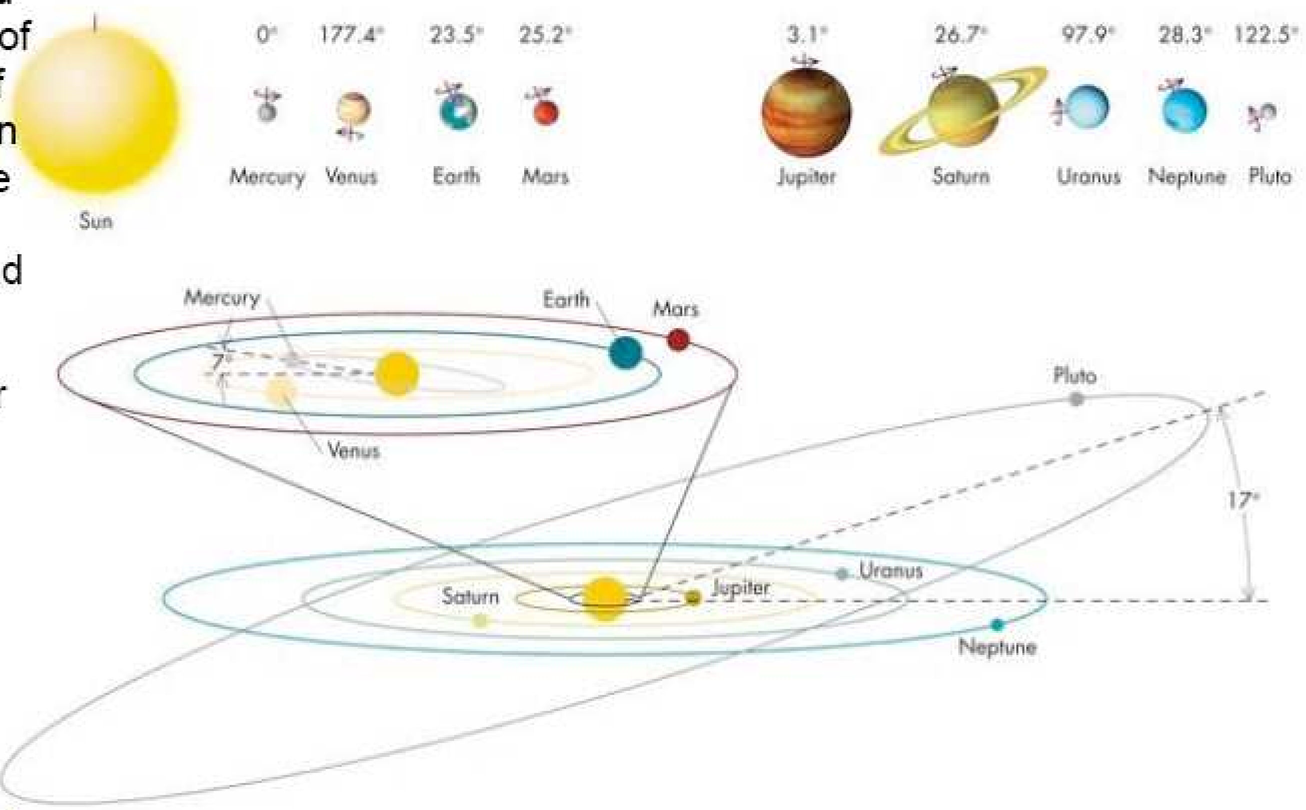
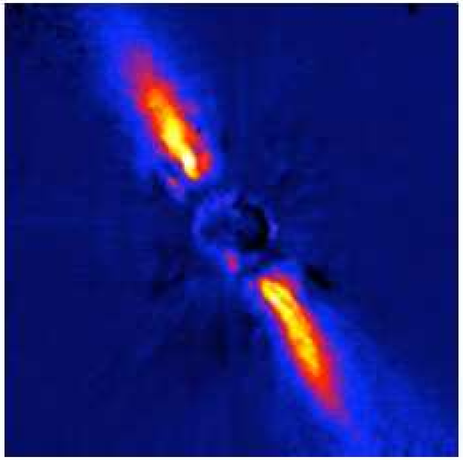
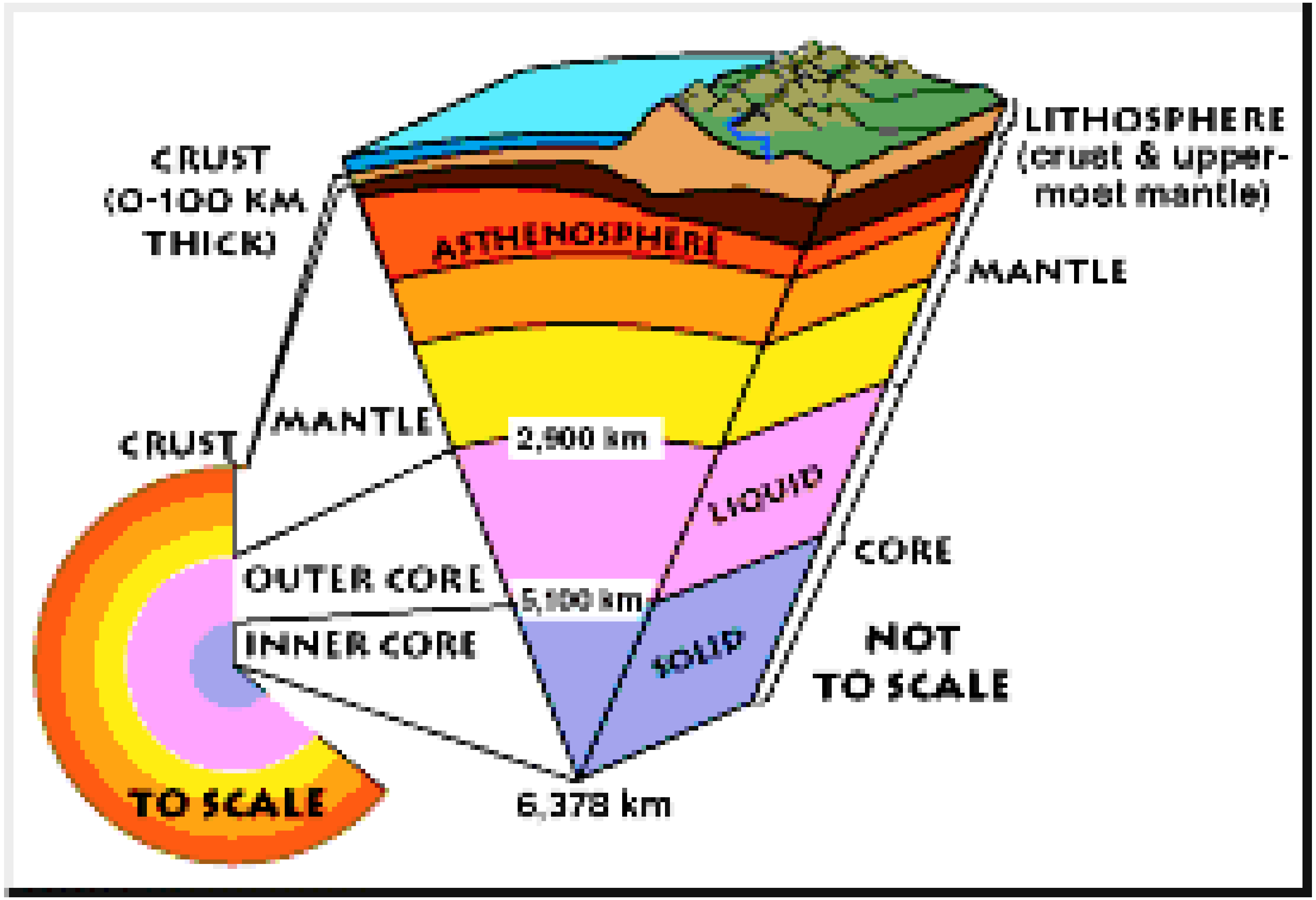
The Solar System formed by gravitational collapse of a large, **rotating** cloud of matter. The central region grew denser and became the Sun. The remainder became a **disk** of gas and dust, **the solar nebula**.

We can see circumstellar discs that support this theory





Beta Pictoris (55.4 light years away) is surrounded by a “debris disk” of dust 1-30 micron size. Transient spectral features may be due to infalling comets. There is little dust within 20 AU of the star, probably because it has coalesced into planetesimals /grains: A solar system in the making.

CRUST
(0-100 KM
THICK)
LITHOSPHERE
(crust & upper-
most mantle)
ASTHENOSPHERE
MANTLE
CRUST
MANTLE
2,900 km
LIQUID
CORE
OUTER CORE
5,100 km
INNER CORE
SOLID
NOT
TO SCALE
TO SCALE
6,378 km

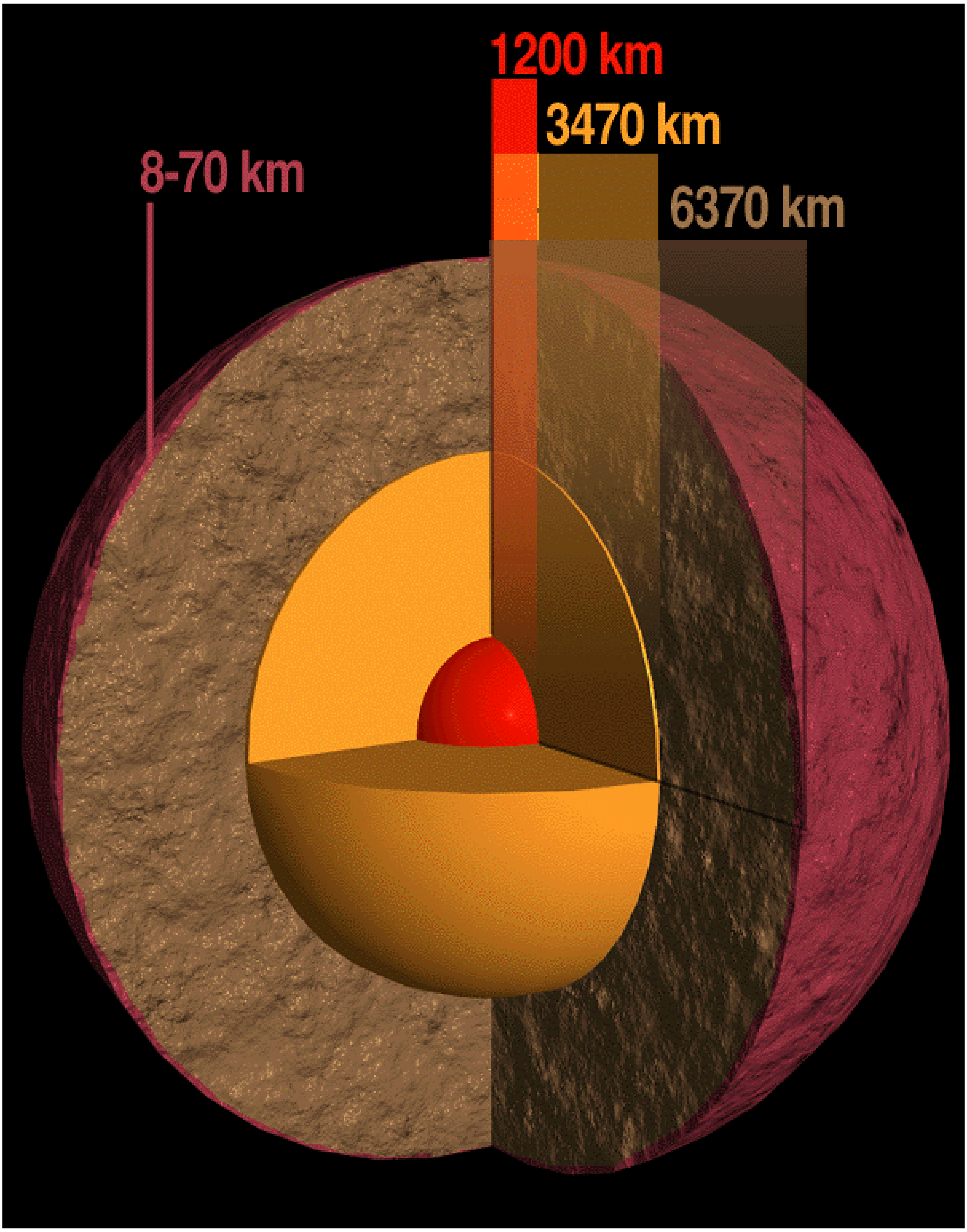

1200 km
3470 km
8-70 km
6370 km

TABLE 2.1 Comparison of the chemical composition of Earth with that of the sun and meteorites (weight percent of element).[a]

		Earth				Meteorites			
Element	Sun	Whole Earth	Continental Crust	Oceanic Crust	Mantle	Average Iron	Average Silicate[b]	Average Chondrite[b]	Carbonaceous Chondrite
Fe	0.00032	35.0	5.63	8.56	5.3	90.78	9.88	27.24	18.75
O	0.078	30.0	46.40	43.8			43.7	33.24	41.93
Si	0.0027	15.0	28.15	24.0	22.0		22.5	17.10	10.58
Mg	0.0021	13.0	2.33	4.5	22.7		18.8	14.29	9.56
Ni	0.00007	2.4	0.0075	0.015		8.59		1.64	1.02
S	0.0017	1.9	0.026	0.025				1.93	6.09
Ca	0.00012	1.1	4.15	6.72	2.0		1.67	1.27	1.11
Al	0.00014	1.1	8.23	8.76	2.2		1.60	1.22	0.87
Na	0.00017	0.57	2.36	1.94	0.4		0.84	0.64	0.56
Cr	0.000014	0.26	0.01	0.02	0.1		0.38	0.29	0.24
Co	0.000004	0.13	0.0025	0.0048		0.63		0.09	0.04
P	0.000019	0.10	0.105	0.14			0.14	0.11	0.18
K	0.000004	0.07	2.09	0.83	0.2		0.11	0.08	0.06
Ti	0.000004	0.05	0.57	0.90	0.1		0.08	0.06	0.04
Mn	0.000007	0.22	0.095	0.15			0.33	0.25	0.16
H	86.0		0.14	0.2					0.21
He	13.0								3.97
C	0.045								5.53

[a] After Cameron, 1966; Ringwood, 1966; Mason, 1966; Taylor, 1964; and Anderson, 1989.

[b] Stony meteorites.

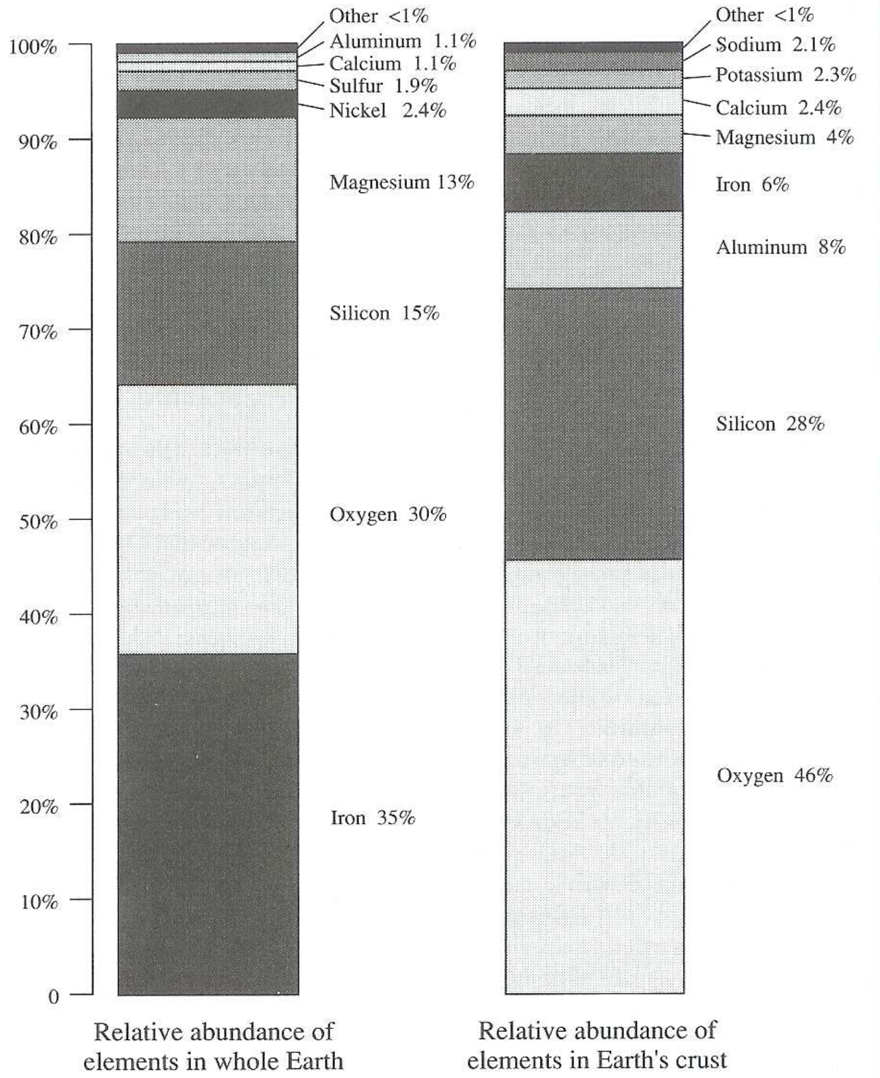


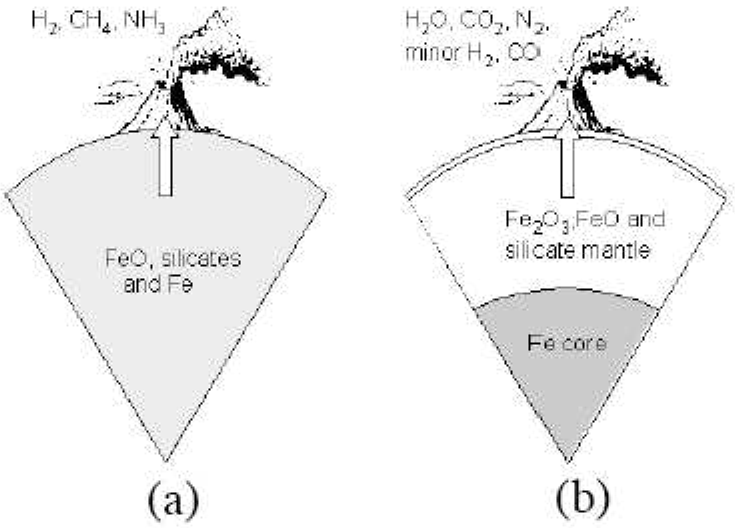
Figure 2.3 Relative abundance of elements by weight in the whole Earth and the Earth's crust. From Earth 4/E. By Frank Press and Raymond Siever. Copyright 1986 by W. H. Freeman and Company. Reprinted by permission.

Origin of Earth's atmosphere & ocean

The early atmosphere came from **outgassing** (release of gases from the solid Earth) and **impact degassing** (release of gases when ice-rich asteroids hit)

Volcanoes give out mostly water and CO_2, with relatively small quantities of H_2, CO, and CH_4, and no O_2.

Before the Earth's iron core formed, during 4.5-4.4 Ga, Earth's atmosphere may have contained a considerable proportion of H_2 and other **reducing** gases (those that would tend to react with oxygen, were it present).



The reduced to oxidized gas ratio (H_2/H_2O, CH_4/CO_2, etc.) in volcanic gases, in particular, depends on the degree of oxidation in the upper mantle, the source region for such gases.

(a) before (b) after core formation

Table 2.1 Composition of Volcanic Gases Released from the Kudryavy and Other Volcanoes

Volcano	Units	H_2O	H_2	CO_2	SO_2	H_2S	HCl	HF	N_2	NH_3	O_2	Ar	CH_4	Reference
Kudryavy, Russia	mole %	95.00	0.56	2.00	1.32	0.41	0.3700	0.030	0.21	—	0.03	0.002	0.002	Taran et al. (1995)
Nevado del Ruiz, Colombia	wgt. %	94.90		2.91	2.74	0.80	0.0052							Williams et al. (1986)
Kamchatka, Russia	vol. %	78.60	3.01	4.87	0.03	0.16	0.5700	0.056	11.87	0.11	0.01	0.060	0.440	Dobrovolsky (1994)

Planetary Conditions for Life

Fundamental Properties

(basic properties of the primitive planet itself)

Positional Properties

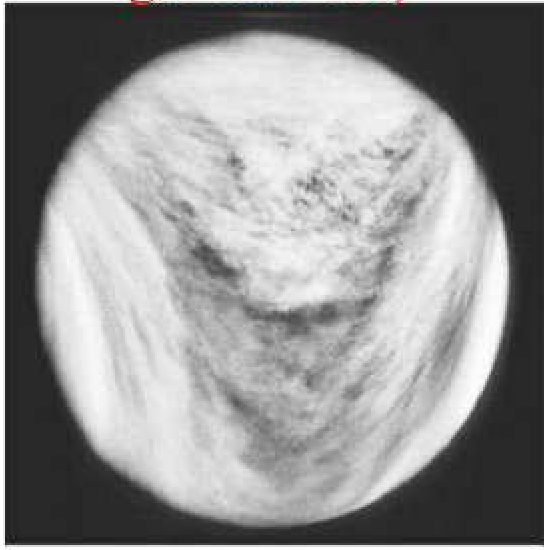
(relative to star or other things in space)

Resultant Properties

(due to combined factors + time)

What makes a good planet go bad?

Venus
(runaway
greenhouse)



- Oceans boiled away
- No more weathering
- Carbon partitions to atmosphere
- CO_2 is ~245,000 times that on Earth

Ts = 460 C

Earth
("just right")

- has oceans
- hydrological cycle
- weathering returns CO_2 to lithosphere
- plate tectonics (volcanoes) return carbon to atmos.
- negative feedback

Mars
(virtually no
greenhouse)

- farther from Sun; too cold for liquid water
- no water vapor greenhouse
- too small for plate tectonics
- no carbon cycle
- CO_2 is ~16 times Earth

$T_s = -55C$

Periodic Table of the Elements*

Atomic Number
Symbol
Atomic Mass**

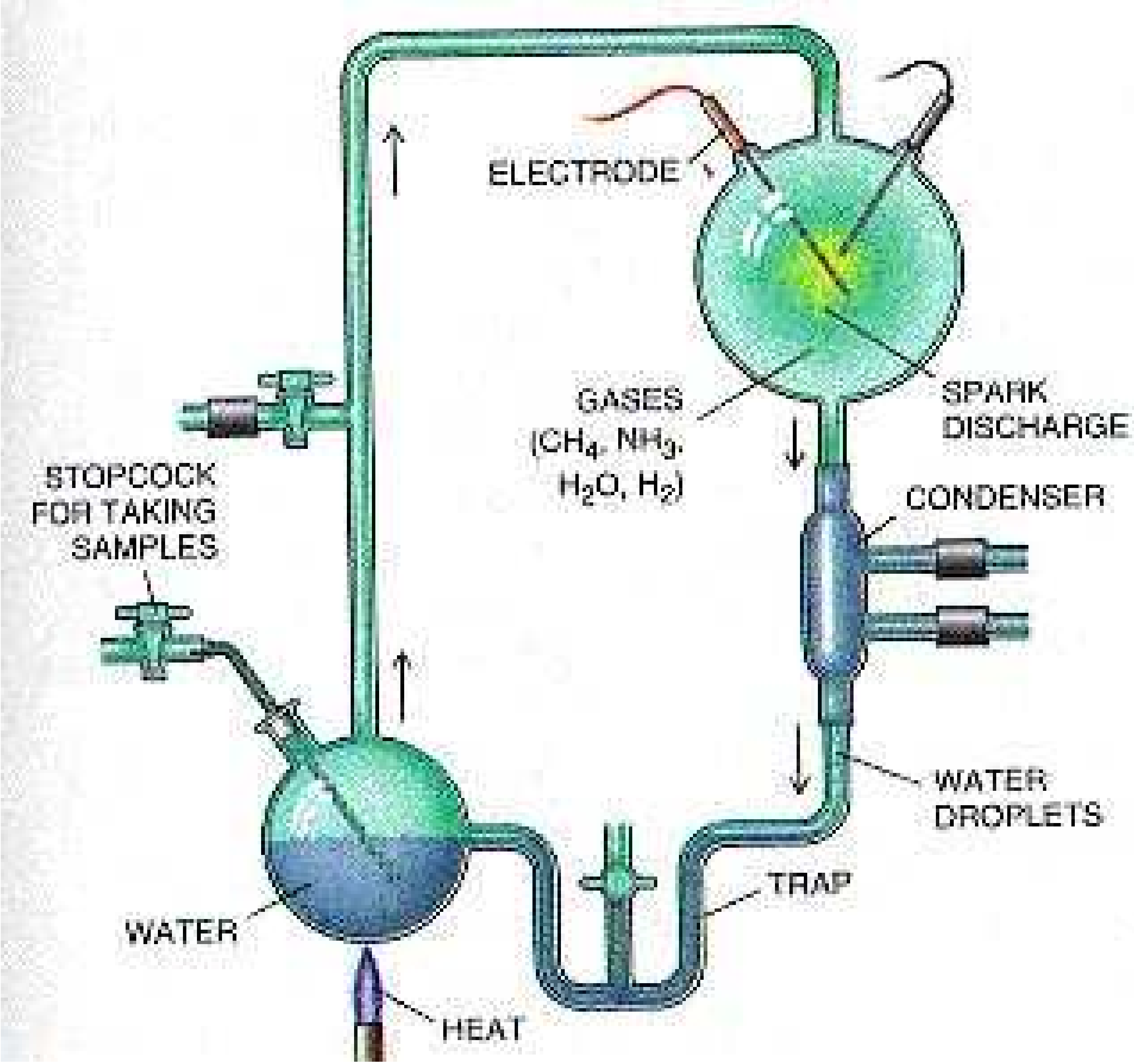
3 Li 6.941

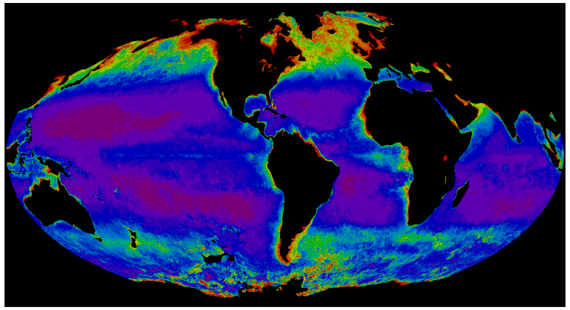
IA	IIA	III B	IV B	V B	VI B	VII B	VIII B			I B	II B	III A	IV A	V A	VI A	VII A	VIII A
1 H 1.0079																	2 He 4.0026
3 Li 6.941	4 Be 9.0122											5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
11 Na 22.990	12 Mg 24.305											13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.066	17 Cl 35.453	18 Ar 39.948
19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.867	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.845	27 Co 58.933	28 Ni 58.693	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.906	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.62	53 I 126.90	54 Xe 131.29
55 Cs 132.90	56 Ba 137.33	57 †La 138.90	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 ‡Ac (227)	104 Rf (261)	105 Ha (262)													

† Lanthanides	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.92	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
‡ Actinides	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lw (262)

* Data adapted from Lide, D.R., Editor (1995) *CRC Handbook of Chemistry and Physics*, 76th Edition. CRC Press, Boca Raton, Florida.

** Atomic mass values in parentheses denote the atomic mass of the most stable isotope of those elements too unstable for the determination of a standard atomic mass.


ELECTRODE
GASES
$(CH_4, NH_3,$
$H_2O, H_2)$
SPARK
DISCHARGE
CONDENSER
STOPCOCK
FOR TAKING
SAMPLES
WATER
DROPLETS
TRAP
WATER
HEAT



Building Blocks of Life

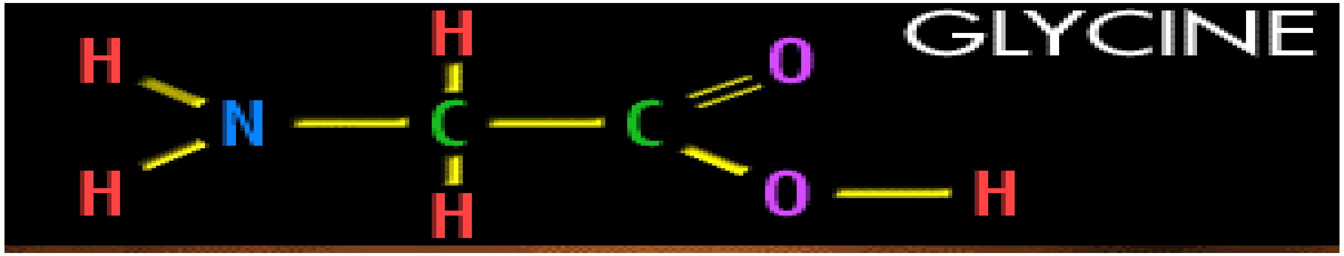
- Four classes of organic molecules are most important to life:
  - Carbohydrates (e.g., sugars, starch, cellulose)
  - Lipids (e.g., fats, oils)
  - Proteins (e.g., meat, tofu)
  - Nucleic acids (e.g., RNA, DNA)

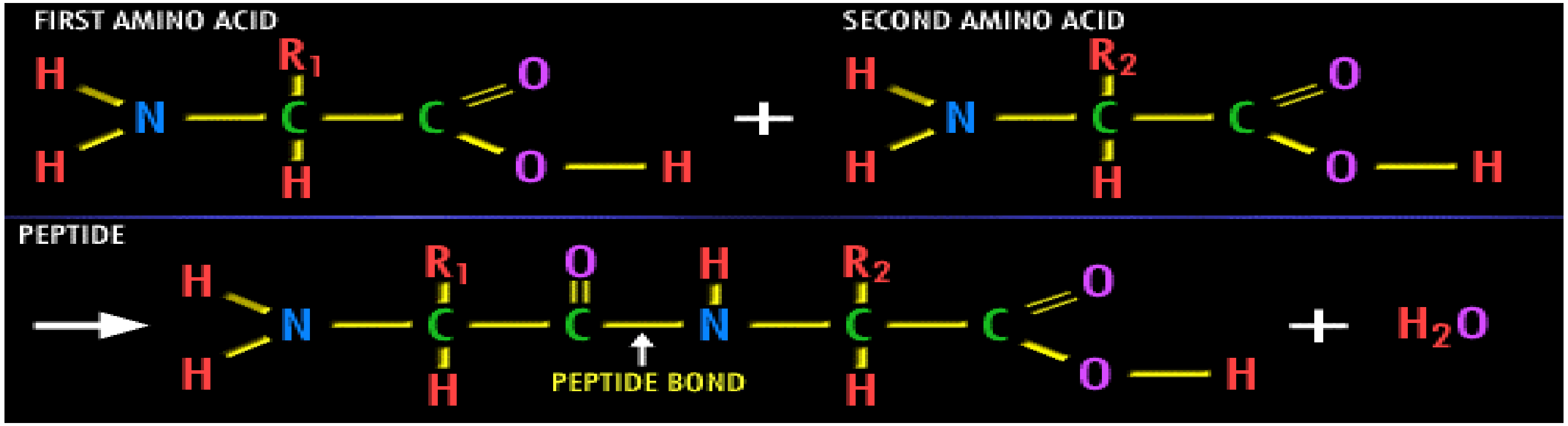
Step 1: Rapid chemical synthesis of raw materials in the atmosphere produces amino acids:

$$NH_3 + 2CH_4 + 2H_20 + energy = C_2H_5O_2N + 5H_2$$

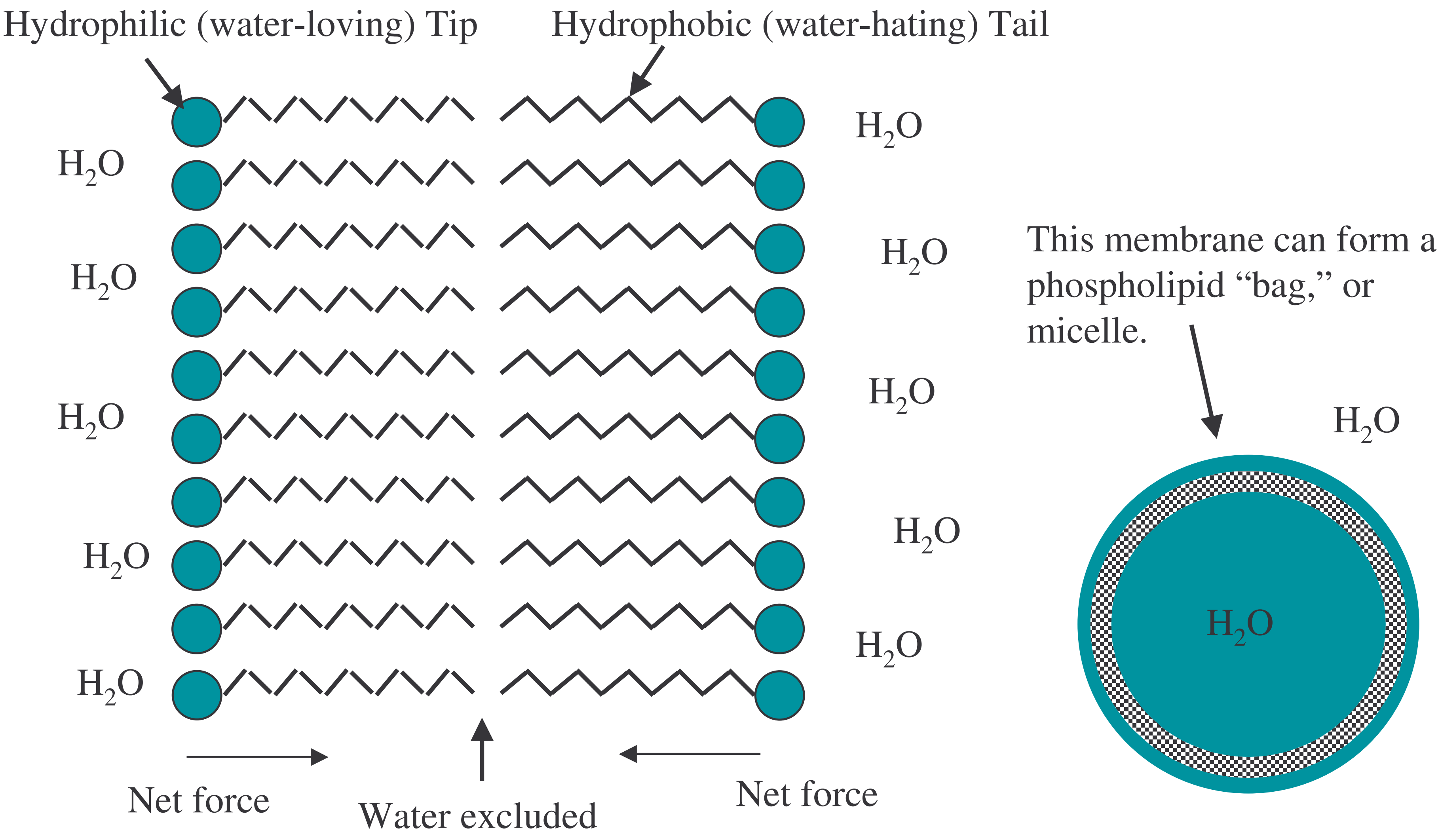
$$5H_2CO = Ribose(food)$$

$$5HCN + UV + NH_3 = Adenine(anotheraminoacid)$$





Phospholipids make a bi-layer membrane



This membrane can form a phospholipid “bag,” or micelle.