TwoOldGuys™ Study Guides
BI114 Biological Concepts for Teachers
Chapter 4. History of Life
4.1. Invasion of Land, part 1

Based on Indiana's Academic Standards, Science, as adopted by the Indiana State Board of Education, Nov 2000.

Numbers refer to the age-appropriate grade-level for the content.

Review

Life is believed to have originated in the oceans, a process that some scientists suspect may still be occurring on the bottom of the Atlantic Ocean at volcanoes called black smokers. After the first mass extinction, with the development of an oxygen atmosphere complete with ozone layer, there would have been a dramatic reduction in mutation rate. The slower mutation rate is believed by some biologists to have allowed for the development of more complex life forms: algae and protozoa (Protista), then multicellular plants (red, brown and green algae or seaweed) and multicellular animals (sponges, jellyfish and primitive worms). The primitive worms evolved to complex worms, marine invertebrates (trilobites, crabs, lobsters, shrimps) and even vertebrates (fish).

the Invasion of Land, Part 1

grades secondary: to college:

Wave action

Waves move up and down on the open waters of the ocean(or a lake), or in and out along the beach. Imagine the beach to be a mud flat rather than a nice sandy beach. One example is off the west coast of France, where at high tide there was a castle about 1.2 kilometers (1 mile) off shore on a tiny island. A low tide you could have walked across the mud flat to the castle. This may be the most extreme example of an inter-tidal zone [the zone between low and high tides]. You should probably know that high tide occurs whenever the Sun, Moon and Earth line up. The combined gravitational pull of the Sun and of the Moon on the ocean results in the highest tides of the lunar [monthly] cycle. These high tides occur every twelve hours around the time of the full Moon or the new Moon. Perpendicular to the line of the Sun – Moon – Earth, the tides reach their lowest levels of the lunar cycle. These low tides follow the high tides by six hours. At the first quarter Moon and the third quarter Moon, the gravity of the Sun and the gravity of the Moon are at right angles, resulting in a “Neap tide” during which there is almost no difference between the sea level during the twenty-four hour day. While the tide establishes the location of “sea level,” waves are added, which means that waves rise above and fall below the tidal sea level.

If you have ever watched waves running up on the shore, you will have observed that debris is often carried up beach and back out with the waves. However there is a debris line that matches the highest waves of the day. We have observed seaweed and even animals carried up into the debris line, but the live creatures stranded by the waves tend to die quickly.

Hypothesis:

Two seaweeds of shallow oceans waters above the continental shelf are *Ulva* or sea lettuce, a green algae, and *Laminaria* or kelp, a brown algae. The *Ulva* is interesting because it has the same chlorophyll chemicals as do land plants, and the *Laminaria* is interesting because it has an epidermis as do the land plants.

When *Ulva* becomes stranded on the beach, it can dry out and die within a few hours or less, but *Laminaria* can survive for up to 15 hours. Since the tide comes in every 12 hours, *Laminaria* can survive until the next high tide. One hypothesis suggests that an *Ulva*-like seaweed by the beginning of the Silurian [440 Myr BP], had developed an epidermis similar to the *Laminaria*, allowing it to survive from one high tide to the next. This Silurian green algae seaweed is hypothesized also to have tissues modified for the transport of minerals from the sea floor up to an extensive blade system. This adaptation would have allowed the plant to transport both minerals and water from the mud to the rest of the plant. Such plants would have appeared on the beach up to the high tide line as rather slimy green sheets, barely noticeable from any distance.

The new semi-terrestrial green algae would have been at fairly high risk of being buried under the mud as the waves moved mud around on the beach. This burial would result in the algae suffocating unless a new mutation were to occur that would allow vertical growth. The characteristic of living land plants that allows vertical growth upward is auxin, a growth hormone that detects the direction “up” by suppressing growth unless gravity pulls the hormone away from the stem tip. The hypothetical land plant that would result could grow upward through the mud, to emerge and continue photosynthesis. Because the entire plant was soft tissue, it would look similar to green strings rising about 20 mm above the mud surface. (The height of 20 mm was estimated by holding a piece of string between my pointer finger and thumb, then increasing height of the string above my fingers slowly until the string fell down.) From a distance, these plants would have looked like a green fuzz covering the muddy beach. The next mutation required to make this story work is to deposit the protein lignin in the cell walls of the conducting tissue, providing the stem with much greater strength. Such plants have been found in Silurian fossil beds [440 – 400 Myr BP]. The plants would have looked similar to green number 2 lead pencils up to 0.2 meters [almost 8 inches] tall. These new plants match the fossil species *Rhynia* & *Cooksonia*, class Rhyniopsida, division Psilophyta [see section 2.6 Vascular plants, lower plants]. The final mutation that allowed these whisk ferns to invade the land was the development of thick walled spores that are wind-carried and drought resistant.

A later improvement was a mutation to make leaves, but the oldest known fossils plants with leaves did not appear for another 50 million years or so, in the Devonian [400-350 Myr BP].

2nd Hypothesis:

Another amusing little story with a surprise ending.

Growing on the bottom of shallow fresh-water lakes and ponds (on soils derived from limestone) is a fresh water green algae, *Chara* or stonewort. These plants have a single pale green to brownish stem with whorls of green branches [resembling a horsetail, see section 2.6. vascular plants, lower plants; except the dominant plant is the gametophyte]. Because of their unique, among algae, archegonia (egg-producing organs) and antheridia (sperm-producing organs), they are often given their own Phylum: Charophyta. Normally these algae are rooted in the soil at the bottom of the pond. However, waves sometimes break off the plants which then float as mats just under the water surface, where they survive the rest of the growing season. If any part of the plant breaks the water surface, that part dries out and dies within minutes.

Another plant, peat moss, *Sphagnum*, class Sphagnopsida, phylum Bryophyta, also occurs as floating mats just above the water surface. These also have a pale green to brownish single stem with whorls of green branches. The stems are thicker in diameter than *Chara* due to the presence of cells on the epidermis that transport water by wick-action, keeping the plant moist up to 180 mm [7 inches], based on measurements I have made in peat bogs of Michigan's Upper Peninsula and of Wisconsin. The branches are much denser than *Chara*, again to maximize the wicking of water. The gametophytes are the dominant plants, with archegonia and antheridia that are very similar to those of the *Chara*.

The obvious hypothesis is that a Devonian [400-350 Myr BP] *Chara* evolved into a *Sphagnum*, creating the first land plants a second time. Since plants don't talk to each other very much the stoneworts who became peat moss were unaware that other land plants were already living along the ocean coasts. Fossils of *Sphagnum* are less than 0.2m tall, and look almost exactly like modern, living plants. Some older textbooks listed the Bryophyte phylum as the evolutionary origin of the vascular plants. I have always had two problems with this concept: (1) the vascular plants have dominant sporophytes, while the bryophytes have dominant gametophytes (with no explanation of how this switch could possibly occur); and fossil vascular plants are known from the Silurian [440 Myr BP], while bryophyte fossil go back only to the Devonian [400 Myr BP]. I prefer universes in which the parents are not about 50 million years younger than their children.

A later improvement was mutations to make mosses and liverworts, which also occurred during the Devonian [400-350 Myr BP].