Notes 12/3

Monday, December 03, 2007
10:01 AM

Notes 123

Audio recording started: 10:02 AM Monday, December 03, 2007

FINAL SLIDES:

Electron Transport

Dec. 3, 2007

Overview

- Carbon tracing practice problem
- Mitochondrial Transport Systems
- Reduction potentials
- Electron-transport chain

- Slide 3: Carbon tracing practice problem
  - An experiment using ^{14}C labeled carbon sources is carried out on a yeast extract maintained under strictly anaerobic conditions to produce ethanol. The experiment consists of incubating a very small amount of ^{13}C labeled substrate with the yeast extract just long enough for each intermediate in the pathway to become labeled.
  - If [1-^{14}C] glucose (glucose labeled at C-1 with ^{14}C) is used as a substrate, what is the location of C^{14} in the product ethanol? Explain.

    Glucose goes through glycolysis so follow 1-^{14}C through.
- Slide 4: glycolysis diagram to aid in carbon tracing practice problem (red stars represent traced C^{14})
  - Step 2 from G6P to F6P 1-^{14}C moves outside ring.
  - Step 4/5
    - Carbon 3 of DHAP, Carbon 3 of GAP
  - Step 6
    - 1,3-BPG Carbon 3
  - Steps 7-10
    - Doesn't really move, can follow down easily
- Slide 5: Pyruvate to Ethanol pictures
  - C 3 of pyruvate
  - C2 of acetaldehyde
  - C2 of ethanol
- Slide 6: Cytoplasmic NADH Shuttle Systems
  - Functions to transport cytosolic NADH into mitochondrion
  - Inner mitochondrial membrane lacks an NADH transport protein
    - So NADH cannot cross into mitochondria
  - Why is NADH important? Its electrons can be used to create ATP via the electron-transport process.

Cytoplasmic shuttle systems transport NADH electrons across the inner mitochondrial membrane

Electron Transport

Dec. 3, 2007

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Overview

- Carbon tracing practice problem
- Mitochondrial transport systems
- Reduction potentials
- Electron-transport chain

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Carbon tracing practice problem

- An experiment using ^{14}C -labeled carbon sources is carried out on a yeast extract maintained under strictly anaerobic conditions to produce ethanol. The experiment consists of incubating a very small amount of ^{14}C -labeled substrate with the yeast extract just long enough for each intermediate in the pathway to become labeled.

  If [1-^{14}C] glucose (glucose labeled at C-1 with ^{14}C) is used as a substrate, what is the location of ^{14}C in the product ethanol? Explain.

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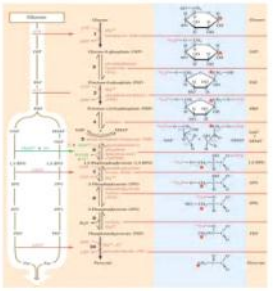

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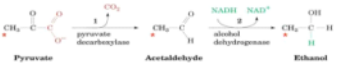
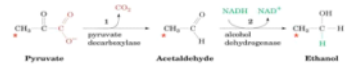


- Why is NADH important? Its electrons can be used to create ATP via the electron-transport process.

Cytoplasmic shuttle systems transport NADH electrons across the inner mitochondrial membrane

- Glycerophosphate shuttle in insects (in insect wings)
  - 2 ATP per cytoplasmic NADH
- Malate-aspartate shuttle in mammals
  - 3 ATP per cytoplasmic NADH
  - More efficient than glycerphosphate shuttle
  - Involves malate and aspartate



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Cytoplasmic NADH Shuttle Systems

- Function to transport cytosolic NADH into the mitochondrion
- Inner mitochondrial membrane lacks an NADH transport protein
- Why is cytosolic NADH important? Its electrons can be used to create ATP via the electron-transport process.

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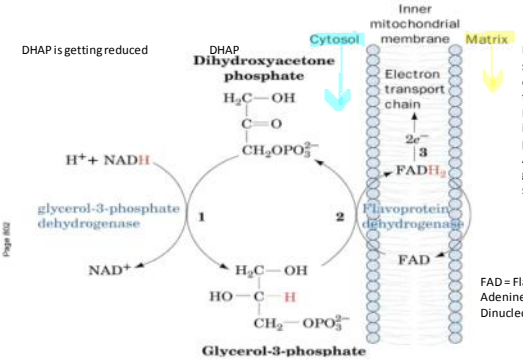
Figure 22-8 The glycerophosphate shuttle.



DHAP is getting reduced

DHAP

Electrons are shuttled off on electron transport chain. Energy on chain is used to produce ATP (2 ATP for glycerphosphate shuttle)

FAD = Flavin Adenine Dinucleotide

Flavoprotein dehydrogenase is reminiscent Succinate dehydrgogenase

Cytoplasmic shuttle systems transport NADH electrons across the inner mitochondrial membrane

- Glycerophosphate shuttle in insects
  - 2 ATP per cytoplasmic NADH
- Malate-aspartate shuttle in mammals
  - 3 ATP per cytoplasmic NADH

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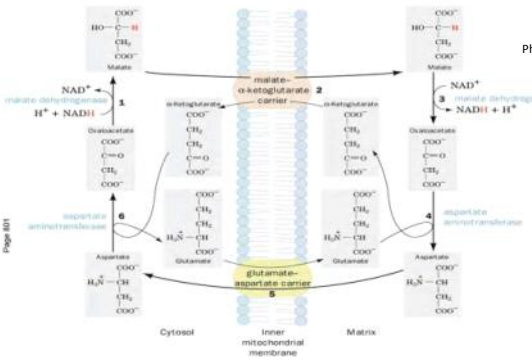
Overall goal: transfer cytosolic NADH to mitochondrial NADH

Figure 22-7 The malate–aspartate shuttle.



Phase A
Transport of e^- into matrix
Step 1,2,3

Phase B
Regeneration of cytoplasmic OAA
Step 4,5,6

Figure 22-8 The glycerophosphate shuttle.

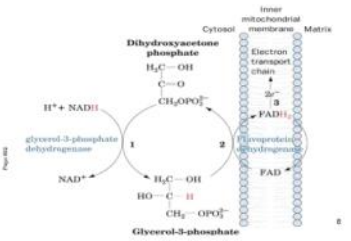
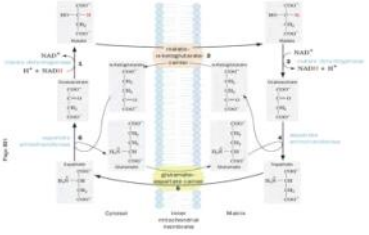


Figure 22-7 The malate–aspartate shuttle.



- Slide 10: Thermodynamics of electron transport
  - The free energy of electron…. Missed.
- Slide 11: Redox Potentials
  - Redox reactions can be written as two half reacitons
  - $Fe^{3+} + Cu^+ <---> Fe^{2+} + Cu^{2+}$
    - Fe gains electron so it is being reduced
    - Cu loses electron so it is oxidized
  - $Fe^{3+} + e^- --> Fe^{2+}$ (reduction)
  - $Cu^+ --> Cu^{2+} + e^-$ (oxidation)
- Slide 12: Redox Potentials (aka Electromotive force)
  - $Fe^{3+} + Cu^+ --> Fe^{2+} + Cu^{2+}$
  - $A_{ox}^{n+} + B_{red} <--> A_{red} + B_{ox}^{n+}$
  - Nearnst equation: used to calculate free energy of redox reaction

$$\Delta G = \Delta G^\circ + RT \ln\left(\frac{[A_{RED}][B_{ox}^{n+}]}{[A_{ox}^{n+}][B_{RED}]}\right)$$

° refers to standard conditions

$\Delta G = -w_{el}$ $\quad w_{el}$ = electrical work

$w_{el} = nF\Delta\mathcal{E}$ $\quad F$ = faraday's constant, n = moles

$$\Delta G = -nF\Delta\mathcal{E}$$

$$\Delta\mathcal{E} = \Delta\mathcal{E}^\circ - \frac{RT}{nF} \ln\left(\frac{[A_{RED}][B_{ox}^{n+}]}{[A_{ox}^{n+}][B_{RED}]}\right)$$

- Slide 13: Reduction Potentials
  - $A_{OX}^{n+} + B_{RED} \rightarrow A_{RED} + B_{OX}^{n+}$
  - By convention, both half reactions are written as reductions
  - $A_{OX}^{n+} + ne^- \rightarrow A_{RED}$
  - $B_{OX}^{n+} + ne^- \rightarrow B_{RED}$

$$\mathcal{E}_A = \mathcal{E}_A^\circ - \frac{RT}{nF} \ln\left(\frac{[A_{RED}]}{[A_{ox}^{n+}]}\right)$$

$$\Delta\mathcal{E}^\circ = \mathcal{E}^\circ_{(e^- \text{ acceptor})} - \mathcal{E}^\circ_{(e^- \text{ donor})}$$

- Slide 14: Table 16-4B standard reduction potentials of some biochemically important half reactions

DONE NO MORE TIME DID NOT COVER ADDITIONAL SLIDES

Thermodynamics of Electron Transport

- The free energy of electron transfer from NADH and $FADH_2$ to O_2 is coupled to ATP synthesis.

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Redox Potentials

- Redox rxns can be written as two half-rxns
- $Fe^{3+} + Cu^+ \leftrightarrow Fe^{2+} + Cu^{2+}$
- $Fe^{3+} + e^- \leftrightarrow Fe^{2+}$ (reduction)
- $Cu^+ \leftrightarrow Cu^{2+} + e^-$ (oxidation)

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Figure 22-9
The mitochondrial electron-transport chain.

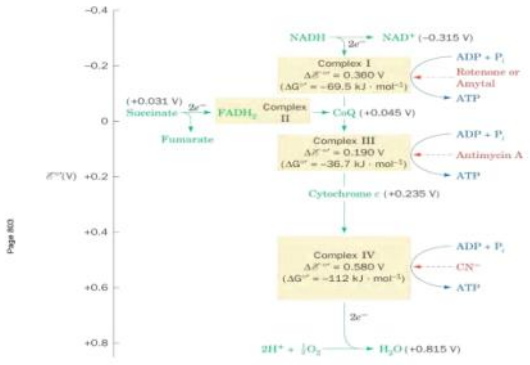

Table 22-1 Reduction Potentials of Electron-Transport Chain Components in Resting Mitochondria.

Component	$\mathcal{E}^{\circ\prime}$ (V)
NADH	−0.315

Redox Potentials (a.k.a. Electromotive Force)

- $Fe^{3+} + Cu^+ \leftrightarrow Fe^{2+} + Cu^{2+}$
- $A_{ox}^{n+} + B_{red} \leftrightarrow A_{red} + B_{ox}^{n+}$
- Nearnst equation:

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Reduction potentials

- $A_{ox}^{n+} + B_{red} \leftrightarrow A_{red} + B_{ox}^{n+}$
- By convention, both half-rxns are written as reductions
- $A_{ox}^{n+} + ne^- \leftrightarrow A_{red}$
- $B_{ox}^{n+} + ne^- \leftrightarrow B_{red}$

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Complex I (NADH:CoQ oxidoreductase;	900 kD, 43 subunits):
FMN	?
(Fe–S)N-1a	−0.380
(Fe–S)N-1b	−0.250
(Fe–S)N-2	−0.030
(Fe–S)N-3,4	−0.245
(Fe–S)N-5,6	−0.270
Succinate	0.031

Source: Mainly Wilson, D.F., Erecinska, M., and Dutton, P.L., *Annu. Rev. Biophys. Bioeng.* **3,** 205 and 208 (1974); *and* Wilson, D.F., *In* Bittar, E.E. (Ed.), *Membrane Structure and Function,* Vol. 1, *p.* 160, Wiley (1980).

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Table 16-4b Standard Reduction Potentials of Some Biochemically Important Half-reactions

Half-Reaction	$\mathcal{E}'^{\circ}$ (V)
$FAD + 2H^+ + 2e^- \rightleftharpoons FADH_2$	−0.040
$Oxaloacetate^- + 2H^+ + 2e^- \rightleftharpoons malate^-$	−0.166
$Pyruvate^- + 2H^+ + 2e^- \rightleftharpoons lactate^-$	−0.185
$Acetaldehyde + 2H^+ + 2e^- \rightleftharpoons ethanol$	−0.197
$FAD + 2H^+ + 2e^- \rightleftharpoons FADH_2$	−0.219
$S + 2H^+ + 2e^- \rightleftharpoons H_2S$	−0.23
$Lipoic\ acid + 2H^+ + 2e^- \rightleftharpoons dihydrolipoic\ acid$	−0.29
$NAD^+ + H^+ + 2e^- \rightleftharpoons NADH$	−0.315
$NADP^+ + H^+ + 2e^- \rightleftharpoons NADPH$	−0.320
$Cystine + 2H^+ + 2e^- \rightleftharpoons 2\ cysteine$	−0.340
$Acetoacetate^- + 2H^+ + 2e^- \rightleftharpoons \beta\text{-hydroxybutyrate}$	−0.346
$H^+ + e^- \rightleftharpoons \frac{1}{2}H_2$	−0.421
$Acetate^- + 3H^+ + 2e^- \rightleftharpoons acetaldehyde + H_2O$	−0.581

Source: Mostly from Loach, P.A., *in* Fasman, G.D. (Ed.), *Handbook of Biochemistry and Molecular Biology* (3rd ed.), *Physical and Chemical Data,* Vol. 1, *pp.* 123–130, CRC Press (1976).

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Figure 22-14
The mitochondrial electron-transport chain.

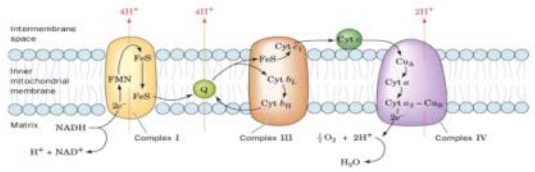

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Figure 22-16 X-Ray structure of ferredoxin from *Peptococcus aerogenes.*

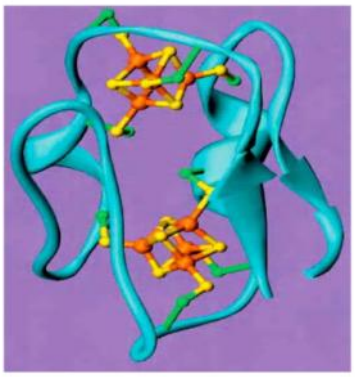

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Figure 22-17a
Oxidation states of the coenzymes of complex I. (*a*) FMN.

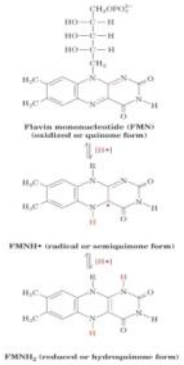

Figure 22-17b

Oxidation states of the coenzymes of complex I. (*b*) CoQ.