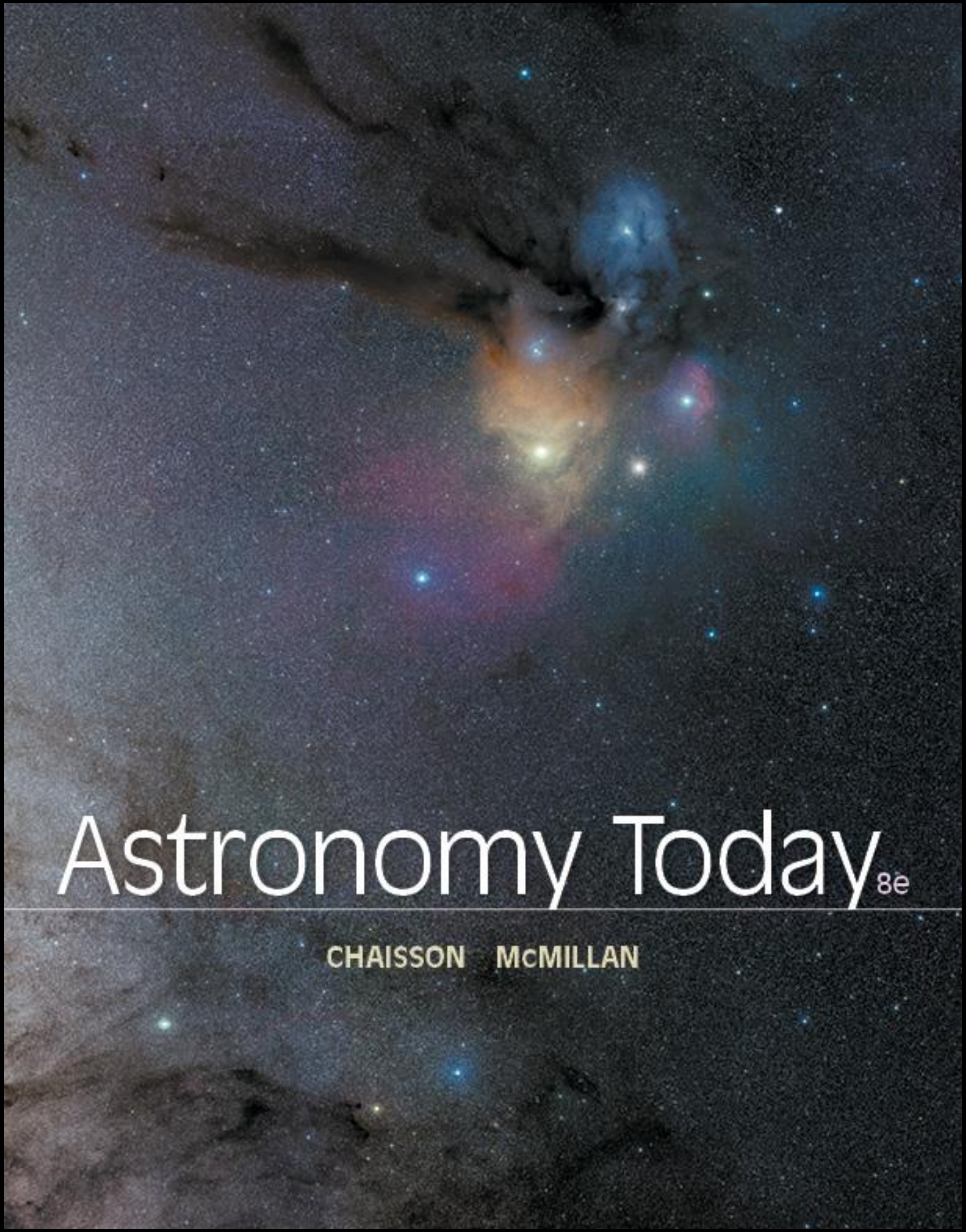


Lecture Outlines

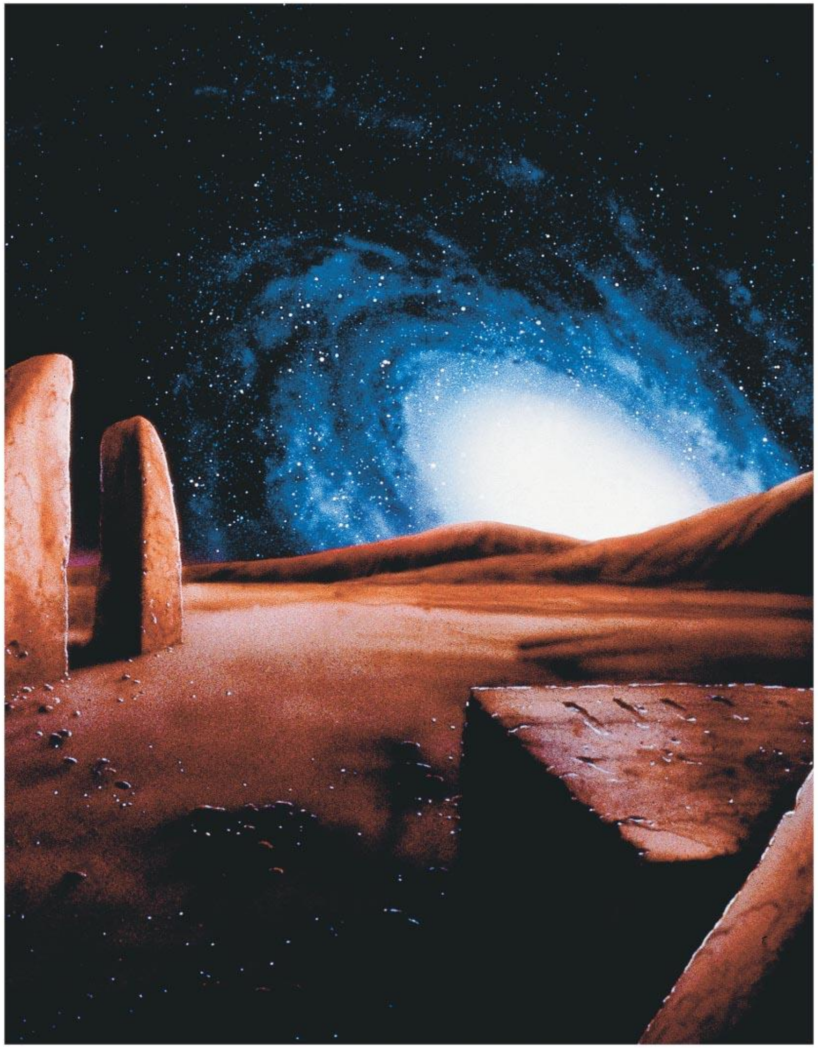
Chapter 28

Astronomy Today

8th Edition

Chaisson/McMillan

Chapter 28
Life in the Universe



Units of Chapter 28

28.1 Cosmic Evolution

If we are going to be looking for life elsewhere in the universe, we need to define what we mean by "life."

It turns out not to be so easy, particularly if we want to allow for types of life that do not appear on Earth!

28.1 Cosmic Evolution

These are some generally agreed-upon characteristics that any life form should have:

- Ability to react to environment
- Ability to grow by taking in nourishment and processing it into energy
- Ability to reproduce, with offspring having some characteristics of parent
- Ability to evolve

28.1 Cosmic Evolution

The image below shows the seven phases of cosmic evolution. We have already discussed particulate, galactic, stellar, and planetary, and will continue with chemical evolution.

28.1 Cosmic Evolution

We have very little information about the first billion years of the Earth's existence; the Earth was simply too active at that time.

It is believed that there were many volcanoes, and an atmosphere of hydrogen, nitrogen, and carbon compounds.

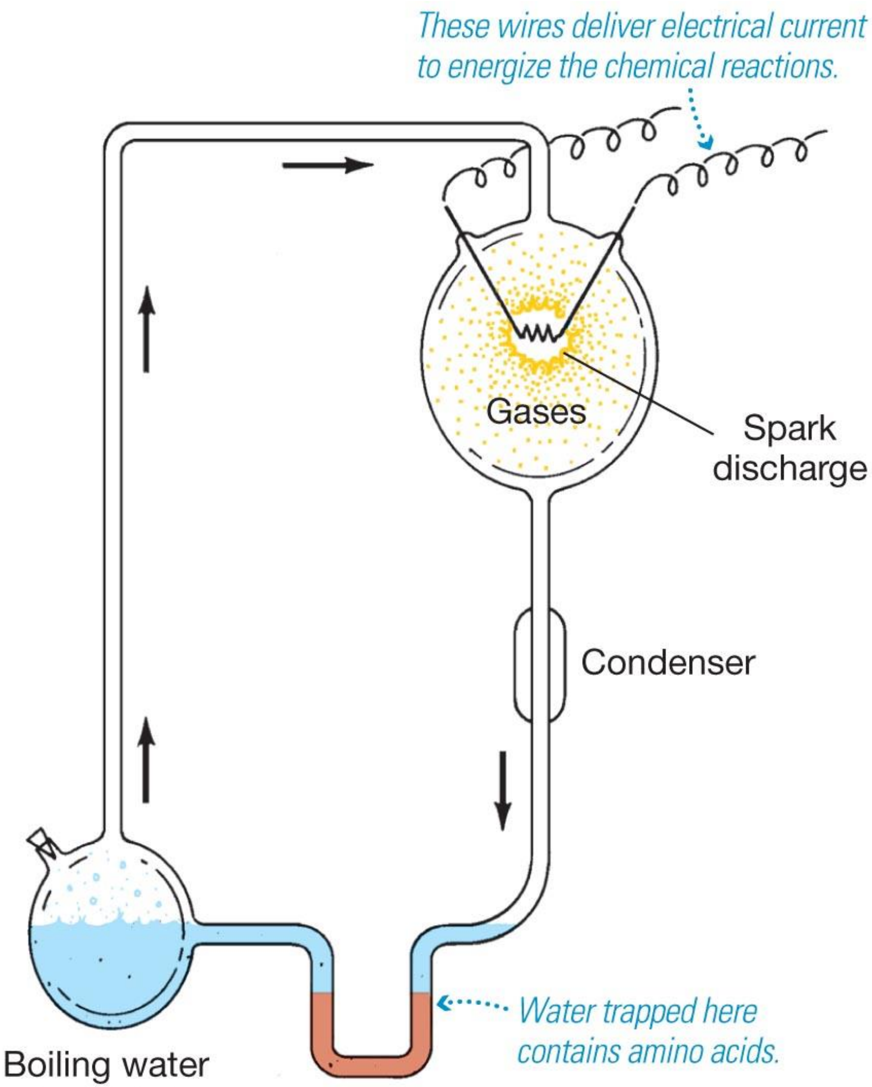
As the Earth cooled, methane, ammonia, carbon dioxide, and water formed.

28.1 Cosmic Evolution

The Earth was subject to volcanoes, lightning, radioactivity, ultraviolet radiation, and meteoroid impacts.

Over a billion years or so, amino acids and nucleotide bases formed. The process by which this happens has been recreated in the laboratory.

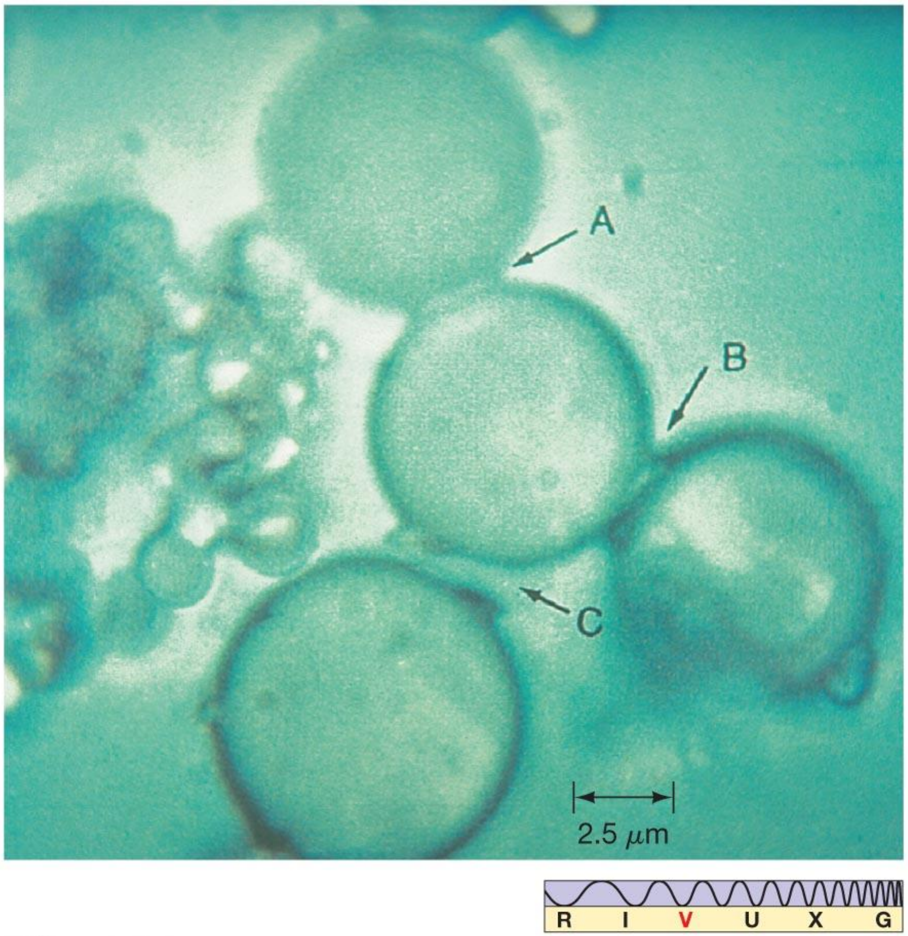
28.1 Cosmic Evolution



This is a schematic of the Urey–Miller experiment, first done in the 1930s, that demonstrated the formation of amino acids from the gases present in the early Earth's atmosphere, excited by lightning.

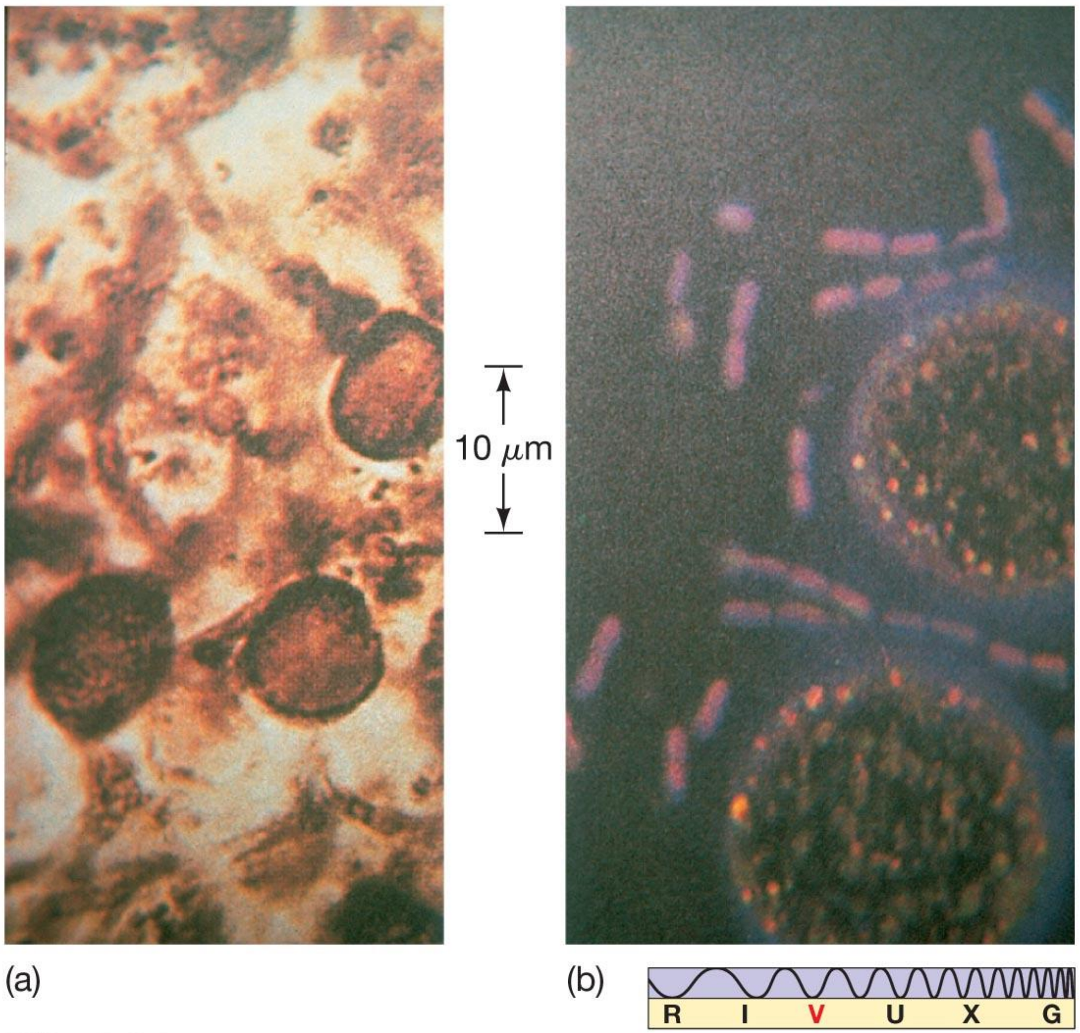
28.1 Cosmic Evolution

These three photographs, taken through a microscope, show structures on the scale of 1 micrometer, which equals 1/10,000 of a centimeter.



This image shows protein–like droplets created from clusters of billions of amino acid molecules: These droplets can grow, and can split into smaller droplets.

28.1 Cosmic Evolution

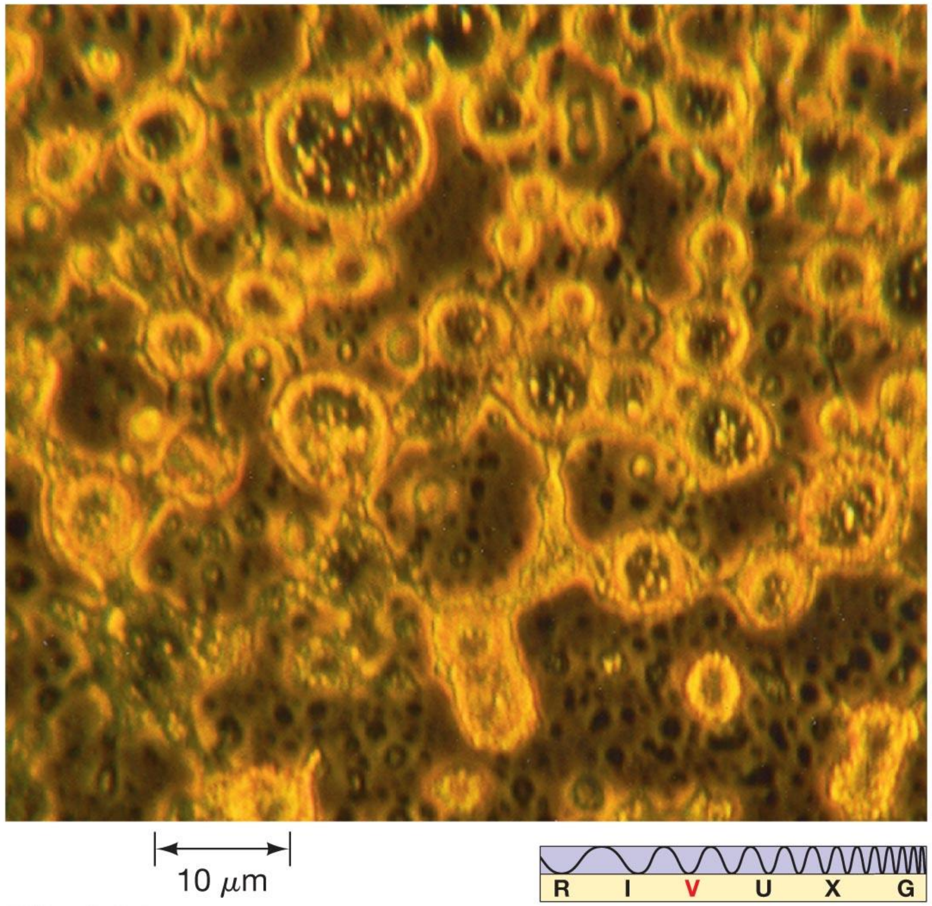


On the left are fossilized remains of single-celled creatures found in 2-billion-year-old sediments.

On the right is living algae. Both resemble the drops in the previous image.

28.1 Cosmic Evolution

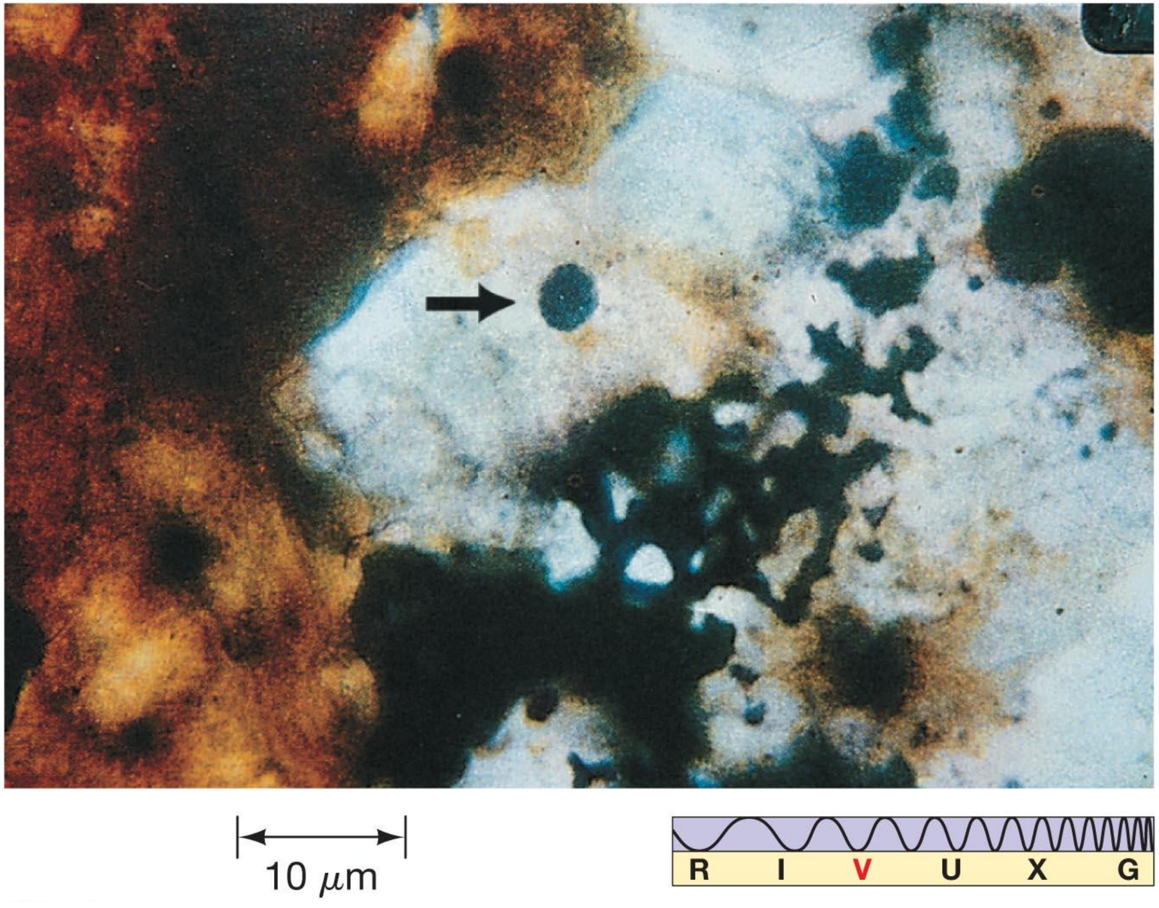
It is also possible that the source of complex organic molecules could be from outside the Earth, on meteorites or comets.



This image shows droplets rich in amino acids, formed when a freezing mix of primordial matter was subjected to harsh ultraviolet radiation.

28.1 Cosmic Evolution

This meteorite, which fell in Australia, contains 12 different amino acids found in Earthly life, although some of them are slightly different in form.



28.1 Cosmic Evolution

- Simple one-celled creatures, such as algae, appeared on Earth about 3.5 billion years ago.
- More complex one-celled creatures, such as the amoeba, appeared about 2 billion years ago.
- Multicellular organisms began to appear about 1 billion years ago.
- The entirety of human civilization has been created in the last 10,000 years.

Discovery 28-1: The Virus

Are viruses alive? They contain some protein and genetic material but cannot be considered alive until they become part of a host cell. They transfer their genetic material into the cell, take over the chemical activity, and reproduce.

Viruses are in a “gray area” between living and nonliving, and serve as a reminder of how complex the definition of life can be.

28.2 Life in the Solar System

Life as we know it: carbon-based, originated in liquid water

Is such life likely to be found elsewhere in our Solar System?

- Best bet: Mars
- Long shots: some icy moons of outer planets

Other places are all but ruled out

28.2 Life in the Solar System

Mars has had liquid water on its surface in the past. Martian landers have analyzed soil, looking for signs of life—either fossilized or recent—but have found nothing.

28.2 Life in the Solar System

Even on Earth, organisms called extremophiles survive in environments long thought impossible—here, hydrothermal vents emitting boiling water rich in sulfur.

28.2 Life in the Solar System

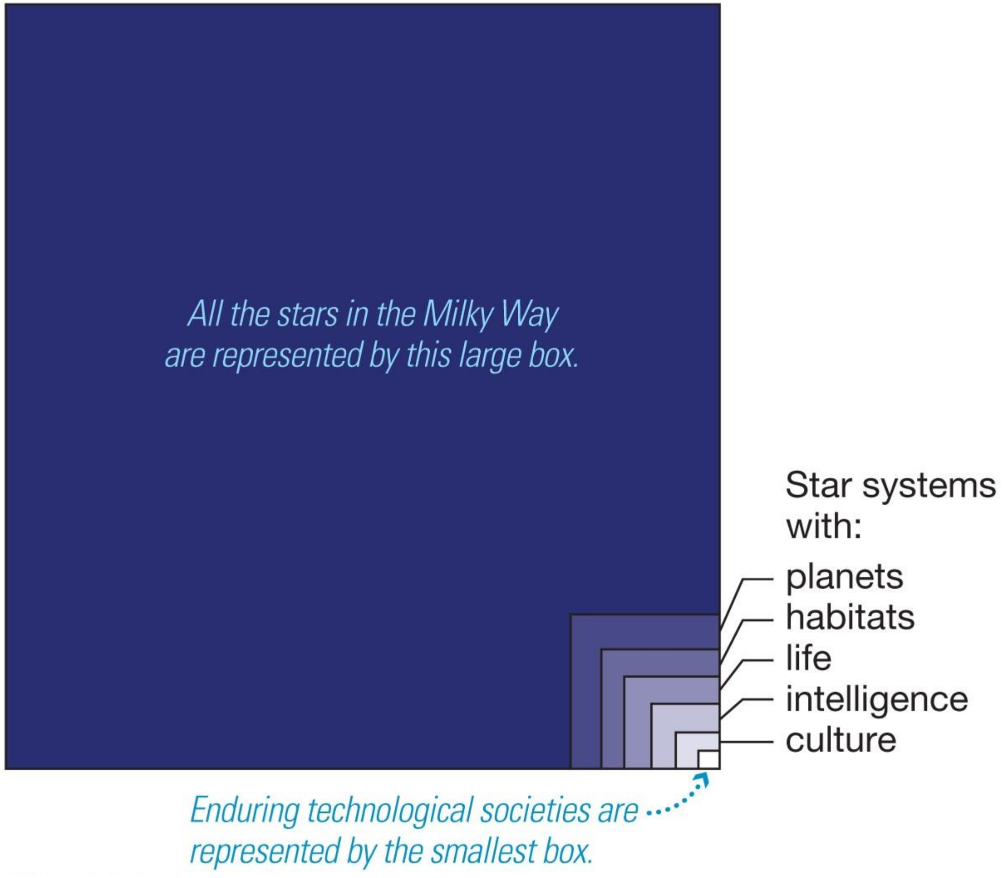
What about alternative biochemistries?

Some have suggested that life could be based on silicon rather than carbon, as it has similar chemistry.

Or the liquid could be ammonia or methane rather than water.

However, silicon is much less likely to form complex molecules, and liquid ammonia or methane would be very cold, making chemical reactions proceed very slowly.

28.3 Intelligent Life in the Galaxy



The Drake equation, illustrated here, is a series of estimates of factors that must be present for a long-lasting technological civilization to arise.

28.3 Intelligent Life in the Galaxy

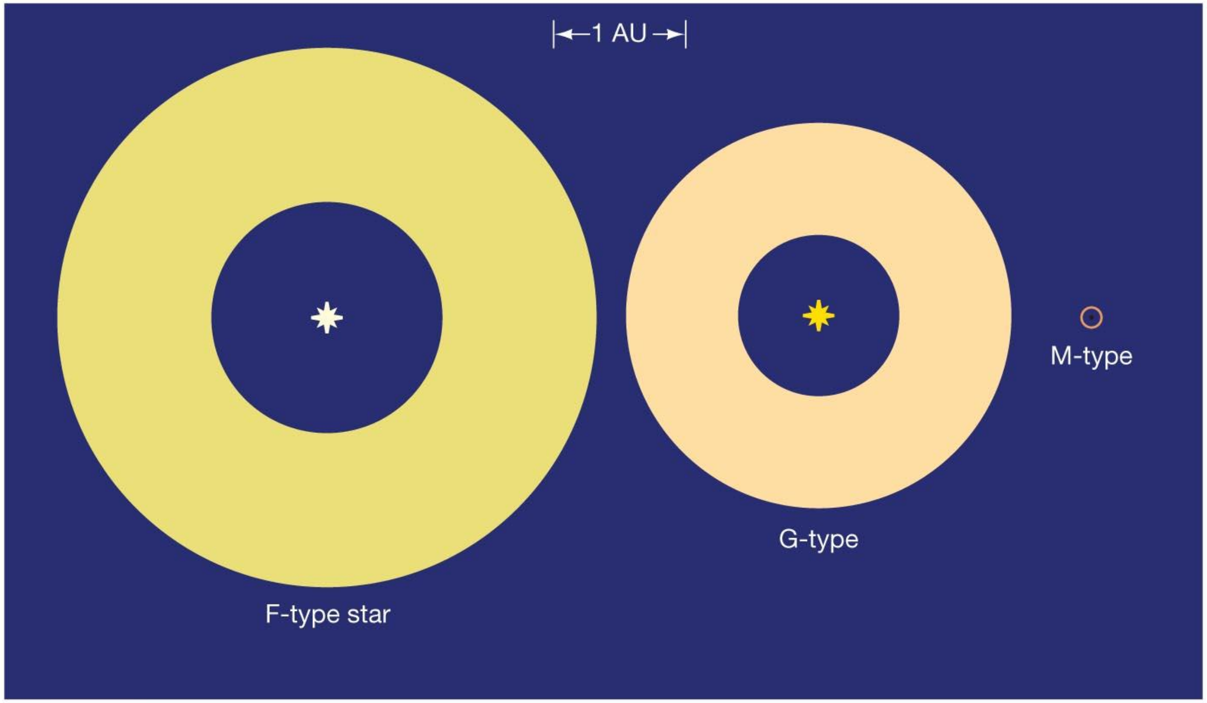
number of technological, intelligent civilizations now present in the Galaxy	=	**rate of star formation,** averaged over the lifetime of the Galaxy	×	fraction of stars having **planetary systems**	×	average number of **habitable planets** within those planetary systems	×	fraction of those habitable planets on which **life arises**	×	fraction of those life-bearing planets on which **intelligence evolves**	×	fraction of those intelligent-life planets that develop **technological society**	×	average **lifetime** of a technologically competent civilization.

28.3 Intelligent Life in the Galaxy (cont.)

- The rate of star formation: 10 stars per year (dividing population of Milky Way by its present age)
- Fraction of stars having planetary systems: most planetary systems like our own have not been detected yet, but we expect to detect them using current methods after increasing telescope visibility.

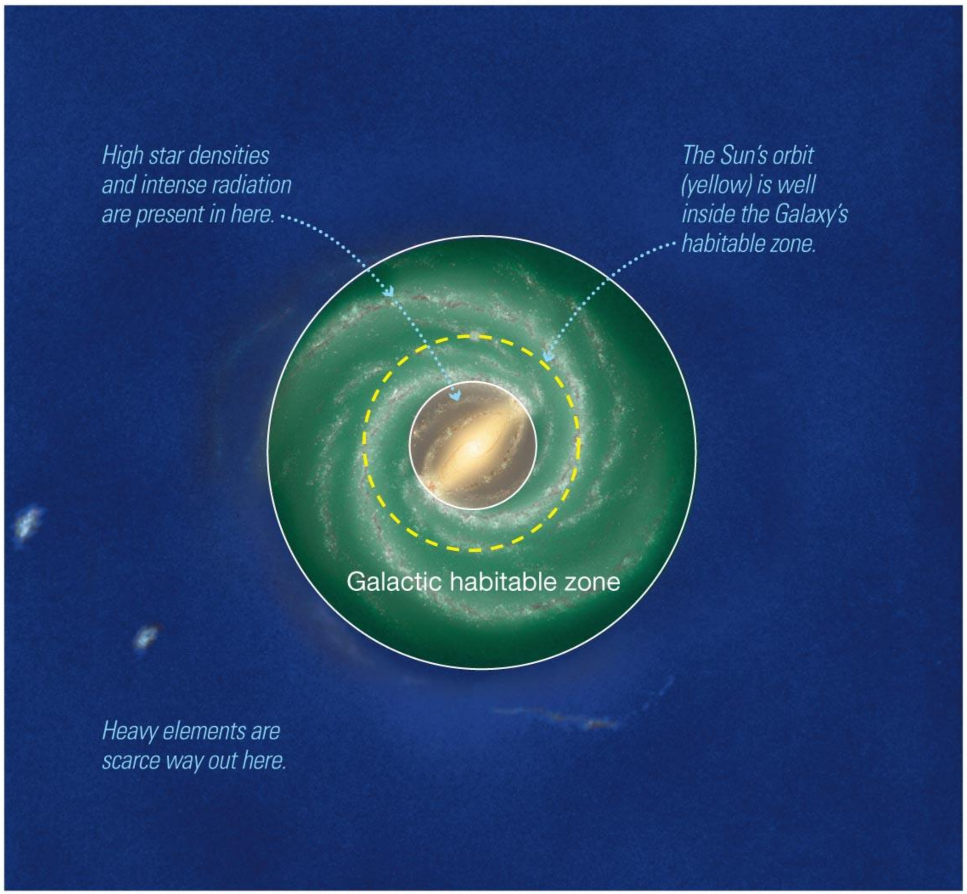
28.3 Intelligent Life in the Galaxy (cont.)

- Number of habitable planets per planetary system: probably only significant around A-, F-, G-, and K-type stars. Smaller stars have a too-small habitable zone and are prone to violent surface activity, and lifetimes of larger stars are too short.



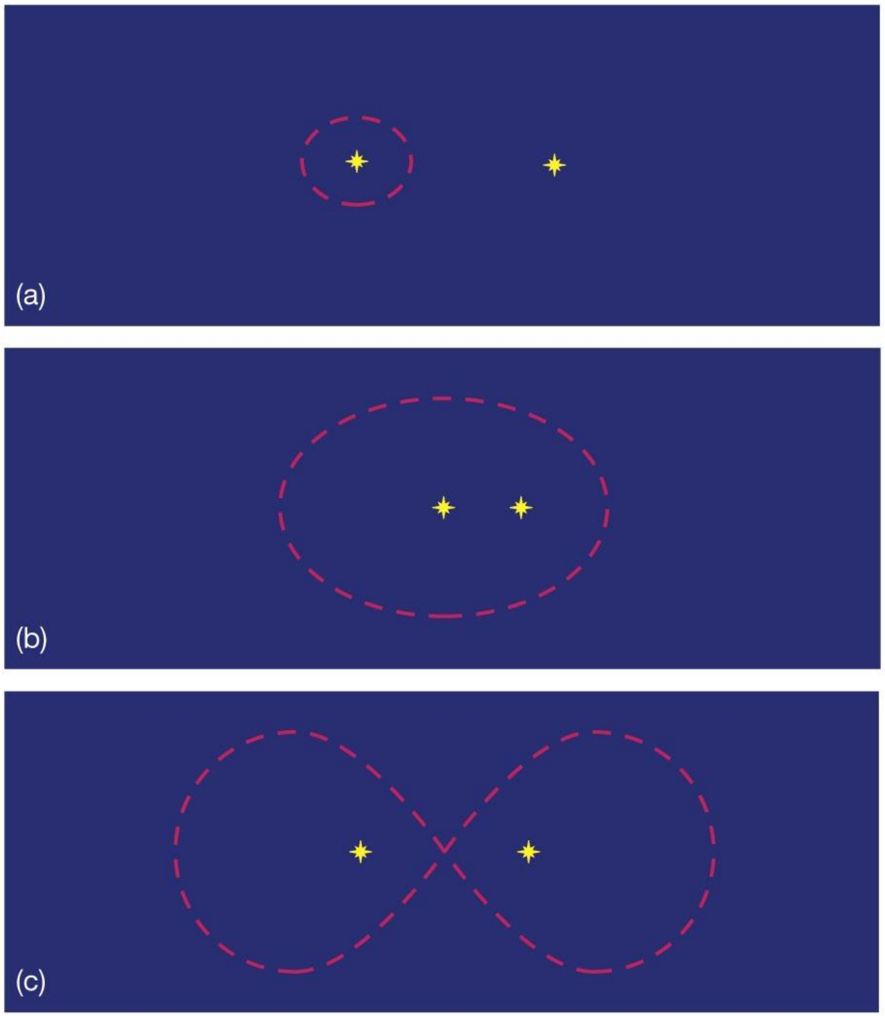
28.3 Intelligent Life in the Galaxy (cont.)

In addition, there are Galactic habitable zones—



there must not be too much radiation, or too few heavy elements.

28.3 Intelligent Life in the Galaxy (cont.)



Finally, it is very unlikely that a planet in a binary system would have a stable orbit unless it is extremely close to one star, or very far away from both.

Give this factor a value of 1/10: one habitable planet in every 10 planetary systems.

28.3 Intelligent Life in the Galaxy (cont.)

- Fraction of habitable planets on which life actually arises:

  Experiments suggest that this may be quite likely; on the other hand, it might be extremely improbable!

  We'll be optimistic, and give this factor a value of one.

28.3 Intelligent Life in the Galaxy (cont.)

- Fraction of life-bearing planets where intelligence arises:

  Here we have essentially no facts, just speculation and opinion.

  We'll continue being optimistic, and assign this factor a value of one.

28.3 Intelligent Life in the Galaxy (cont.)

- Fraction of planets where intelligent life develops and uses technology:

Again, we have no facts, but it does seem reasonable to assume that intelligent life will develop technology sooner or later.

We'll give this factor a value of one also.

28.3 Intelligent Life in the Galaxy (cont.)

So, right now the first six factors, as we've assigned values to them, give:

10 x 1 x 1/10 x 1 x 1 x 1 = 1

Therefore:

number of technological intelligent civilizations now present in the Milky Way Galaxy = average lifetime of a technologically competent civilization in years.

28.3 Intelligent Life in the Galaxy (cont.)

For the average lifetime of a technological civilization, we can't even use ourselves as an example—our civilization has been technological for about 100 years, but who knows how long it will last?

Also, we assigned a value of one to several very uncertain factors; even if only one of them is low, the number of expected civilizations drops quickly.

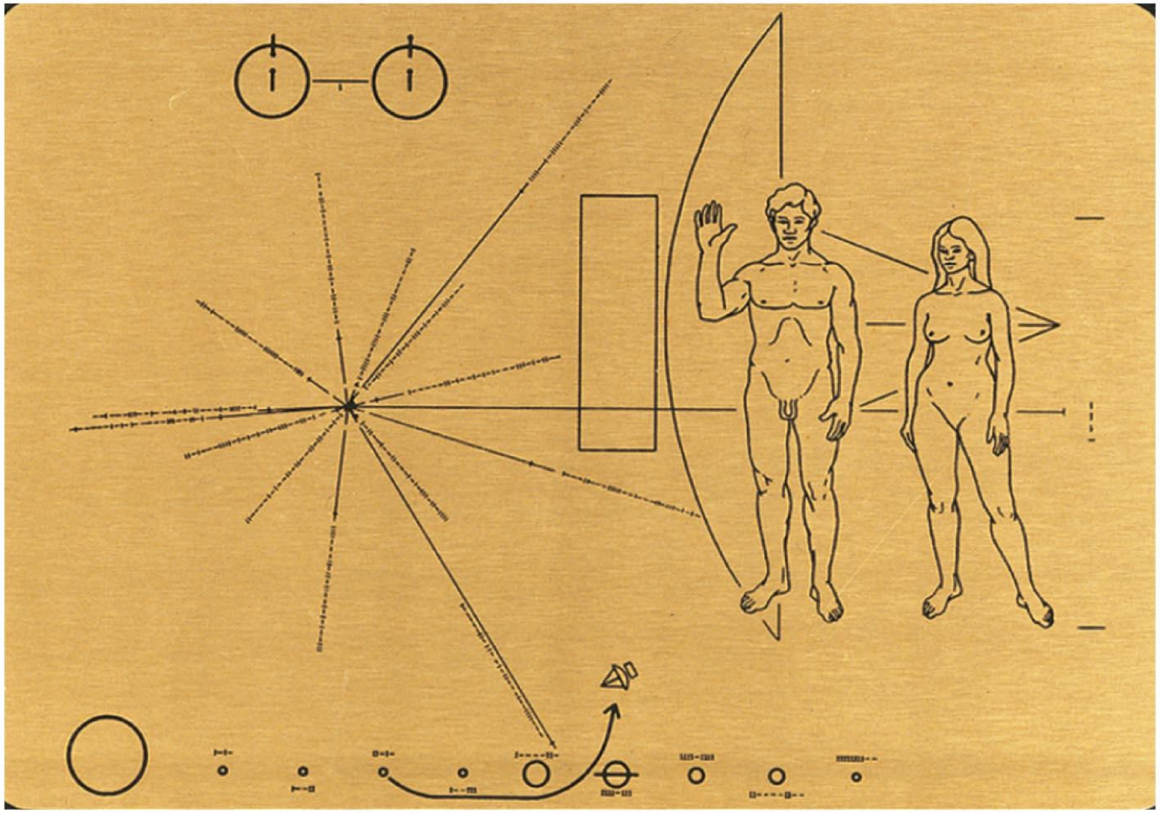
28.4 The Search for Extraterrestrial Intelligence (cont.)

If the average lifetime of a technological civilization is one million years, there should be a million such civilizations in our Galaxy, spaced about 30 pc, or 100 ly, apart on average.

This means that any two-way communication will take about 200 years (if there is in fact a technological civilization 100 light-years or less away from us).

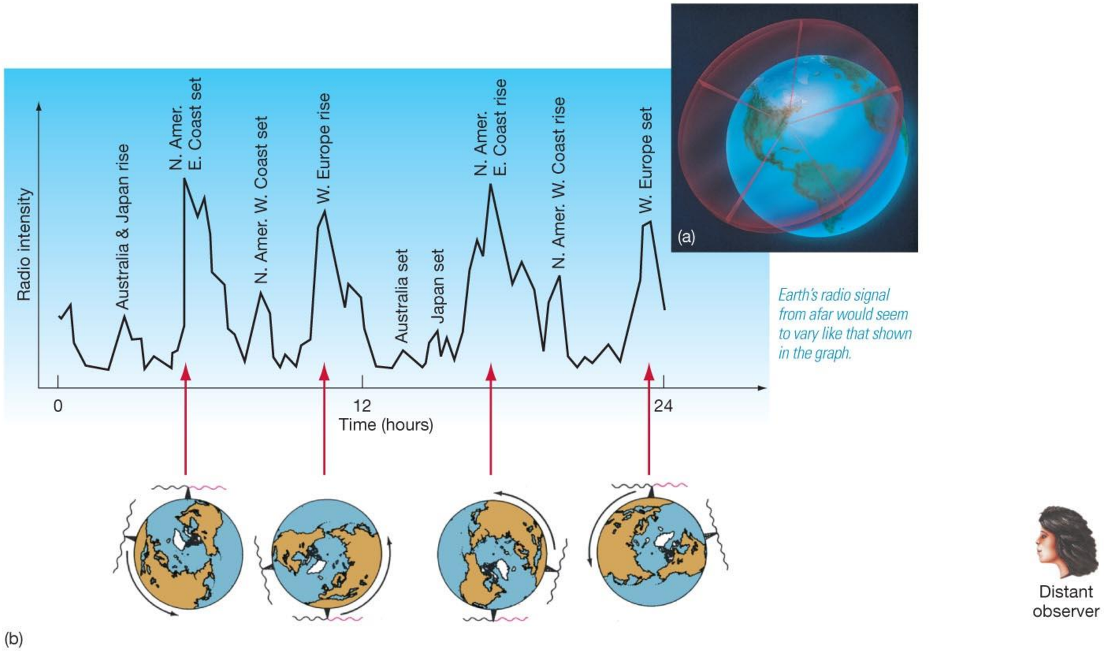
28.4 The Search for Extraterrestrial Intelligence (cont.)

We have already launched interstellar probes. This is a plaque on the *Pioneer 10* spacecraft.



28.4 The Search for Extraterrestrial Intelligence (cont.)

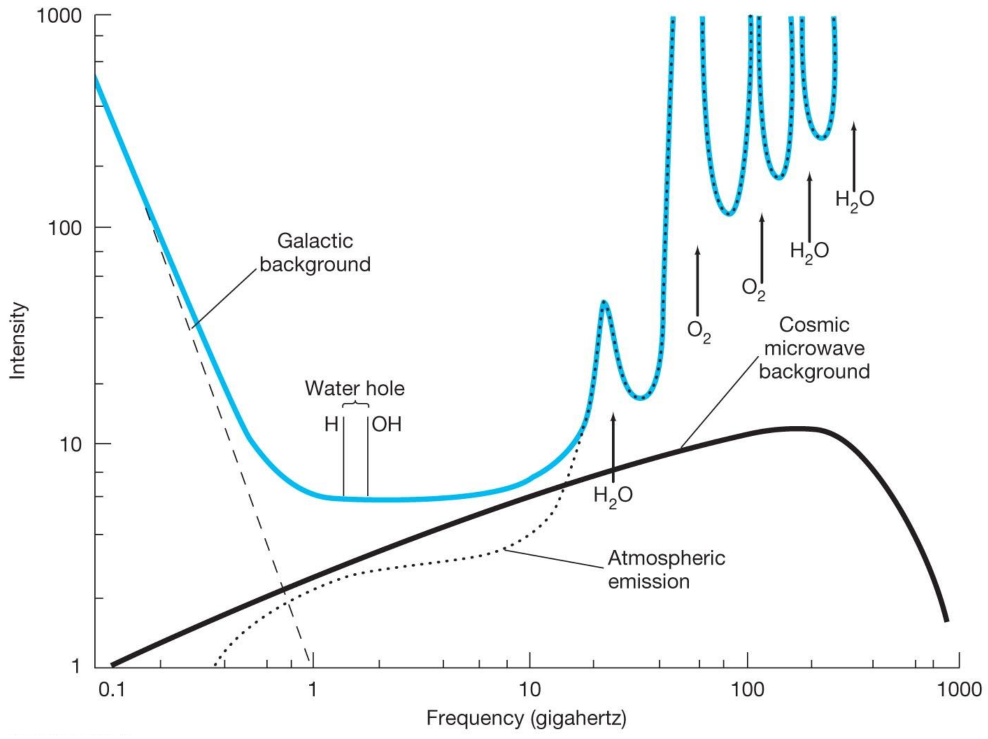
We are also communicating—although not deliberately—through radio waves emitted by broadcast stations.



These have a 24-hour pattern, as different broadcast areas rotate into view.

28.4 The Search for Extraterrestrial Intelligence (cont.)

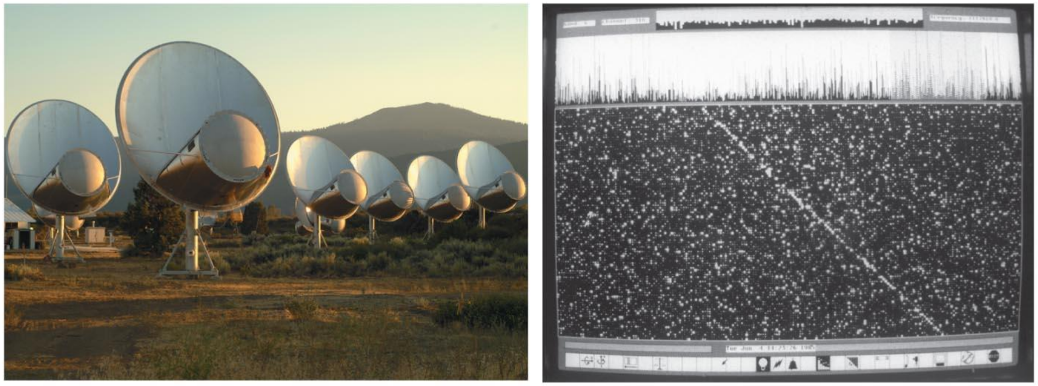
If we were to deliberately broadcast signals that we wished to be found, what would be a good frequency?



There is a feature called the "water hole" around the radio frequencies of hydrogen and the hydroxyl molecule. The background is minimal there, and it is where we have been focusing many of our searches.

28.4 The Search for Extraterrestrial Intelligence (cont.)

This is a view of the SETI array of telescopes, designed to search for extraterrestrial signals. The inset is a test using the *Pioneer 10* spacecraft; no true extraterrestrial signal has ever been found.



(a) (b)

Summary of Chapter 28

- The history of the universe can be divided into phases: particulate, galactic, stellar, planetary, chemical, biological, and cultural.
- This whole process is called cosmic evolution.
- Living organisms should be able to react to their environment, grow by taking in nutrients, reproduce, and evolve.
- Amino acids could have formed in the conditions present on the early Earth, or in space.

Summary of Chapter 28 (cont.)

- Other places in our solar system that may harbor life are Mars and some of the icy moons of the outer planets.
- The Drake equation can be used to estimate the total number of intelligent civilizations in our galaxy, although a number of its factors are extremely uncertain.
- Even using optimistic assumptions, the next nearest technological civilization is likely to be hundreds of parsecs away.

Summary of Chapter 28 (cont.)

- We have sent probes that will get to interstellar space eventually; they include information about us.
- We also "leak" radio signals, which to an outside observer would exhibit a 24-hour periodic variation.
- The "water hole"—a frequency around the hydrogen and OH frequencies—is a good place both to broadcast and to seek messages.