7.014

Lecture 17:

Carbon and Energy Metabolism

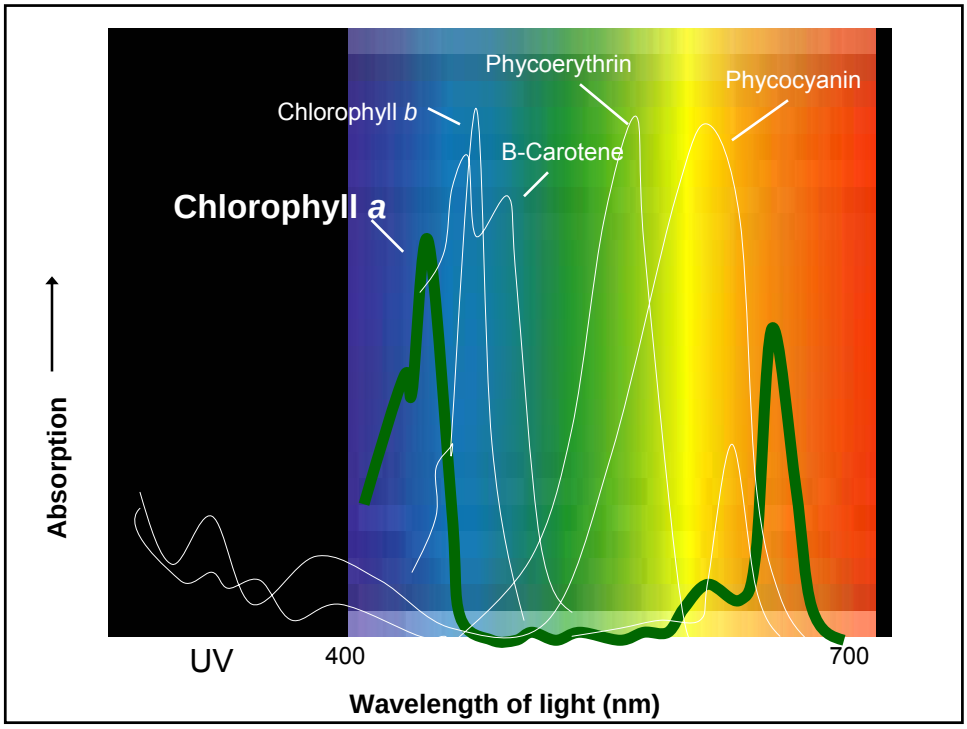
March 14, 2005

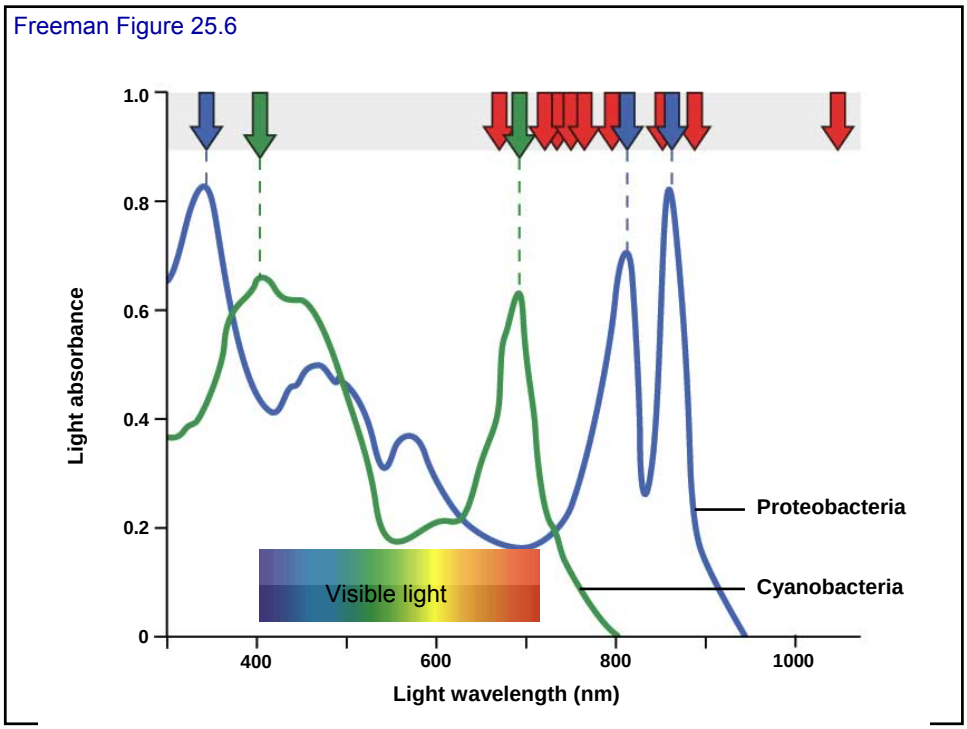
Summary of the options for Life

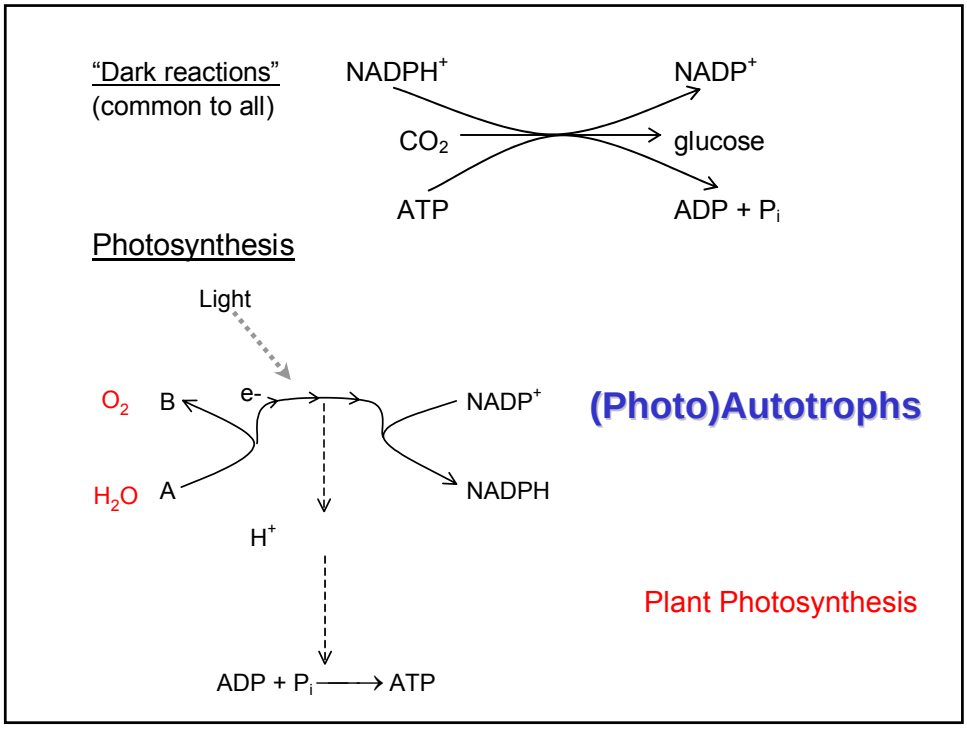
(the simplified view – see also Freeman Ch 25)

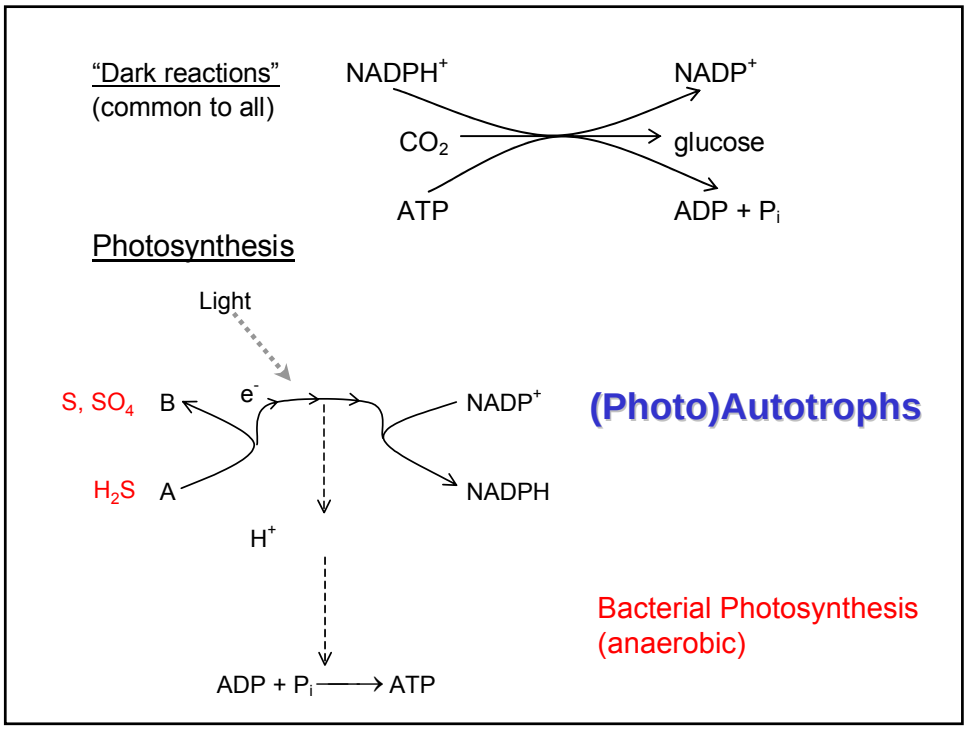
	Organism	Carbon Source	Energy Source
Autotrophs			
Oxygenic Photosynthesis	pro and euk	CO_2	sun
Anoxygenic Photosynthesis	prokaryotic	CO_2	sun
Chemosynthesis	prokaryotic	CO_2	Reduced chemical compounds
Heterotrophs			
Aerobic Respiration	pro or euk	organic C	organic C
Anaerobic Respiration	pro or euk	organic C	organic C
Fermentation	pro or euk	organic C	organic C

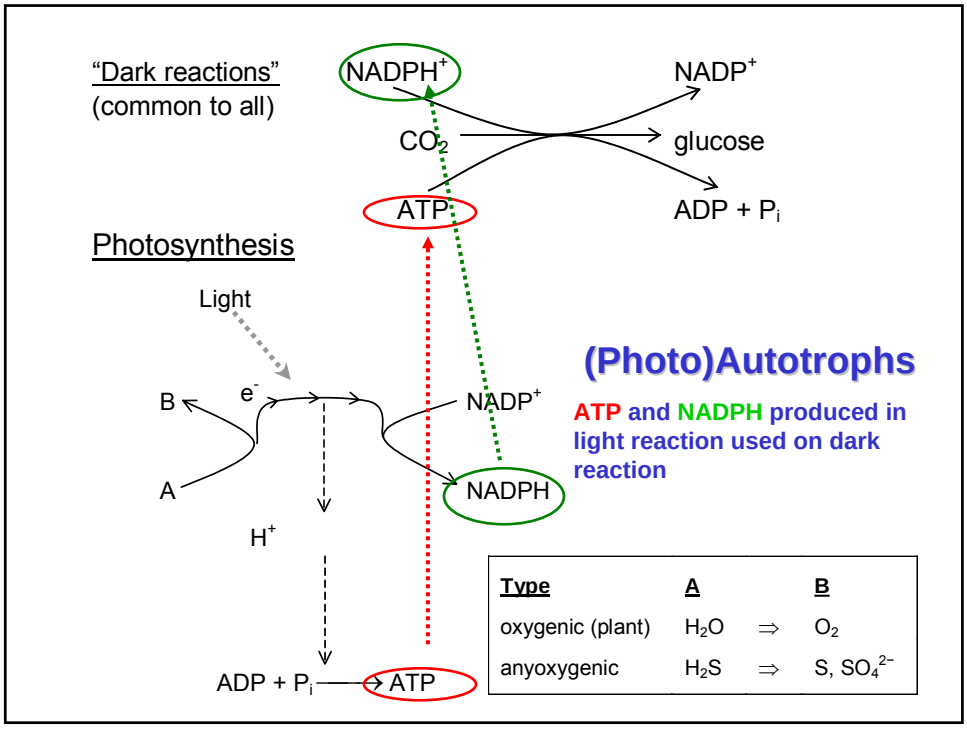
euk = eukaryotic

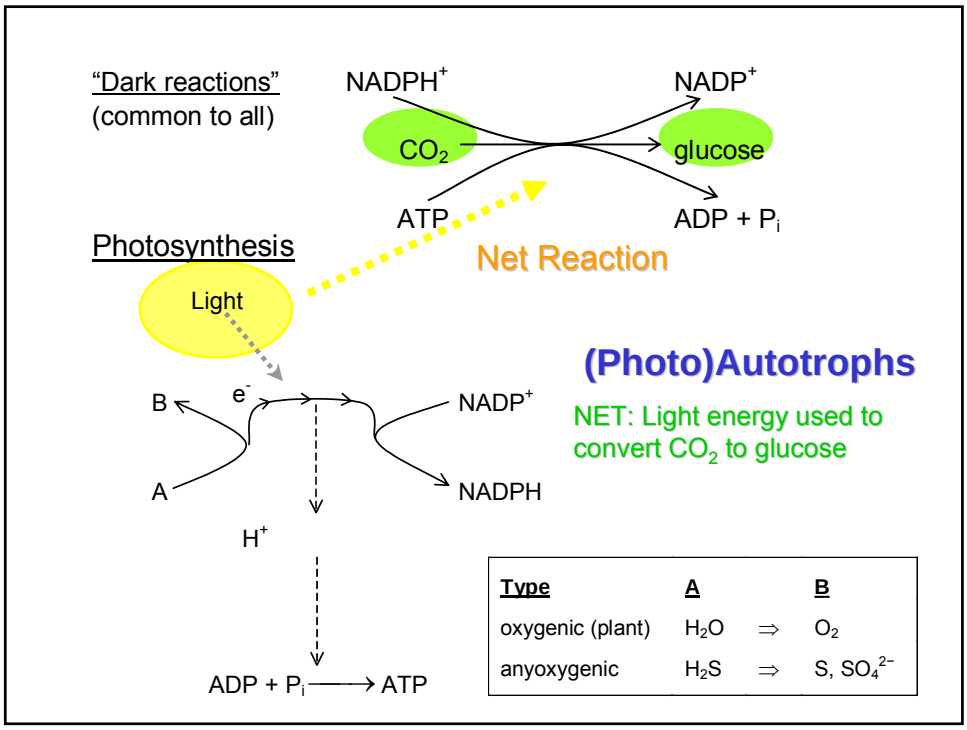

Phycoerythrin
Phycocyanin
Chlorophyll b
B-Carotene
Chlorophyll a
Absorption
UV
400
700
Wavelength of light (nm)


Freeman Figure 25.6
1.0
0.8
0.6
0.4
0.2
0
Light absorbance
Visible light
Proteobacteria
Cyanobacteria
400
600
800
1000
Light wavelength (nm)


"Dark reactions"
(common to all)
NADPH+
NADP+
CO2
glucose
ATP
ADP + Pi
Photosynthesis
Light
O2
B
e-
NADP+
H2O
A
NADPH
H+
ADP + Pi
ATP
(Photo)Autotrophs
Plant Photosynthesis

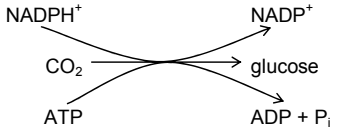

"Dark reactions"
(common to all)
NADPH+
NADP+
CO2
glucose
ATP
ADP + Pi
Photosynthesis
Light
S, SO4
B
e-
NADP+
H2S
A
NADPH
H+
ADP + Pi
ATP
(Photo)Autotrophs
Bacterial Photosynthesis
(anaerobic)


"Dark reactions"
(common to all)
NADPH+
NADP+
CO2
glucose
ATP
ADP + Pi
Photosynthesis
Light
B
e-
NADP+
A
NADPH
H+
ADP + Pi
ATP
(Photo)Autotrophs
ATP and NADPH produced in light reaction used on dark reaction
Type | A | | B
oxygenic (plant) | H2O | ⇒ | O2
anyoxygenic | H2S | ⇒ | S, SO4 2–

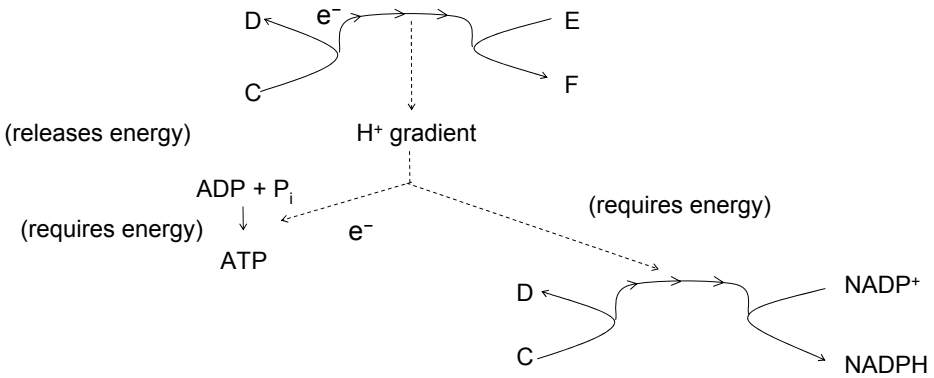

"Dark reactions"
(common to all)
NADPH+
NADP+
CO2
glucose
ATP
ADP + Pi
Photosynthesis
Net Reaction
Light
B
e-
NADP+
A
NADPH
H+
ADP + Pi
ATP
(Photo)Autotrophs
NET: Light energy used to convert CO2 to glucose
Type | A | | B
oxygenic (plant) | H2O | ⇒ | O2
anyoxygenic | H2S | ⇒ | S, SO4 2–

(Chemo) Autotrophs

"Dark reactions" (common to all)



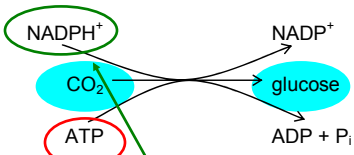
Chemosynthesis



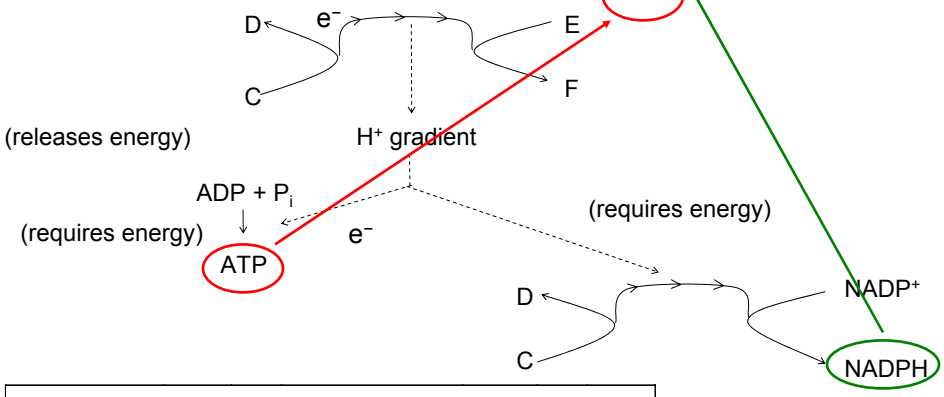
Type	C		D	E		F
sulfur-oxidizing	H_2S	⇒	S, SO_4^{2-}	O_2	⇒	H_2O
	H_2S	⇒	S, SO_4^{2-}	NO_3^-	⇒	N_2O
nitrifying	NH_3 NO_2	⇒	NO_3^-	O_2	⇒	H_2O

(Chemo) Autotrophs

"Dark reactions" (common to all)



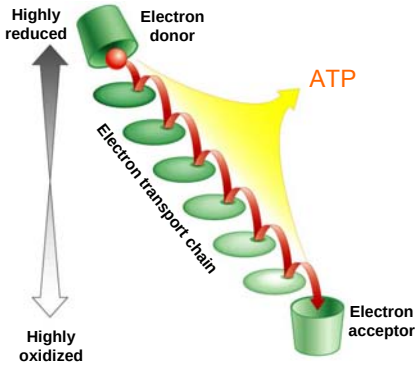
Chemosynthesis



Type	C		D	E		F
sulfur-oxidizing	H_2S	⇒	S, SO_4^{2-}	O_2	⇒	H_2O
	H_2S	⇒	S, SO_4^{2-}	NO_3^-	⇒	N_2O
nitrifying	NH_3 NO_2	⇒	NO_3^-	O_2	⇒	H_2O

Chemical energy used to convert CO_2 to glucose

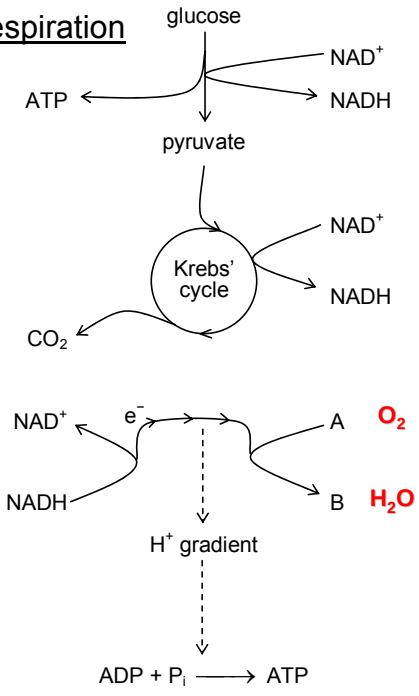
Freeman Figure 25.5



Chemosynthesis

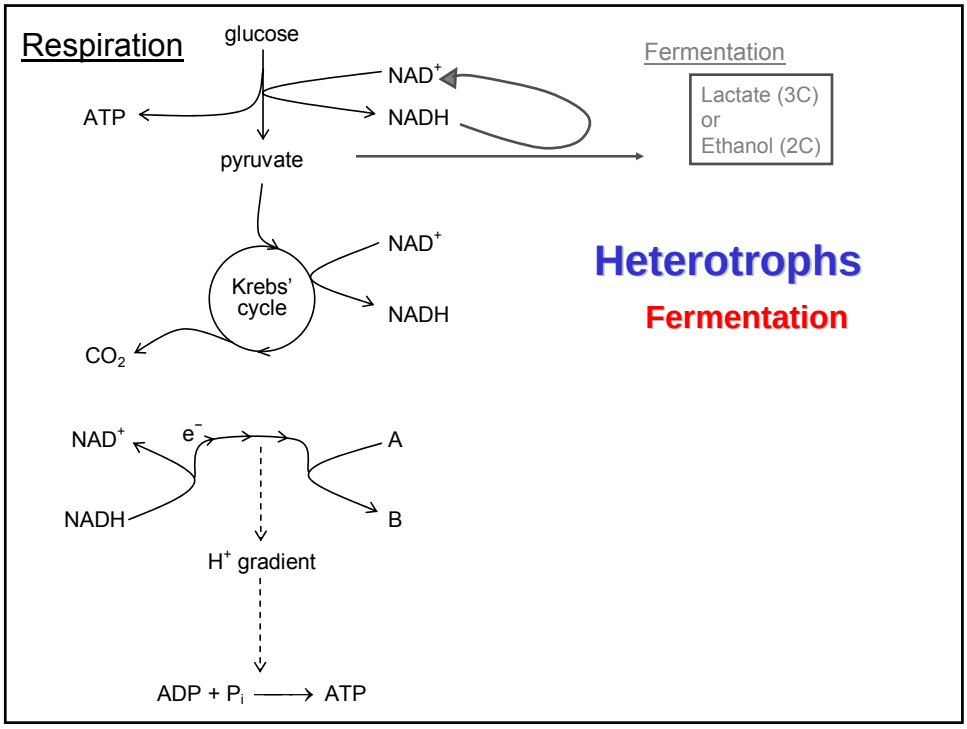
	Electron Donor	Electron Receptor	Product
Sulfate Reducers	H_2 or organic compounds	SO_4^{2-}	H_2S
Methanogens	H_2	CO_2	CH_4
Methanotrophs	CH_4	O_2	CO_2
Sulfur Bacteria	S or H_2S	O_2	SO_4^{2-}
Iron-Reducers	organic compounds	Fe^{3+}	Fe^{2+}
Nitrifiers	NH_3	O_2	NO_2^-
Nitrosifiers	NO_2^-	O_2	NO_3^-
Denitrifiers	organic compounds	NO_3^-	N_2O, NO, N_2

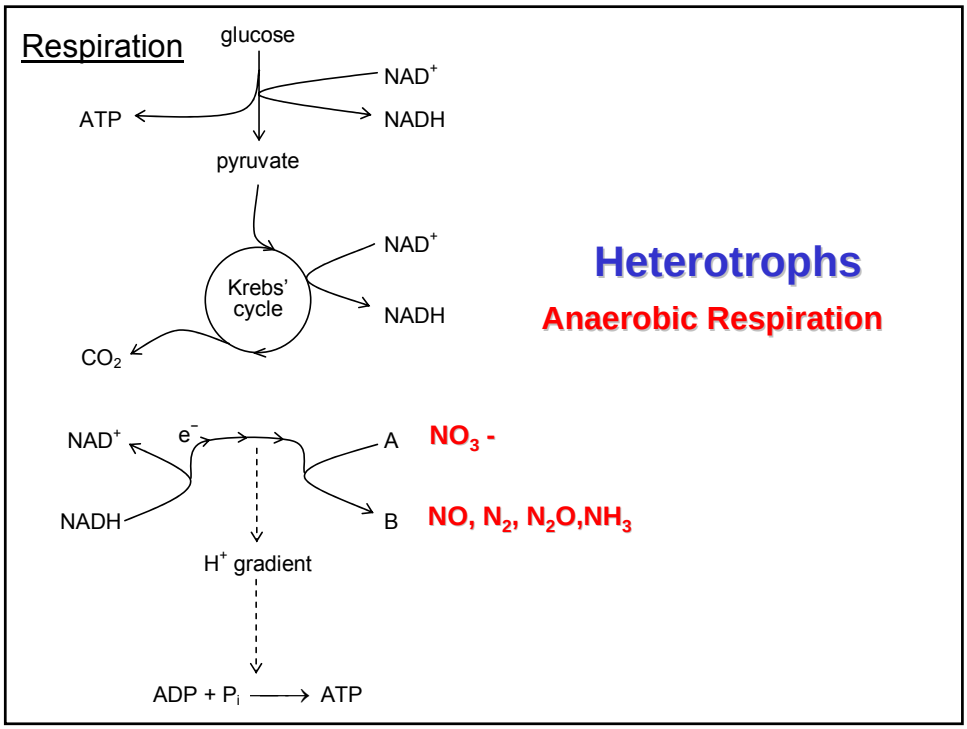
Respiration



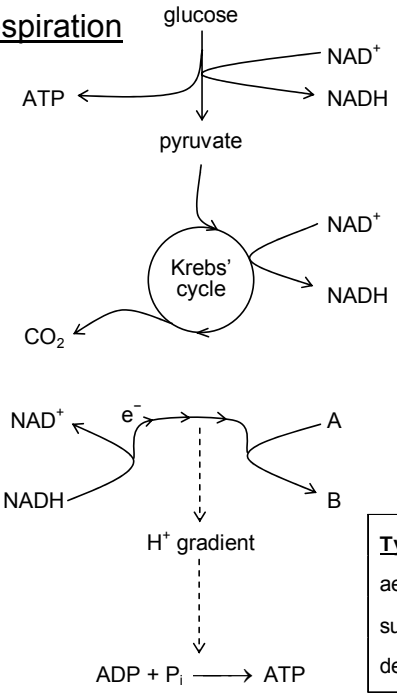
Heterotrophs

Aerobic Respiration


Respiration
glucose
NAD+
ATP
NADH
pyruvate
Fermentation
Lactate (3C)
or
Ethanol (2C)
NAD+
Krebs' cycle
NADH
CO2
NAD+
e-
A
NADH
B
H+ gradient
ADP + Pi
ATP
Heterotrophs
Fermentation


Respiration
glucose
NAD+
ATP
NADH
pyruvate
NAD+
Krebs' cycle
NADH
CO2
NAD+
e-
A
NADH
B
H+ gradient
ADP + Pi
ATP
Heterotrophs
Anaerobic Respiration
NO3 -
NO, N2, N2O,NH3

Respiration



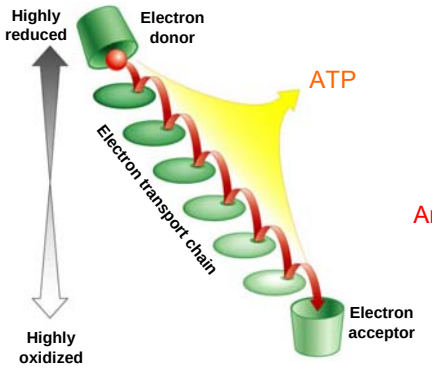
Heterotrophs

Anaerobic Respiration

These are examples: Many things can serve as electron acceptors

Type	A		B
aerobic	O_2	⇒	H_2O
sulfate-reducing	SO_4^{2-}	⇒	H_2S or S
denitrifying	NO_3^-	⇒	NO, N_2, N_2O, NH_3

Freeman Figure 25.5



Anaerobic Respiration

	Electron Donor	Electron Receptor	Product
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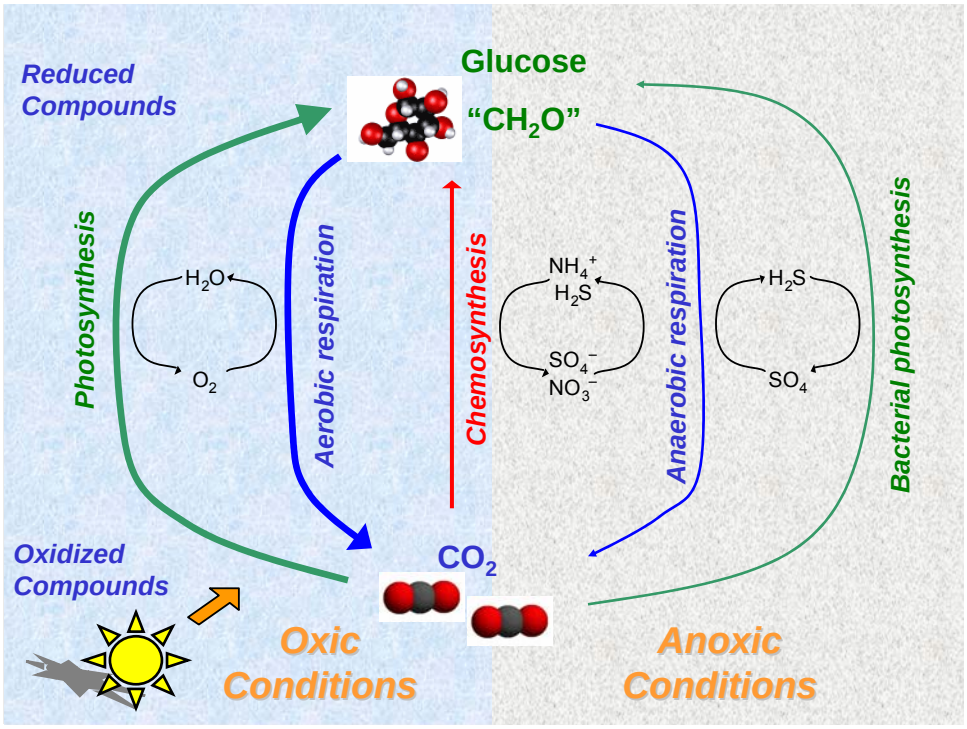
Methanogens	H_2	CO_2	CH_4
Methanotrophs	CH_4	O_2	CO_2
Sulfur Bacteria	S or H_2S	O_2	SO_4^{2-}
Iron-Reducers	organic compounds	Fe^{3+}	Fe^{2+}
Nitrifiers	NH_3	O_2	NO_2^-
Nitrosifiers	NO_2^-	O_2	NO_3^-
Denitrifiers	organic compounds	NO_3^-	N_2O, NO, N_2



Take Home Messages

- There is more than one way to be alive – *energy and carbon and electrons*
- Microbes have most of the metabolic diversity available
- Products of one organism are the substrate for another
- Where metabolic pathway is energetically favorable, a microbe has evolved to take advantage of it