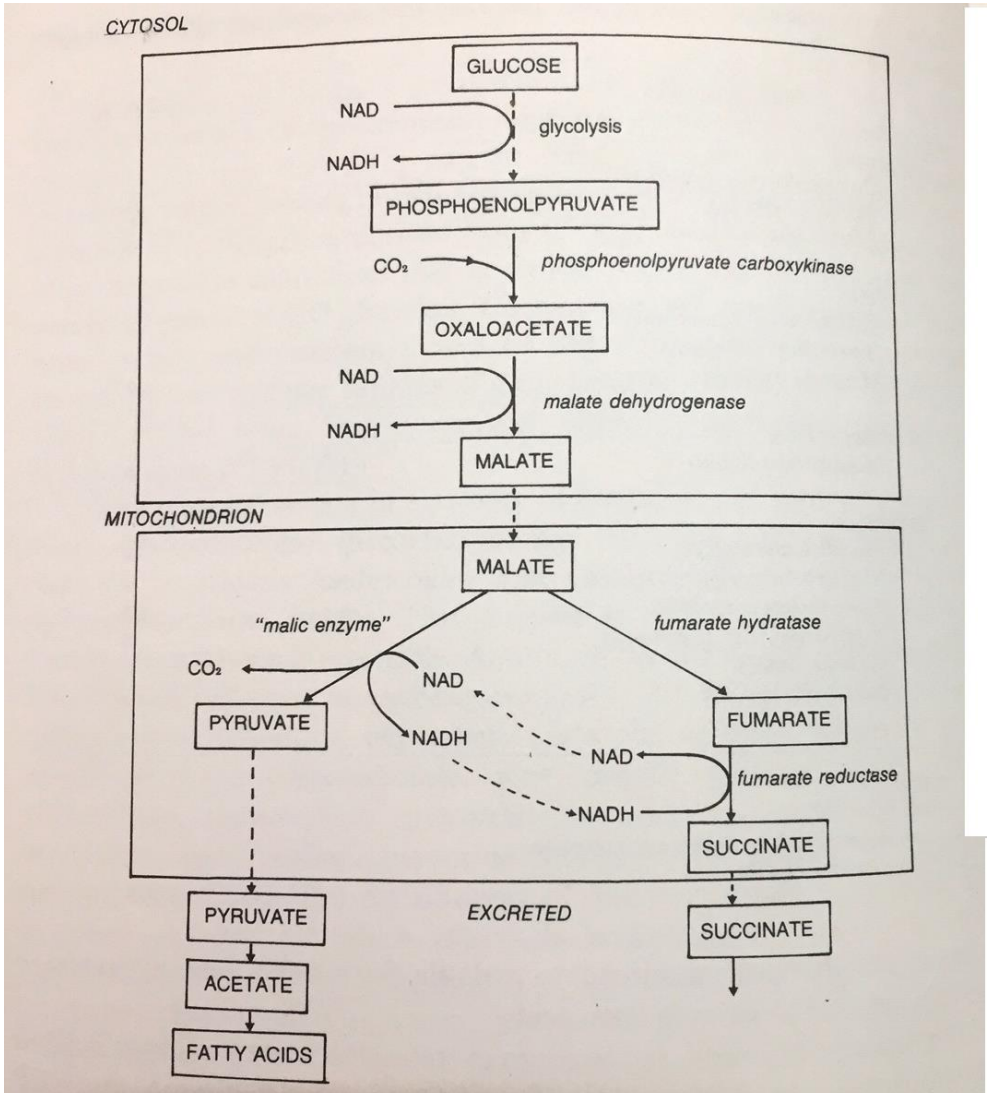


Figure 3.2 The roles of "malic enzyme" (ME) and phosphoenolpyruvate carboxykinase (PEPCK) in CO_2 fixation by the nematode *Ascaris lumbricoides* (from Bryant, 1975).

Occurrence of "malic enzyme" (ME) and PEP carboxykinase (PEPCK) in some helminth parasites.

Parasite species	ME	PEPCK
Digenea		
Dicrocoelium dendriticum	?	+
Fasciola hepatica	+	+
Schistosoma mansoni	?	+
Cestoda		
Echinococcus granulosus	+	+
Hymenolepis diminuta	+	+
Moniezia expansa	+	+
Acanthocephala		
Moniliformis dubius	+ (?)	+
Nematoda		
Ascaris lumbricoides	+	+
Dictyocaulus viviparus	−	+
Haemonchus contortus	+	+
Nippostrongylus brasiliensis	−	+
Syphacea muris	−	+
Trichinella spiralis	+	+

+ = present
− = not detected
(?) = not determined or uncertain presence
Data from Bryant (1975)

TCA Cycle

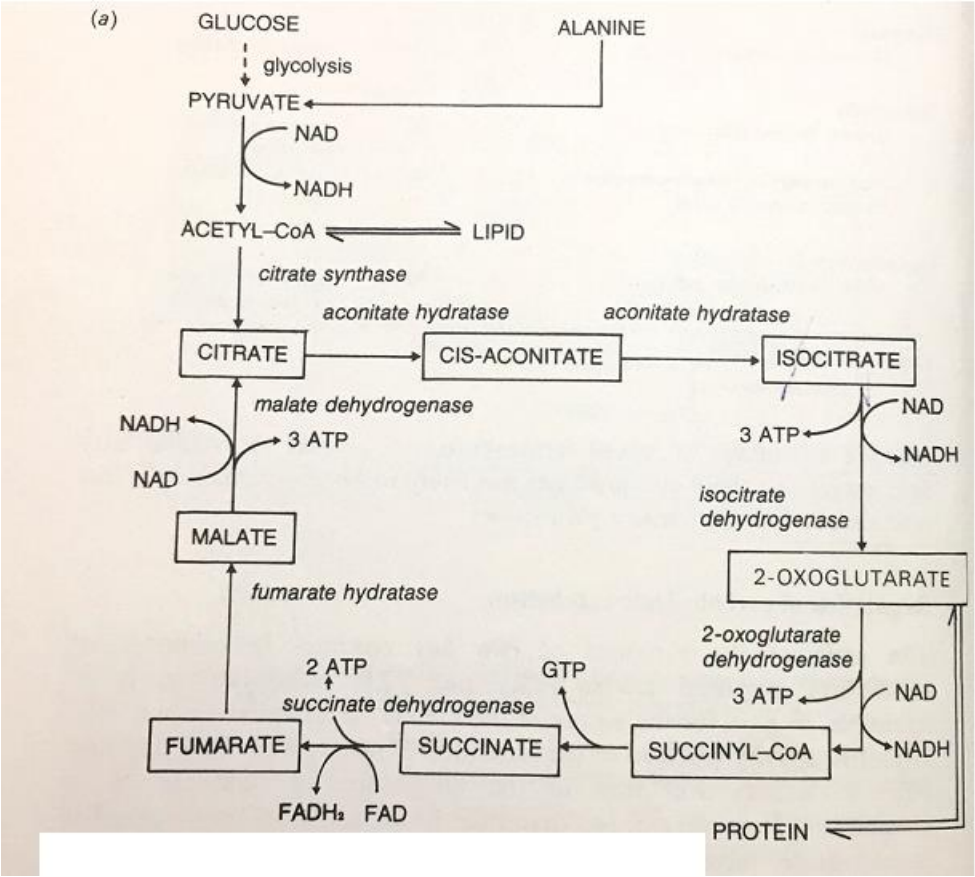
Complete oxidation of carbohydrate and other metabolites (amino acids/fatty acids) is normally carried out in presence of oxygen with a well studied pathway called TCA cycle. This cycle is also known as Kreb's cycle or Citric acid cycle. This pathway it is catabolic as well as anabolic.

- Anabolically it is fundamental source of many carbohydrates, amino acids and fat.
- However, catabolically it yields ATP.

Attempt to study the TCA cycle in various parasite reveal that –

1. this cycle is not universally present in parasitic animals.
2. There are parasites where it is present like- Avian malarial parasite, some trypanosomes, *Trichomonas gallinae*, larval schistosomes some nematodes
3. This cycle is completely absent in *H. diminuta, Moniezia expensa,F.hepatica,Ascaris lumbricoides*.

4. Where there it is present, complete set of enzymes and various intermediatas nhave not been localization and it is belived that though this cycle is present but certain reactons are not mediated by by the same enzymes.



Role of Oxygen in energy metabolism of Parasites

From the foregoing discussion two facts are clear-

A. Many parasites obtain energy from anaerobic metabolism of carbohydrate and and tend to inhibit area in host body with low oxygen.
B. Almost all parasites do consume oxygen.

Now question arises what for then they consume oxygen if the metabolism is primarily anaerobic. Barrett (1999) is of openion that oxygen do plays some role in energy metabolism besides being used in the formation of egg shell. Despite this, there are certainly few questions-

1. What is the mechanism of up take?
2. Does this oxygen lead to the production of ATP?
3. If so, what contribution exactly oxidative phosphorylation makes and how?

These questions were addressed by many workers and it was found that most of the parasites have both anaerobic and aerobic ways of living. When ever they get chance they consume and use oxygen. The porphyrene in one or the other form which is responsible for the uptake of oxygen and its transport with in the body. However oxygen enters the body through the tegument by diffusion.

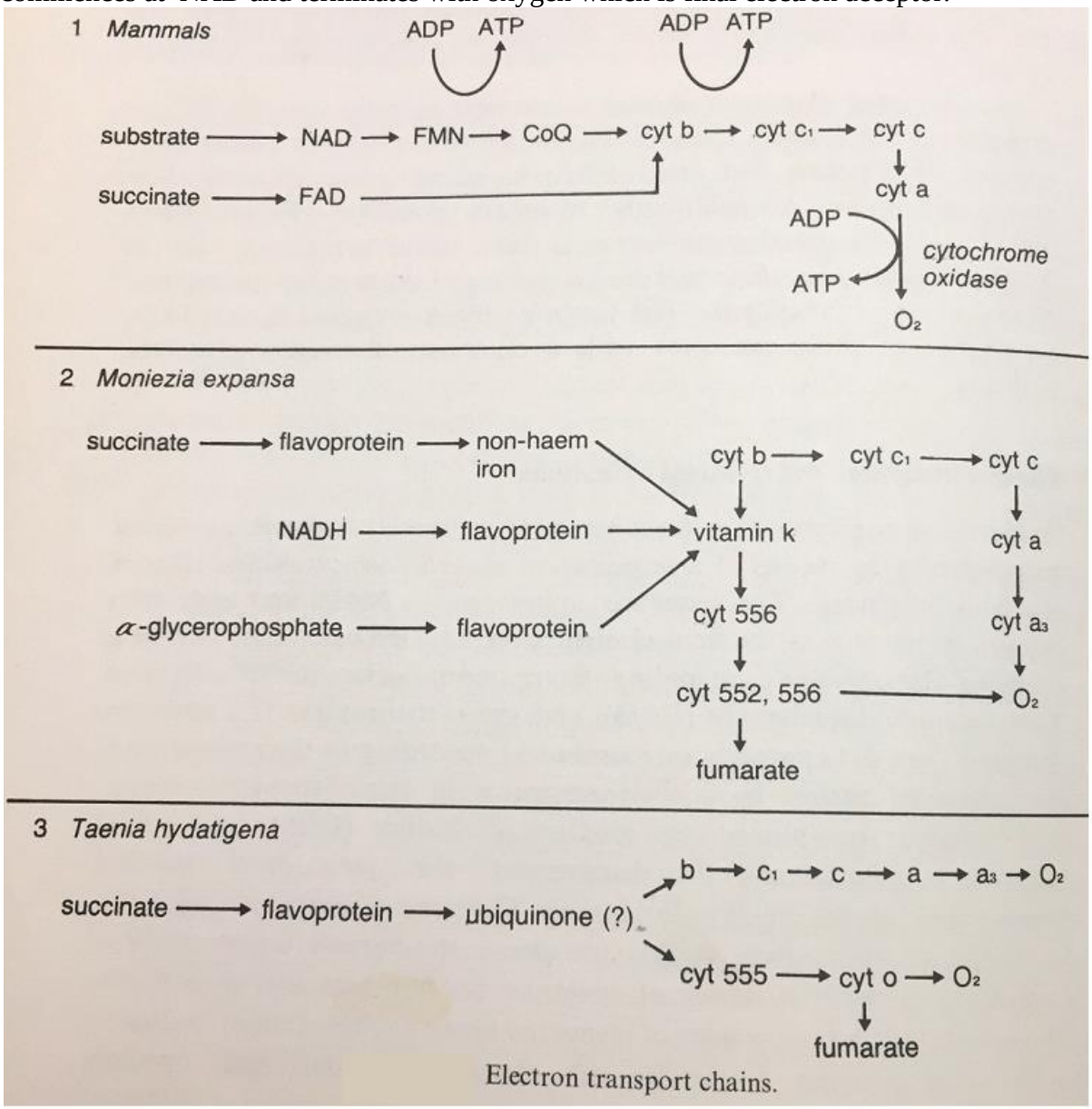
This has recently been advocated that these parasite have very well designed mechanism to switch on and switch off the synthesis of aerobic and anaerobic set of enzymes at gene level.

This has also been observed that parasites use to exhibit Pasteur effect and Carbtree Effect.

1. In presence of oxygen rate of glycolysis decreases
2. In presence of high concentration of glucose rate of oxygen uptake is inhibited respectively

Electron Transport System

Aerobic ATP synthesis (Oxydative Phosphorylation) takes place within mitochondria by means of sequence of electron acceptors and doners, called as electron transport system. This sequence commences at NAD and terminates with oxygen which is final electron acceptor.



Electron transport chains.

Between these two there exists a chain of flavoproteins including FMN and FAD and cytochromes. According to absorption characteristics cytochrome in mammals is designated as b,c1,c,a and a3. Ever growing literature on electron transport system has proved that the parasites have functional electron transport system. Its important feature is, it is branched which give more than one terminal oxidase thus more efficient as compared to other animals.