

# KEY

I. Some bacteria deliver the electrons generated from carbohydrate metabolism to elemental sulfur (S) to create hydrogen sulfide (H<sub>2</sub>S). Assuming that the action of the inhibitors, electron donors, and electron-extracting compounds function as efficiently in these bacteria as in mammals, what would be the P/S ratio if the following could be added to bacteria containing sufficient ADP and P, and an active ATP synthase?

A. succinate and antimycin A ↗ blocks w/ in complex III so no H<sup>+</sup> transport

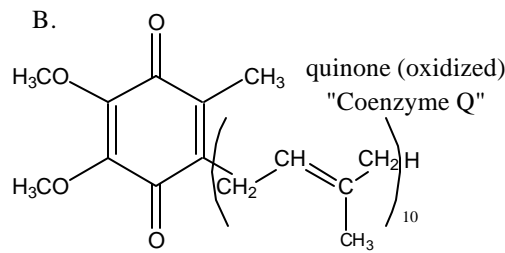
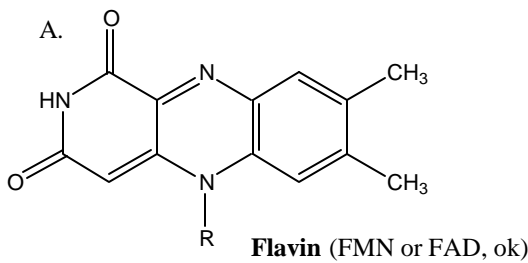
↳ e<sup>-</sup>s into complex II => Answer: 0

B. β-hydroxybutyrate and exogenous cytochrome C

↳ e<sup>-</sup>s into complex I --> complex III --> cyt c

H<sup>+</sup> pumped, each w/ 1 ATP produced. => Answer: 2

II. Give the name of the following co-factors:

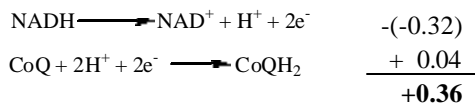


III. Use the Table to answer the following questions (and please show your work):

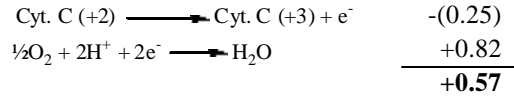
Oxidant	Reductant	n	E <sub>0</sub> , V
Acetate + CO <sub>2</sub> + 2H <sup>+</sup>	Pyruvate + H <sub>2</sub> O	2	-0.70
Succinate + CO <sub>2</sub> + 2H <sup>+</sup>	α-Ketoglutarate + H <sub>2</sub> O	2	-0.67
Acetate + 3H <sup>+</sup>	Acetaldehyde + H <sub>2</sub> O	2	-0.60
O <sub>2</sub>	O <sub>2</sub> <sup>-</sup>	1	-0.45
Ferredoxin (oxidized)	Ferredoxin (reduced)	1	-0.43
2H <sup>+</sup>	H <sub>2</sub>	2	-0.42
Acetoacetate + 2H <sup>+</sup>	β-Hydroxybutyrate	2	-0.35
Pyruvate + CO <sub>2</sub> + H <sup>+</sup>	Malate	2	-0.33
NAD <sup>+</sup> + H <sup>+</sup>	NADH	2	-0.32
NADP <sup>+</sup> + H <sup>+</sup>	NADPH	2	-0.32
FMN (enzyme-bound) + 2H <sup>+</sup>	FMNH <sub>2</sub> (enzyme-bound)	2	-0.30
Lipoate (oxidized) + 2H <sup>+</sup>	Lipoate (reduced)	2	-0.29
1,3-Bisphosphoglycerate + 2H <sup>+</sup>	Glyceraldehyde-3-phosphate + P <sub>i</sub>	2	-0.29
Glutathione (oxidized) + 2H <sup>+</sup>	2 Glutathione (reduced)	2	-0.23
FAD + 2H <sup>+</sup>	FADH <sub>2</sub>	2	-0.22
Acetaldehyde + 2H <sup>+</sup>	Ethanol	2	-0.20
Pyruvate + 2H <sup>+</sup>	Lactate	2	-0.19
Oxaloacetate + 2H <sup>+</sup>	Malate	2	-0.17
α-Ketoglutarate + NH <sub>4</sub> <sup>+</sup> + 2H <sup>+</sup>	Glutamate + H <sub>2</sub> O	2	-0.14
Methylene blue (oxidized) + 2H <sup>+</sup>	Methylene blue (reduced)	2	0.01
Fumarate + 2H <sup>+</sup>	Succinate	2	0.03
CoQ + 2H <sup>+</sup>	CoQH <sub>2</sub>	2	0.04
Cytochrome b (+3)	Cytochrome b (+2)	1	0.07
Dehydroascorbate + 2H <sup>+</sup>	Ascorbate	2	0.08
Cytochrome c <sub>1</sub> (+3)	Cytochrome c <sub>1</sub> (+2)	1	0.23
Cytochrome c (+3)	Cytochrome c (+2)	1	0.25
Cytochrome a (+3)	Cytochrome a (+2)	1	0.29
½O <sub>2</sub> + H <sub>2</sub> O	H <sub>2</sub> O <sub>2</sub>	2	0.30
Ferricyanide	Ferrocyanide	2	0.36
Nitrate + 2H <sup>+</sup>	Nitrite + H <sub>2</sub> O	1	0.42
Cytochrome a <sub>3</sub> (+3)	Cytochrome a <sub>3</sub> (+2)	1	0.55
Fe (+3)	Fe (+2)	1	0.77
½O <sub>2</sub> + 2H <sup>+</sup>	H <sub>2</sub> O	2	0.82

Note: E<sub>0</sub> is the standard reduction potential at pH 7 and 25°C, n is the number of electrons transferred, and each potential is for the partial reaction written as follows: Oxidant + ne<sup>-</sup> → reductant.

A. What is the electromotive force (in E<sup>o</sup>, in Volts) for the delivery of the two electrons from NADH completely through complex I?



B. What is the electromotive force for the delivery of the two electrons from cytochrome c completely through cytochrome oxidase?



IV. Multiple Choice: Select the best answer:

A. Which of the following statements about the ATP synthase is false?

- i) The proton gradient drives the release of ATP from the enzyme
- ii) The F1 portion projects into the intermembrane space of the mitochondria
- iii) There are 3 independent sites in the enzyme that represent stages in the enzyme cycle
- iv) The  $\alpha$  and  $\beta$  subunits are components of the F1 portion of the enzyme

F1 is in  
MATRIX!

B. Which of the following statements about cytochromes is false?

- i) They are approximately 130,000 Daltons in molecular mass
- ii) They are highly conserved across all species
- iii) Iron is bound in the proteins via a heme-group
- iv) Cytochrome C is protein-linked via a cysteine residue

cytochromes are ~13,000D

V. Short answer:

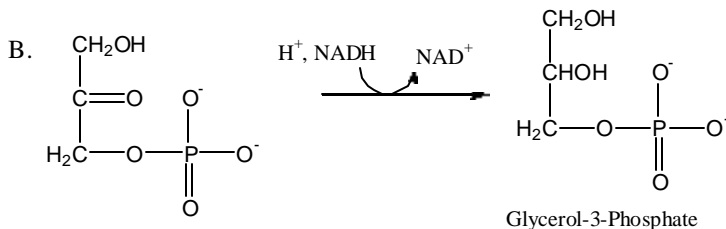
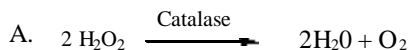
A. Which metal is present only in cytochrome oxidase?

Copper

B. Name an inhibitor of the Adenine nucleotide translocase (ATP/ADP transporter):

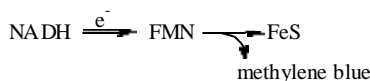
Bonqkreic Acid OR Atractyloside

VI. Draw the structures of the products of the following reactions:



VII. Deciphering the pathway:

A. Under conditions in which mitochondria are respiring and ATP synthesis proceeds, what inhibitor will lead to the strongest oxidation of methylene blue?



Inhibited by:  
**Rotenone Amytal**

B. What complex (give the proper name) of the electron transport chain is inhibited by carbon monoxide?

Inhibits Cyt a<sub>3</sub> in cytochrome (c) oxidase

VIII. Choose one uncoupling mechanism or uncoupler and explain how it works:

- DNP shuttles  $H^+$  across membrane
- Skunk Cabbage: Complex I + Cyt oxidase are expressed that fail to transport protons.
- Valinomycin:  $K^+$  transport -> breaks down the  $pnF$
- Nigericin:  $K^+/H^+$  transport -> breaks down  $pnF$
- Brown fat: No  $H^+$  export w/ eTC