Wednesday, December 1
Life As We *Don't* Know It

Final exam: Tuesday, Dec. 7, 1:30 pm.

Life As We Don't Know It
Key Concepts

1) Life on Earth has both universal characteristics and parochial characteristics.

2) Alien life might show universal characteristics resulting from convergent evolution.

3) Silicon might substitute for carbon, or ammonia might substitute for water, in alien life.

Extraterrestrial beings are usually depicted as bipeds.

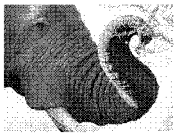
This says less about science than about the power of the Screen Actor's Guild.

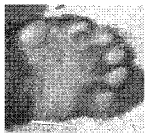
Do we expect actual extraterrestrial beings to look **anything** like humans?

Here on Earth, organisms have both **universal** characteristics and **parochial** characteristics.

Universal: properties that are similar in species that are not closely related (for instance, eyes, wings, limbs, photosynthesis).

Parochial: properties that are unique to one species (for instance, elephant's trunk, panda's thumb).

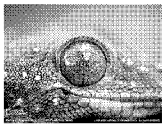


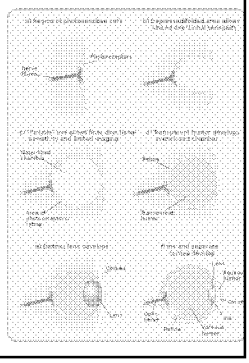


Universal characteristics are so useful, they've emerged many times in different species.

Example: **Eyes**

Sensing light is useful, so eyes are common in Earth species, in slightly different forms.



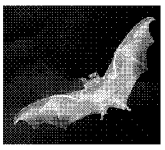


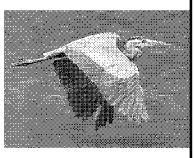
Convergent evolution describes how similar traits are acquired by unrelated lineages.

Example: **Wings**

Bats and birds independently evolved powered flight using wings developed from limbs.

The common ancestor of bats & birds was wingless.





The basic shape of a wing is dictated by physics.

Convergent evolution might cause extraterrestrial beings to have some similar traits to us.

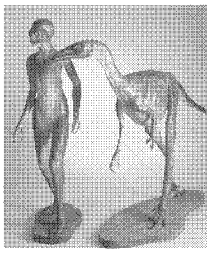
Some universal characteristics may represent the best possible structure given similar biological challenges.

Examples:
- Light-sensitive sense organs (eyes).
- Skeletons (or exoskeletons?)
- Limbs (wings, legs, arms, tentacles).

However, there's always a random element to evolution, driven by unrepeatable contingencies.

What if an asteroid hadn't hit the Earth 65 million years ago?

Perhaps a population of bipedal, big-brained dinosaurs.



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CHON: The primary elements of life are **C**arbon, **H**ydrogen, **O**xygen, & **N**itrogen.

Carbon ("organic") chemistry is the basis of life.
Water (H_2O) is the universal solvent of life.
Nitrogen is a key component of amino acids & DNA.

Other elements are also needed:

P – Phosphorus (DNA, RNA, & ATP/ADP)

S – Sulfur (some amino acids)

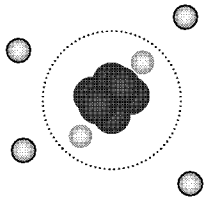
The chemical properties of **carbon** make it extremely versatile.

A carbon nucleus has 6 protons (and usually 6 neutrons).

It's surrounded by 6 electrons:

2 inner shell (non-bonding) electrons

4 valence electrons available for chemical bonds with other elements, *including other carbon atoms*.



Carbon can form single, double, and triple bonds.

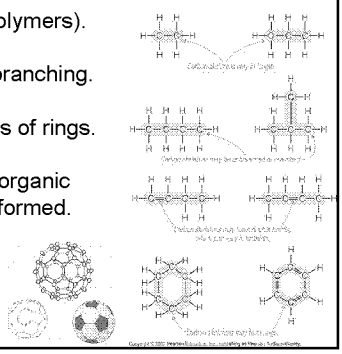
Carbon is able to form a vast variety of organic compounds.

Long linear chains (polymers).

Chains with complex branching.

Close rings or networks of rings.

Millions of possible organic compounds can be formed.



Silicon is chemically similar to carbon: it also has 4 outer electrons.

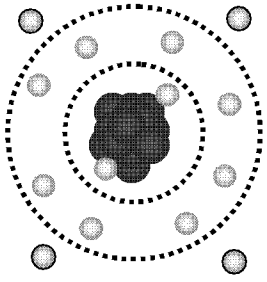
A silicon nucleus has 14 protons (and 14 neutrons).

It's surrounded by 14 electrons:

2 inner shell (non-bonding) electrons

8 second shell (non-bonding) electrons

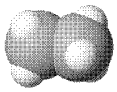
4 valence electrons available for chemical bonds.



In many ways, silicon chemistry is analogous to carbon chemistry.

Silane: SiH_4 – silicon analog of methane.

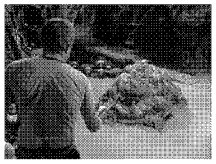
Disilane: Si_2H_6 – silicon analog of ethane.



Silicon can also form chains and rings. In principle, silicon chemistry could be as rich as carbon chemistry.

Silicon-based life would be quite different from carbon-based life.

It could be crystalline, and tolerate high temperatures.

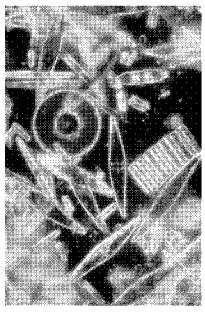


Silicon-based life is a favorite theme of science fiction.

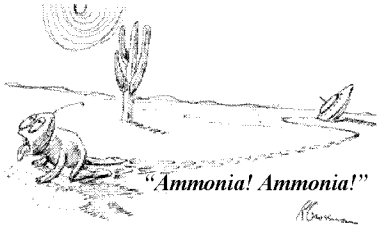
However, silicon has problems as an alternative to carbon.

Si-Si bonds are half as strong as C-C bonds. Silicon chains and rings are **unstable**.

It's much easier to make SiO_2 (silica) than SiH_4. SiO_2 is not water soluble.



Ammonia (NH_3) is a plausible alternative to water as a solvent for the chemistry of life.



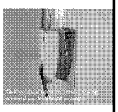
Liquid ammonia dissolves most organic compounds.

Interesting chemistry can occur in liquid ammonia that doesn't occur in liquid water.

At 1 atmosphere of pressure, ammonia is liquid at a narrow range of (cold) temperatures.

Water: liquid from 0 to 100°C (100°C range)

Ammonia: liquid from –78 to –33°C (45°C range)



At 60 atmospheres of pressure, the boiling point of ammonia rises to 98°C.

Such conditions might occur on large rocky planets (superEarths) with reducing atmospheres.

Tomorrow's Lecture:

The Future of the Solar System

Final Exam:

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