INTRODUCTION

In 1991, Arnold Norden and his kids were looking for fossils when he found the femur of an Astrodon, a 60- to 80-foot long dinosaur that roamed Maryland 110 million years ago, in a clay pit near his home in Greenbelt, Maryland. Bill Hubick, a professional photographer, and Jim Brighton started the Maryland Biodiversity Project in 2012 to catalog every living species in Maryland. Wes Knapp and Bill McAvoy, Maryland and Delaware botanists working for their state's Natural Heritage programs, discovered 6 populations of a rare peat moss species, *Sphagnum cyclophyllum*, in 2012 on the Delmarva Peninsula. Whether you consider yourself an amateur or professional naturalist, there are always new discoveries to be made and fascinating information to be learned and shared with others.

The study of natural history encompasses everything from climate to geology to plants and animals. Many naturalists start out as collectors of rocks, shells, fossils, animal bones, insects, or plants and as their collections grow they become more and more interested in the science behind their specimens. Others become fascinated by observations of animal behavior, weather patterns or the life cycle of plants. And some develop their natural history skills because of a practical desire to learn more about weather, insect pests, or medicinal plants. The natural world holds so many fascinating species, patterns, and processes that there is something to interest everyone.

This chapter will cover geology, climate and weather, geography, archaeology and human impacts on Maryland's environment, and more about Maryland naturalists and the skills a naturalist needs to have.

GEOLOGY

Geology is the study of Earth's materials, structures and processes. Scientists are still working out exactly how the Earth formed; but the current leading theory is that it formed approximately 4.6 billion years ago when collisions within a solar nebula, a giant disc-shaped cloud of materials and gases, began to form small proto-planets and the Sun. Gravity drew more materials to the forming planets.

Early on, much of the Earth was a molten ball exhibiting extreme volcanic activity and experiencing frequent collisions with asteroids and other debris. By about 10 million years after its formation, the Earth had assembled into its configuration of:

1. a solid **inner core**, about 1,540 miles across. Intense pressure keeps the core from liquefying despite high temperatures.
2. a molten **outer core**, 1,400 miles thick. The rotation of the outer core is thought to contribute to the Earth's magnetic field.
3. a viscous **mantle**, 1,800 miles thick, parts of which are semi-molten, flowing in sluggish currents.

4. and a thin solid **crust**, about 4 miles thick under oceans, but up to 40 miles thick under mountains. The rocks forming the crust are less dense than the mantle's rock.

Figure 1. Earth's internal structure. Figure from http://pubs.usgs.gov/gip/dynamic/inside.html.

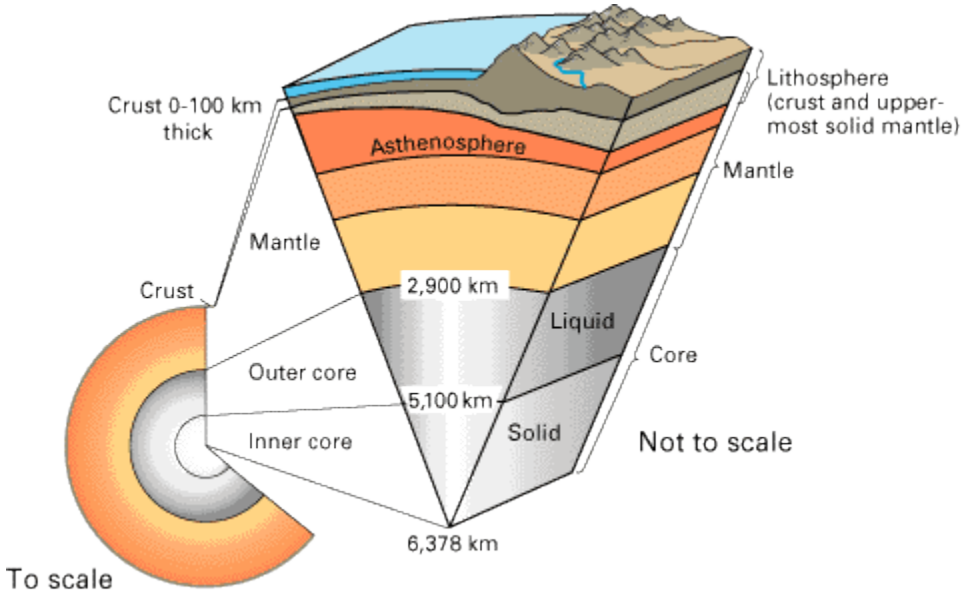


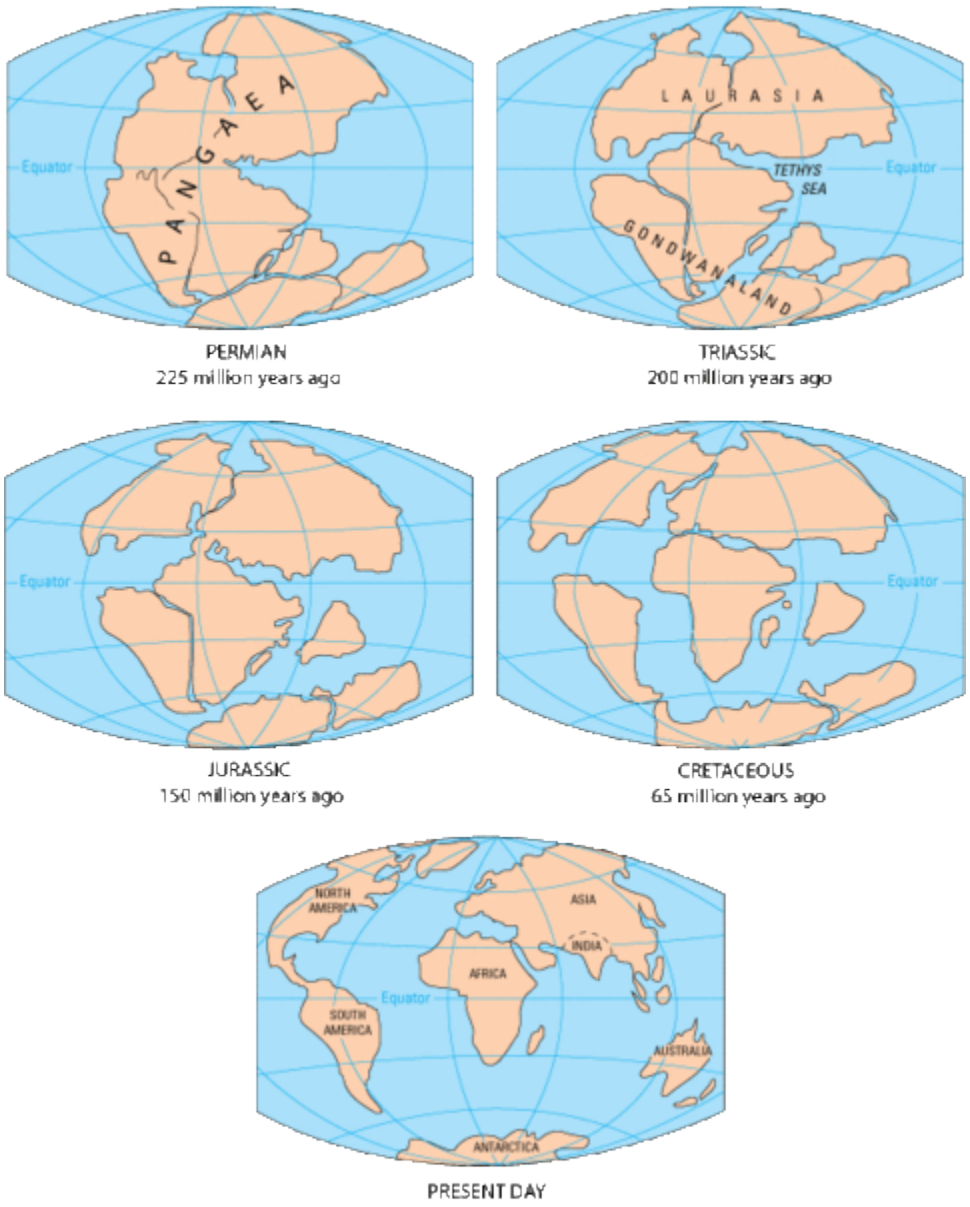
Plate tectonics

The uppermost part of the mantle and the crust make up the **lithosphere**. The lithosphere is divided into about twelve large plates that float over the molten mantle. The plates slowly move around, a few centimeters per year, and at their intersections we see mountain ranges like the Rocky Mountains, huge troughs like the Marianas Trench in the North Pacific ocean, volcanoes, and earthquakes along fault lines. The theory of how the plates move around on the mantle is called plate tectonics. Plate tectonics has replaced the theory of continental drift which was developed by German meteorologist Alfred Lothar Wegener in 1912 before there was a way of studying the ocean floor. Still unresolved is exactly what forces propel the plates across the mantle.

Pangaea -- About 225 million years ago, the Earth's continents were grouped together in a huge supercontinent called Pangaea (Figure 2). Much of the evidence for Pangaea comes from studying fossils and unique geological formations found where the continents would have at one time been joined. Seafloor explorations have located regions of frequent seismic activity that is still shaing the Earth's land masses today. In the Atlantic, the seafloor is spreading apart along the oceanic ridge. In the Pacific, the Earth's crust on the seafloor is subducting (one plate sliding under another) creating the oceanic trench. Notice that North and South America did not have a land link until relatively recently, resulting in much different species compositions on the two

continents. North America's species tend to show a closer relationship with species from Europe and Asia.

Figure 2. Movement of the continental plates from 225 million years ago to today. Figure from http://pubs.usgs.gov/gip/dynamic/historical.html



Formation of the Appalachians - About 750 million years ago the crust of Pangaea began to thin and pull apart. A deep basin filled with sea water formed over what are now the western Carolinas, northern Georgia and eastern Tennessee. Deep layers of sediments built up over time in the basin forming the bedrock of the Great Smoky Mountains. Meanwhile, volcanoes were erupting in Virginia, the Carolinas and Georgia creating very different bedrock as seen in the Blue Ridge Mountains. The continents continued to drift apart and new oceans formed in

shallow areas between the plates. Then the drift of the North American, African, and European plates changed direction. A series of collisions occurring between 470 - 220 million years ago began pushing up the Appalachian Mountains in what is called the Appalacian Orogeny. When they were at their tallest, the Appalachians probably reached heights similar to the present-day Rocky Mountains.

Rocks

Rocks are formed from elements and minerals arranged and held together by chemical bonds. The most common elements are oxygen and silicon. The six metals - aluminum, iron, calcium, sodium, potassium and magnesium - are the next most common elements. Minerals can be made up of a single element (e.g. gold), or they can be made of multiple elements (e.g. silicates containing silicon and oxygen). How rocks are formed determines their mineral content. Generally geologists classify rocks based on their mineral and chemical composition, particle size and texture, and how permeable the rock to air and water. There are three main classes of rocks: igneous, sedimentary, and metamorphic.

Rock Reference Sites:

http://ratw.asu.edu/aboutrocks_whatarerocks.html

and

http://ontariogeoscience.net/keyconceptitems/rocksandminerals.html

Igneous -- The term igneous comes from *ignis*, the Latin word for fire. These rocks are formed from cooled magma or lava. Granite, pumice, and basalt are all types of igneous rocks. Granite forms when magma solidifies within the Earth's crust, while pumice and basalt form when magma solidifies on or above the Earth's surface. Igneous rocks vary in their content of silica (SiO_2) and feldspar (minerals containing silicate), quartz, and iron or magnesium minerals.

Sedimentary -- Sedimentary rocks form as sediments and organic matter settle out of water or gather on land and are compacted together over time. Different layers of deposition of sediments within sedimentary rocks are often visible. Sandstone, shale, limestone and coal are examples of sedimentary rocks. Sandstone and shale form from sand and silt particles that result from erosion. Limestone forms from the calcium rich skeletons of mollusks and coral. Coal forms from organic matter accumulated from dead plants and animals. Much of the Earth's crust consists of a very thin layer of sedimentary rock over igneous and metamorphic rock.

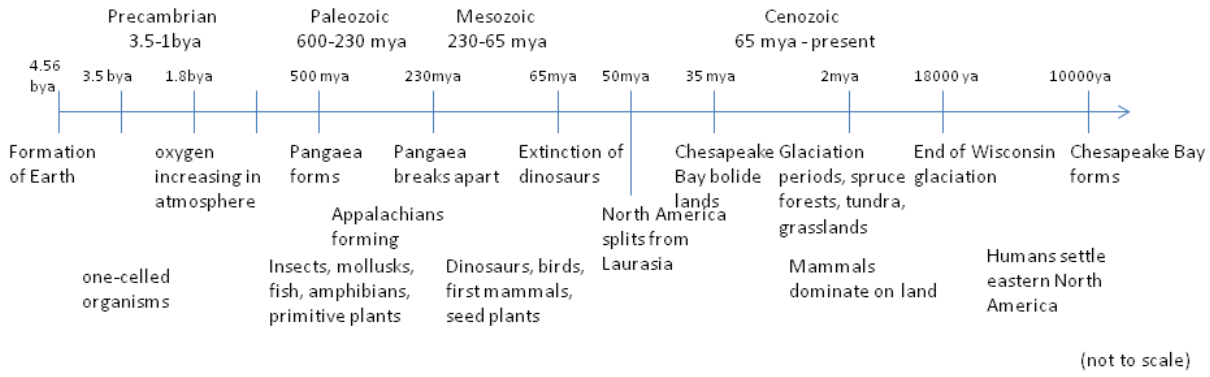
Metamorphic -- Metamorphic rocks are formed when any rock type is subjected to different temperatures and pressures that result in a change in the physical and chemical properties in the rock. This can happen when rock is buried deep beneath the ground under high pressure or when magma heats up surrounding rocks, or when both heat and pressure are active such as in areas where new mountains are forming. Slate, marble, soapstone and serpentine are examples of

metamorphic rocks. Marble forms from carbonate-rich sedimentary rocks like limestone. The colors in marble come from the presence of other impurities such as sand, clay or iron oxides.

The Geological Time Scale

By studying layers of rocks, geologists developed the geological column, a full record of the Earth's crust's rocks from oldest to youngest. The strata of rocks are then used to define the geological time scale. The column is divided into four eons (Hadean, Archean, Proterozoic, and Phanerozoic). The eons are divided into eras, for example the current Phanerozoic eon is divided into the Paleozoic, Mesozoic, and Cenozoic eras. Each era is divided into periods and each period into epochs. We currently live in the Phanerozoic eon, Cenozoic era, Quarternary period, and Holocene epoch. Some scientists have proposed that the name of the next epoch be the Anthropocene, because of the influence humans now have on the environment. For more on the geological time scale, visit the website of the International Commission on Stratigraphy, http://www.stratigraphy.org/index.php/ics-chart-timescale.

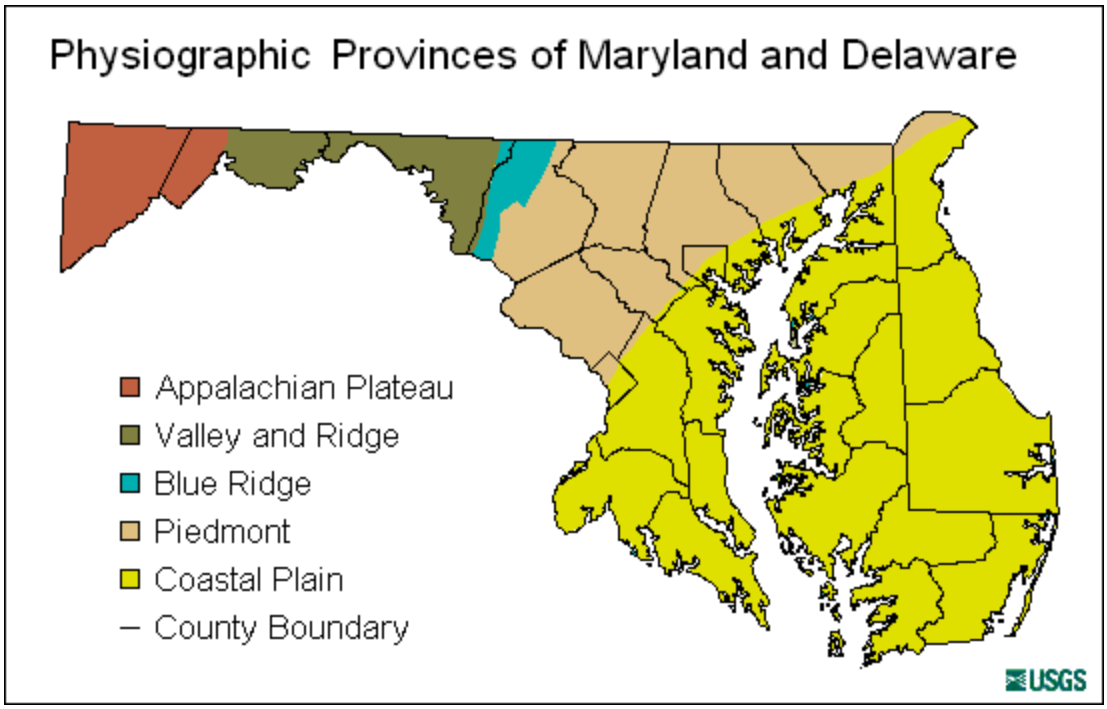
Figure 3. Timeline of major events from Earth's formation to 10,000 years before present (bya = billion years ago, mya = million years ago, ya = years ago).



Maryland Geology

Maryland is divided into several regions based on geology. The Coastal Plain, Piedmont, Blue Ridge Province, Ridge and Valley Province, and Appalachian Plateau. You can see evidence of geologic history by visiting unique locations like 1) the Piedmont serpentine barrens, formed from volcanic activity at Soldier's Delight; 2) quartz atop Sugarloaf Mountain, formed from an ancient ocean; and 3) seams of coal that formed from peat deposits in productive swamps.

Figure 4. Maryland physiographic regions



Coastal plain -- The coastal plain was mainly formed from the deposition of sediments from rivers and streams and from ocean sedimentary deposits. The Chesapeake Bay has been developing since the Pliocene epoch (5.3 - 2.6 million years ago) as ocean levels have risen and fallen. When sea levels were low, rivers excavated channels through the coastal plain. During periods of high sea level, the Delmarva Peninsula expanded as sand was deposited in an ever-elongating spit. The oldest rock formations of the coastal plain occur in the northwest section and the youngest formations at the tip of the Delmarva. The Chesapeake Bay in its current configuration only appeared about 10,000 years ago as the last glaciers melted and sea levels rose, flooding river valleys.

Piedmont -- "Piedmont" means foothills in French. The Piedmont is underlain by metamorphic and igneous rocks. In the eastern part of the Piedmont rocks are mainly of volcanic origin. The western Piedmont has some rocks of volcanic origin, but it also has large areas of sedimentary rocks. Underlying the Frederick Valley, for example, is limestone and dolomite, perhaps formed when there was an inland sea.

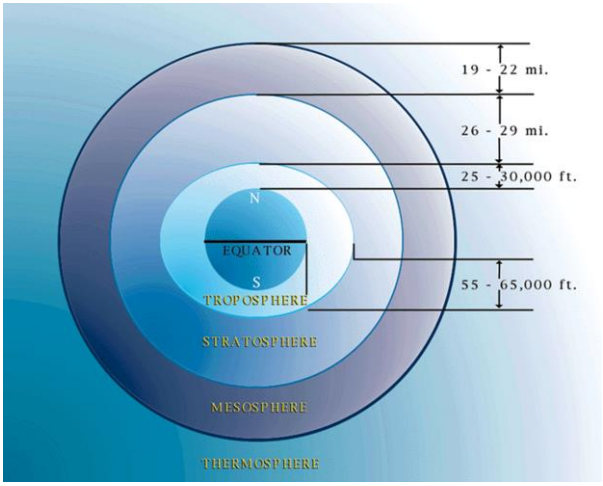
Mountain - the Blue Ridge, Ridge and Valley and Appalachian Plateau are mainly underlain by folded sedimentary rocks. The Appalachian Plateau is relatively flat with folds below the surface. The surface is rugged from valleys carved by streams and rivers. The Ridge and Valley Province features long parallel folds. Differential erosion rates of the exposed rock resulted in the ridges and valleys. The ancient granitic rocks of the Blue Ridge were shoved over top of the sedimentary rocks of the Ridge and Valley along a fault line.

Chesapeake Bay Crater

35 million years ago, a large comet or asteroid (a bolide) smashed into the coastal plain near what is now Cape Charles. Scientists think the comet may have been part of a comet storm that bombarded Earth for about 2 million years causing mass extinctions and a dramatic cooling of the atmosphere. The comet fractured rock to a depth of 7 miles and a width of 85 miles. It would have caused huge tsunamis and the impact would have decimated life along the coast as well as marine life. Rivers changed their courses and salt water intruded into deep aquifers. You can see the impacts of the crater in the 90° bends to the northeast taken by the James and York Rivers in Virginia near the edge of the crater. The land near the crater erodes at a faster rate as coastal lands slip into the crater. Also, earthquakes are more common, as the ground remains unstable. The crater provides a natural low point that helped form the current Chesapeake Bay.

ATMOSPHERE

We live on the Earth's crust in the atmosphere. The atmosphere is a thin layer of gases surrounding the Earth. It contains the air we breathe and it provides a buffer from meteorites and ultraviolet rays.



Layers of the atmosphere

As with the layers of different rock that make up the Earth, the atmosphere is layered and made up of different combinations of gases. The gases are held in place by Earth's gravity.

Troposphere - The troposphere extends from ground level to as high as 11 miles above the Earth's surface. This layer contains the air we breathe and most of our weather - clouds, wind and moisture. It is the narrowest layer of the atmosphere.

Stratosphere – The stratosphere contains the ozone layer which helps to block the sun's ultraviolet rays.

Mesosphere - The mesosphere provides a barrier to most meteors.

Thermosphere - the depth of the thermosphere can range from 220 - 500 miles. The International Space Station orbits in this layer 220 - 240 miles above the Earth.

Ionosphere - The ionosphere encompasses parts of the mesosphere, thermosphere and exosphere. Ions in this layer create an electrical layer that reflects radio waves, making radio transmissions possible from Earth. The colors of the aurora borealis are created in the ionosphere.

Exosphere - The exosphere is mainly composed of hydrogen and helium. Solar storms compress the exosphere, so it varies considerably in depth as it contracts and expands where it meets with the solar winds.

Evolution of our atmosphere

When the Earth first formed, hydrogen was the primary gas in the atmosphere. Gradually the composition changed as volcanoes and asteroids hitting Earth released carbon dioxide and nitrogen gas. Evidence of water on Earth appears at about 3.8 billion years ago and by about 3.4 billion years ago, nitrogen was the major element in the lower atmosphere. Oxygen began to be a significant part of the atmosphere around 1.8 billion years ago. Even though cyanobacteria and algae began to photosynthesize and produce oxygen as long as 3.5 million years ago, the oxygen they produced was quickly consumed in oxidation, particularly by iron.

Air

The air we breathe consists of approximately 78% nitrogen, 21% oxygen, 1% argon, and 0.04% carbon dioxide along with trace amounts of other gases. A small percentage of water vapor also occurs in the air.

CLIMATE AND WEATHER

"Climate is what we expect, weather is what we get." -- Andrew John Herbertson

Climate

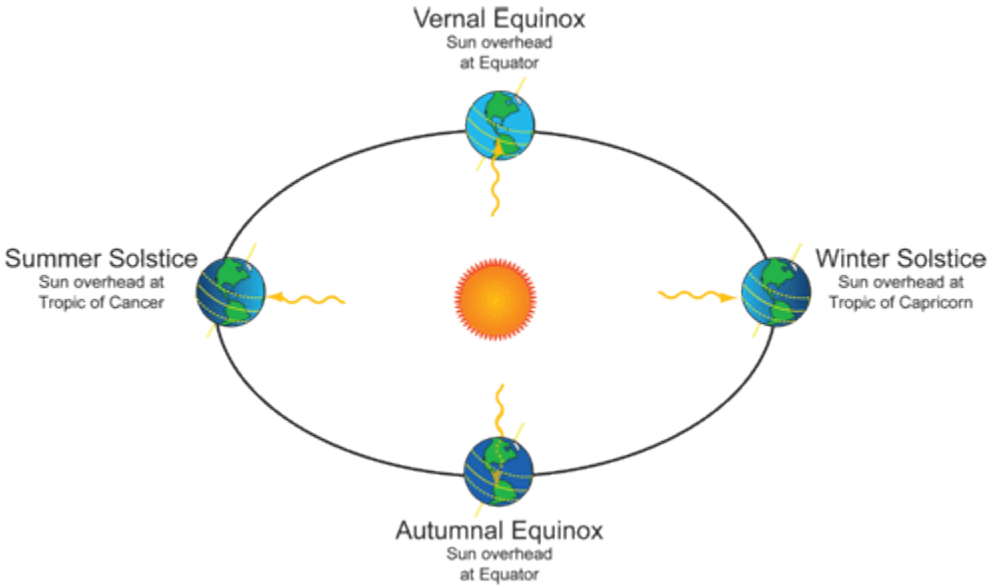
Historical climate - Climate is the average weather over time. It should be noted that, over long periods of time, even climate is variable. Fifty million years ago (mya), Maryland was covered in tropical forests. Between 50 - 25 mya, the climate became cooler and drier and grass and shrublands gradually replaced the rainforests. This change in climate took place as the North American continent drifted northward. Between 10 and 20 mya, mastodons, tapirs, camels, horses and dogs roamed the region and southern Maryland was covered by a shallow sea.

During the Pleistocene epoch, 2.5 million to 11,700 years ago, there were a series of glacial advances and retreats and up to 30% of the Earth may have been covered by ice. The southernmost glaciers reached into Pennsylvania, but left Maryland free of ice. During the Pleistocene epoch, many of the large mammals or "megafauna" became extinct and were

replaced by smaller mammals like deer, beaver and mice. The species *Homo sapiens* also evolved during the Pleistocene. Cyclical changes in the Earth's tilt and orbit and amounts of solar radiation the Earth is exposed to lead to cycles of glaciations, but other possible explanations are still a hot topic for research.

Current climate - Currently we are in an interglacial period that began about 11,500 years ago. Besides solar radiation and the Earth's orientation, our climate is largely determined by wind patterns, mountain ranges, large bodies of water, and ocean currents. Maryland has four seasons because of its latitude and the Earth's tilt on its axis (Figure 5). Winds generally flow west to east because of the Earth's rotation, but different wind currents such as the jet stream (streams of wind 3-6 miles above sea level) can bring cold air from the arctic or humid, warm air from the south. Coastal communities tend to have more moderate temperatures, as do communities at higher elevations in the mountains.

Figure 5. The seasons are determined by the relative position of the sun and Earth at different times of year. Spring begins at the vernal equinox around March 20, the summer solstice is around June 21, Fall begins around Sept. 22, and the winter solstice occurs around Dec. 21. Figure from http://scijinks.nasa.gov/solstice.



There are different ways of defining climate zones. One such way is the Koeppen Climate Classification System which divides Earth's climate into five major groups: tropical, dry, temperate, cold, and polar. The temperate zone is defined as the area between the Tropic of Cancer (23.5°N latitude) and the Arctic Circle (65°N latitude). Maryland lies within the temperate zone, between 38°N and 40°N latitude. It spans two climactic zones as defined by temperature and humidity. Southeastern Maryland is within the humid subtropical climate zone, and western Maryland lies within the humid continental zone. The humid subtropical climate features hot, humid summers and relatively mild winters. The humid continental zone features

somewhat milder summers and winters with frequent subfreezing temperatures and moderate snowfall. Warmest temperatures occur in July, and coldest temperatures in January. Average annual rainfall in Maryland is 43.10" according to NOAA, with peak rainfall in July and August.

Future climate – Average temperatures have been increasing worldwide since the Industrial Revolution because of a dramatic increase in carbon dioxide levels and other greenhouse gasses. In May 2013, carbon dioxide levels reached 400 ppm. Before the Industrial Revolution, carbon dioxide levels were around 280 ppm. The rate of increase in carbon dioxide since the Industrial Revolution is 100 times faster than any increases previously measured. The direct and indirect results of this increase in temperature for Maryland are:

- Warmer winters and summers
    - Predicted average 3°F increase in annual temperatures, with up to 9°F increase in summer temperatures.
- Wetter autumns and springs, drier summers
    - Increased probability of summer droughts.
- Increase in storm severity
    - Rainfall likely to be more intense leading to flooding, particularly in urban areas.
- Sea level rise
    - Increase in shoreline erosion and coastal flooding.

The state of Maryland established a climate change commission in 2007 and drafted a plan to reduce greenhouse gas emissions in 2011. The Department of Natural Resources is working on building resilience to climate change through better planning and resource management actions. Read more about the impact of climate change on plants, animals and ecosystems in the Ecology chapter.

Weather

Weather describes day-to-day conditions and is influenced by a number of factors.

Highs and Lows - High and low pressure systems are measured by the weight of the air column over a particular point and this air pressure is measured using a barometer. Wind is the movement of air from high to low pressure areas. Under high pressure cells, cooler, denser air descends towards Earth creating cooler, drier conditions. Under low pressure cells, warmer, lighter air rises into the atmosphere, often creating clouds and unstable weather.

Fronts - When dense cold air and light warm air masses meet, a frontal system occurs. In a cold front, cold air pushes into a warmer air mass producing showers and thunderstorms. In a warm front, warm air pushes into an existing cold front, but the less dense warm air slides up and over the cold air producing a gradually thicker, lower massing of clouds.

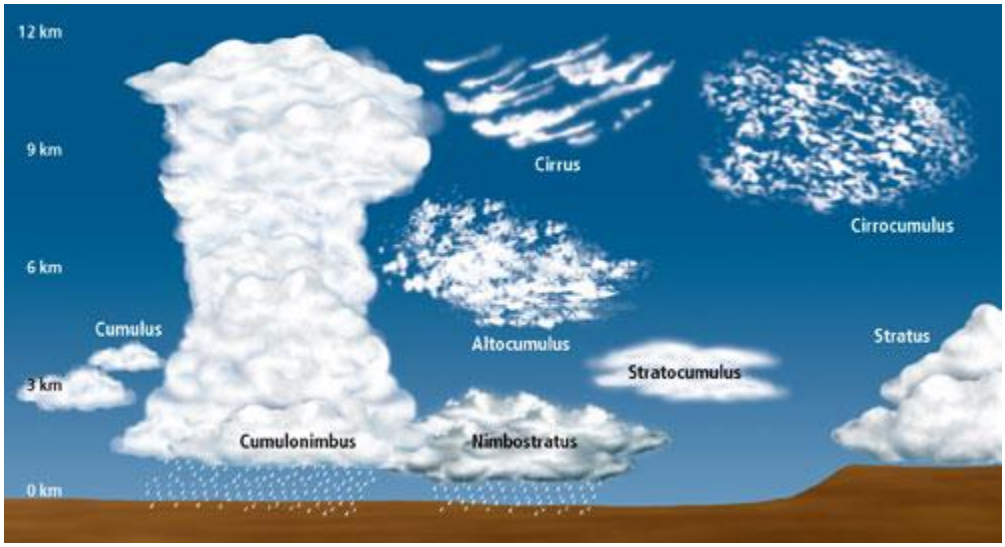
Land and Sea Breezes - Differences in temperature between the ocean and the land can result in a change in wind direction during the day, particularly in summer. During the day, the land heats up more quickly than the ocean causing pressure to fall over land and air to rise. Cooler air rushes in from the water creating a sea breeze. Overnight, the land cools more quickly than the ocean, so land breezes form blowing towards the water.

Clouds - Clouds are visible masses of water droplets or ice crystals suspended in the atmosphere. The current system for classifying the types of clouds can be attributed to Luke Howard, a London pharmacist who kept careful records of weather in London from 1801 to 1841. He was convinced that clouds could be used in weather forecasting, and in 1803 he published a paper entitled "On the Modification of Clouds". As with the naming of species, Howard used Latin names that became widely accepted in the scientific community.

- Alto - "high" - middle and high level clouds
- Cirrus - "filament of hair" - high-level clouds
- Cumulus - "pile or heap" - tall, puffy clouds
- Nimbus - "rain" - rain-bearing clouds
- Stratus - "stratum or layer" - low level clouds and clouds with a layered appearance

These terms are combined to name specific types of clouds such as cumulonimbus: tall clouds that produce rain (Figure 6).

Figure 6. Clouds are defined by their shape and location in the atmosphere.



Fog - fog is a cloud that forms near the ground. Usually fog forms when cool air close to the ground forces water to condense onto atmospheric particles. The particles might be salt near the sea, dust, or smoke. Smog occurs in polluted cities when fog forms around smoke and dust particles.

Hurricanes - Hurricane season in Maryland runs from June to November. Hurricanes in the Atlantic form over warm ocean waters, usually in low pressure areas. Air rising up draws in surrounding air which sucks up more warmth and moisture from the ocean below. The air spins counter-clockwise and as wind speeds increase, the eye of the hurricane is formed. Because of the direction of the spinning winds, hurricanes tend to travel west and north. As ocean temperatures warm with climate change, hurricanes are expected to increase in number and intensity.

WATERSHEDS AND THE CHESAPEAKE BAY

What is a watershed?

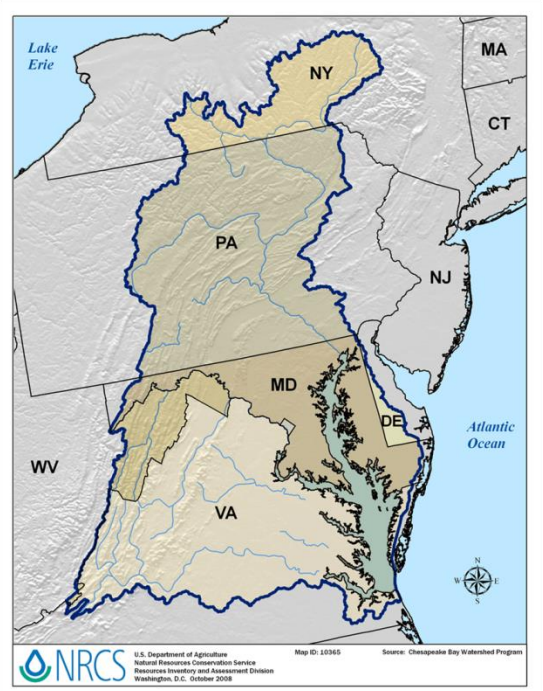
Explorer and geologist John Wesley Powell described a watershed as, "that area of land, a bounded hydrologic system, within which all living things are inextricably linked by their common water course and where, as humans settled, simple logic demanded that they become part of a community." From the 1850s - 1870s Powell explored many rivers in the Mississippi Valley and in the western United States. He was appointed director of the U.S. Geological Survey from 1881 - 1894. Simply put, a watershed is a drainage basin or area of land where all the water on or under it flows to the same place. Watersheds can be as small as a kitchen sink or as large as the Chesapeake Bay watershed spanning multiple states. Most watersheds, though, are linked to specific streams and rivers.

Maryland watersheds

The Maryland Department of the Environment and Department of Natural Resources divide the state in to 13 regional watersheds, with many subwatersheds. All of the major rivers in Maryland, except for the Youghiogheny, flow into the Chesapeake Bay. The Youghiogheny flows northwest to the Monongahela River which is ultimately part of the Mississippi River watershed.

Each of us lives within a watershed that provides our drinking water, habitat for wildlife, soils for growing food, and recreational opportunities. Land development within watersheds can lead to compacted soils, increased stormwater runoff, loss of wildlife habitat, and pollution. Thinking about how human activities impact the environment on the scale of a watershed can lead to better land use planning and better management of environmental problems.

Figure 7. Chesapeake Bay Watershed. Image from http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/programs/farmbill/?cid=stelprdb1047323



Chesapeake Bay

The Chesapeake Bay is an *estuary*, a body of water where salt water from the ocean mixes with fresh water from rivers. Half of the fresh water in the Bay comes from the Susquehanna River, with another 40% coming from the Potomac, James, Rappahannock and York Rivers. The water in the bay is about 10% less salty than ocean water. Salinity levels increase towards the mouth of the Bay. The Chesapeake Bay is the largest estuary in the United States, and one of the largest estuaries in the world. It achieved its present form about 10,000 years ago.

The Chesapeake Bay watershed covers 64,000 square miles across six states and the District of Columbia. It is home to more than 17 million people and 3,600 species of plants and animals. Most historians think the name Chesapeake came from the Algonquin word "chesepiooc," meaning "great shellfish bay." It is an appropriate name given that the Bay supports 173 species of shellfish and produces 500 million pounds of seafood harvest a year!

Physical characteristics - The average depth of the bay is only 21 feet, although there are some deep trenches that run along most of the bay's length. These trenches are thought to be part of the ancient Susquehana River and also a result of the crater formed by the bolide's impact some 2 million years ago (see box under Geology). The deepest part of the bay (174 ft.) is located southeast of Annapolis. The Bay's shallow waters mean that temperatures fluctuate greatly between seasons. Water temperatures reach 34° F in the winter and 84° F in the summer. In spring and summer the warmer, fresher, less dense water floats above a colder, saltier layer of water in the Bay forming a pynocline. In the fall, the surface waters cool more quickly than the lower layer of water and the two layers mix rapidly. This mixing brings nutrients up from the

bottom of the bay and brings dissolved oxygen down into deeper waters. In the winter, water temperatures and salinity are relatively even throughout the water column.

Dissolved oxygen - The aquatic animals that live in the Bay are very dependent on having enough oxygen dissolved in the water. Oxygen enters the water when algae and aquatic plants photosynthesize, releasing oxygen. Oxygen from the atmosphere mixes into surface waters. The fast moving water from rivers and higher-oxygen sea water that mixes together in the Bay also delivers oxygen to aquatic organisms.

Areas of low oxygen frequently form in the Bay due to a combination of factors. Warm water holds less oxygen than cold water, so in summer there tends to be less oxygen available in the Bay's water. When excess nutrients enter the Bay, algae blooms occur and any algae not eaten by the Bay's aquatic life dies and decays in the deeper layer of water in the Bay. As it decays, it uses up oxygen in this lower water layer. Remember that in summer the pynocline prevents the upper and lower layers of water from mixing and replenishing the lower layer of water with oxygen.

This happens most frequently in a few areas where the bottom of the Bay forms a bowl, which more effectively prevents mixing. The areas where "dead zones" frequently occur are in the middle of the Bay from the Bay Bridge south to the mouth of the Potomac, the lower Chester, Potomac, and Rappahannock rivers, and the lower part of Eastern Bay near Kent Island. Aquatic animals like fish, crabs, and shellfish cannot live in these oxygen-deprived waters.

People and the Bay

The ecology of the Bay has changed over the years because of human and natural impacts. Sea level rise and land subsidence has caused erosion of islands and cliffs along the Bay. For example, the Calvert Cliffs explored by John Smith in 1607-1608 have eroded back by about 300 feet. Smith Island has lost 3,000 acres over the last 25 years. In the 1700s much of the land in the Chesapeake Bay watershed was deforested to make way for farms. Huge amounts of sediments eroded off the newly exposed lands and flowed down rivers into the Bay. Joppatowne used to be a port on the Bay, but is now more than 2 miles inland.

Besides sediments, nutrients flowing into the Bay have caused serious changes to its ecology. Excess nitrogen and phosphorus cause algae blooms which in turn block light to aquatic plants and decrease dissolved oxygen levels. Farms and wastewater treatment plants account for more than 50% of pollution from nitrogen and phosphorus, but stormwater runoff and septic systems also contribute to the nutrient load. In 1985, Maryland banned the use of phosphates in detergents, and starting in 2013, both Maryland and Virginia prohibit most lawn fertilizers from containing phosphorous. Maryland also has restrictions on how much fertilizer can be applied to lawns.

Farming is the major source of nutrient pollution in Maryland because of fertilizer applications and animal waste. Farmers are required to have nutrient management plans and are encouraged to maintain buffers of grass and trees around farm fields that will absorb excess nutrients before they reach waterways. Maryland encourages retrofitting of septic systems to models more effective at reducing nitrogen and upgrading sewage treatment plants to reduce nutrient pollution. These and other actions are significantly reducing pollutants entering the Chesapeake Bay.

The Bay provides not just seafood but also recreational opportunities including fishing, boating and swimming. Two major eastern seaports are located within the Bay:, Hampton Roads in Virginia and the port of Baltimore.

HUMAN IMPACTS

Historical

Paleo Indians - The first human inhabitants of the Chesapeake Bay region were the Paleo Indians, 10,000-20,000 years ago. These people probably lived in small nomadic hunter-gatherer groups when the climate was much cooler. Caribou and mastodons roamed open woodlands. The Chesapeake Bay had yet to form. Some scientists think these early hunters could have contributed to the demise of these large animals, but others think people mainly relied on gathering nuts, berries and other plant foods and less on hunting. Archaeologists have identified several places in Maryland where Paleo Indians once lived including Pig Point in Anne Arundel County and along Rock Creek in Maryland and Washington, DC. These sites are often identified by the presence of Clovis spear points: fluted projectile points attributed to these early inhabitants. The Paleo Indians are likely descendants of people who crossed over the land bridge between Asia and North America.

Archaic Period - During the Archaic Period, approximately 9,000 - 2,000 years ago, the climate warmed and numbers of big game animals declined. The forests grew thicker forcing a change in hunting and gathering strategies. The Chesapeake Bay formed creating rich habitat for fish and shellfish. Indian groups began forming small permanent or semi-permanent villages and populations grew. Diverse types of stone tools and stone bowls can be found in Archaic Period settlements around Maryland. One such settlement is the Indian Creek site in Prince George's

Shell Middens

Shell middens provide evidence of the importance of shellfish in the diet of native populations during the Archaic and Woodland periods. These enormous piles of shells can be found along the Chesapeake Bay where tribes harvested oysters, clams and mussels over thousands of years. The calcium in the shells makes the soils that form over shell middens more basic (higher pH). A unique community of plants that prefers this soil type has developed in these areas.

Woodland Period - During the Woodland Period, 2,000 - 400 years ago, the Indians began to grow crops such as corn, beans, squash, sunflowers and tobacco. They lived near a water source in villages often surrounded by wooden stockades, and they built wigwams or longhouses shared by one or more families. Bows and arrows were used during the Woodland period and artifacts such as clay pottery, copper ornaments, arrowheads, and woven mats can be found at archaeological sites from this era.

By the 1400s, the Piscataway were the most populous tribe in Maryland. They occupied the western shore (from what is now Prince George's County east to the bay and south to St. Mary's County) and spoke the Algonquin language. They were also referred to as the Conoy. The Susquehannocks, who spoke Iroquoian, lived in Maryland's northern regions along the Susquehanna River. The Nanticoke were the largest tribe on the eastern shore. They also spoke Algonquin. The Piscataway and Susquehannocks were warrior tribes and engaged in frequent wars after 1400. They sometimes attempted to ally the early European settlers in their battles. By 1500, the population of Native Americans in the Chesapeake Bay region was estimated to be up to 50,000 people.

Native Americans cleared small areas of land for their crops by burning trees. Once the land was exhausted of nutrients, they would repeat the process to create new fields and relocate their villages. This technique, called slash-and-burn agriculture, leaves patches of forest of diverse ages and plant types. It can work well for people and plants and animals as long as populations don't expand so rapidly that the land doesn't have time to recover in between bouts of agriculture.

Native American populations declined rapidly in the 1600s and 1700s as European diseases, such as smallpox and influenza, swept through populations with no immunity. Even before the more permanent European settlements were established, there were reports of abandoned villages and mass deaths. Most tribes lost between 40-90% of their population to disease alone. This rapid population decline may have led to the abundance of game animals like deer and turkey perceived by the early settlers. The weakened tribes were usually forcibly displaced from their lands, particularly in the eastern United States.

Modern Impacts

Hydrological cycle - People must have fresh water to survive, but only 3% of Earth's water supplies are fresh. Fresh water is stored in lakes, rivers, aquifers, and glaciers. Maryland is a relatively water-rich state. One fifth of the state is covered by water, including the Chesapeake Bay. On average, rainfall in Maryland is 43.10" according to NOAA, which equals @ 21,500 million gallons/day (USGS).

Figure 8. Water flow into Maryland from surface waters and precipitation versus water use and loss. Figure from http://pubs.usgs.gov/fs/2003/fs-112-03/figure1_big.gif

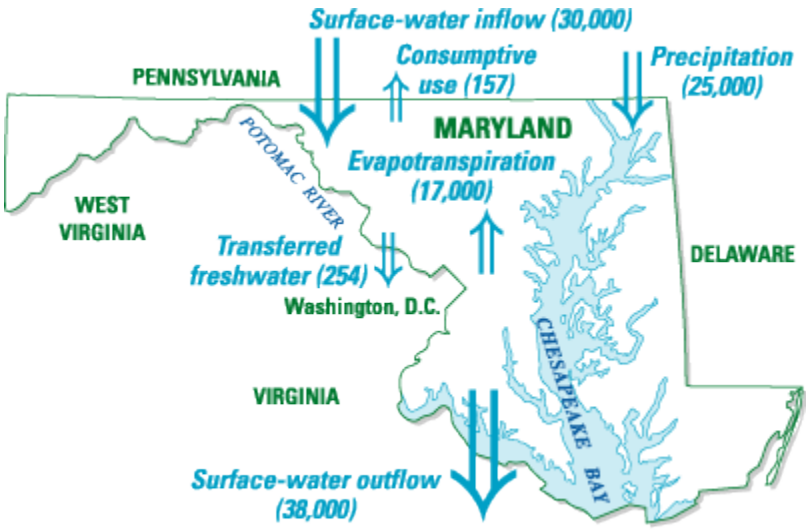


Figure 1. Maryland water budget, in million gallons per day.

Does that mean we don't need to worry about water supplies? Not necessarily. In 2000, USGS calculated that Maryland withdraws 1,450 million gallons per day from surface and groundwater sources. Most of that water is used for public water supplies. Thermoelectric power withdraws the second greatest amount of water, but most of that water is returned to waterways after being used for cooling. Domestic wells, industry and irrigation also use significant amounts of water.

- **Groundwater** - Water stored in the ground in aquifers can be thousands of years old. In fact, water stored in the upper Patapsco Aquifer was dated to be more than a million years old. The amount of water stored in aquifers has been declining as populations have grown, particularly in southern Maryland and the eastern shore. Some groundwater sources have become contaminated from water leaching through old landfills, underground storage tanks, chemical spills, and improperly stored salts and fertilizers. On the eastern shore, aquifers can become contaminated by salt water intrusions as fresh water is pumped out or because of sea level rise.

- **Surface water** - Surface waters in Maryland fluctuate with rainfall amounts. During drought years, the amount of water withdrawn from surface waters can have severe impacts on the flora and fauna that live near lakes and rivers. Surface waters are easily contaminated by stormwater runoff and other sources of pollution.

See the Ecology chapter for more information about the water cycle.

Soils - Soils are composed of minerals from rocks and organic matter. It can take millions of years to form soils, but only an instant to destroy them. Soils hold water and air necessary for plant growth and for the soil organisms to survive. Healthy soils absorb rainfall and mitigate

flooding. Soils provide habitat for microbes, plants and animals. They remove pollutants from water and store carbon.

Human activities can have tremendous effects on soils. Compaction occurs along roads and trails and on construction sites. Compaction reduces the ability of the soil to hold moisture and air. Soils are removed through mining activities, construction, and erosion. The soil biota is killed off through the overuse of fertilizers and pesticides. Introduced species, such as some earthworms and plants, can change soil properties by breaking down organic matter more quickly or raising pH. Soils with different properties support different plant and animal communities.

Natural resource use and abuse - North America was considered a treasure by European settlers because of its vast natural resources. Maryland has mineral resources, forests, wildlife, and water among its treasures.

- **Industrial minerals**: sand and gravel, cement, stone. Sand and gravel operations are common in the coastal plain region. Stone is quarried in the Piedmont and Mountain regions and includes granite, marble, quartzite, slate and sandstone. As of 2010, nearly 400 mines were active in Maryland according to the Maryland Department of the Environment.

- **Fuel minerals**: coal, natural gas. Most coal and natural gas reserves occur in the Mountain region. In 2013, 65 coal mines operated in Maryland producing over 200 million tons of coal each year. Coal production peaked in the early 1900s with at least 450 operating mines and now there are more than 9,500 acres of abandoned coal mines in western Maryland that have not been reclaimed. Reclaiming a mine stabilizes waste piles, old mine shafts, and bare ground, and replaces vegetation. Often, when a mine is abandoned, it also floods with water. The water oxidizes exposed minerals and becomes very acidic. This acid mine drainage is an environmental contaminant that can kill fish and other animals as well as plants downstream from the mine, so treatment and/or containment is important.

  Natural gas production has been fairly low in Maryland; however, a large reserve of natural gas in the Marcellus Shale formation in Garrett and Alleghany counties has recently been targeted by mining companies. In the late 1990s a technique called fracking was developed that made it economical to extract natural gas from shale. In fracking, water is pumped into the ground to fracture rock and release natural gas. The technique uses large quantities of fresh water and there is much concern that it can cause contamination of groundwater and even small earthquakes. Maryland legislators have been debating whether to allow fracking in Maryland.

- **Forests**: In Maryland, trees are used for manufacturing wood products and paper. The most intensive logging took place in the 1800s. Forests began to regrow, but more recently have been diminishing again as development has increased. The number of mills has been declining and stocks of harvestable trees have been increasing. Logging can increase erosion and compact soils, but forests do recover: logging can produce forests of different ages that support a wider variety of wildlife.

  One of the greatest losses in Maryland has been of old growth forest (forests that have been relatively undisturbed for 100+ years). Old growth forests develop a unique ecosystem that is extremely rare now in the state. Forests can also be an important source of products such as firewood, medicinal and edible plants, wild mushrooms, and seasonally-harvested greens such as holly.

- **Wildlife**: Marylanders have been fishing and hunting since people first arrived on the scene 10,000 years ago or more. The commercial fishing industry in Maryland relies principally on catches of oysters, blue crabs, and rockfish. Recreational fishing is also important economically with rockfish, white perch and croaker being commonly caught fish species. The Maryland Department of Natural Resources Fisheries Service regulates catches within both commercial and recreational fisheries in order to protect species from overharvesting. Oyster harvests have declined significantly because of diseases and stress on oysters from climate change and pollution. Chesapeake Bay Foundation's Maryland Oyster Gardening Program is one program that addresses the issue by encouraging citizens to grow caged seed oysters submersed from their private docks. Adult oysters are harvested, transferred to state non-harvestable reefs and replaced by new seed oysters annually.

  Hunters and trappers can hunt deer, rabbits, squirrels, muskrat, turkey, black bear, waterfowl, and other animals, but for most animals the Department of Natural Resources requires a license and determines seasons for hunting as well as bag limits. Hunting of migratory game birds is regulated by the U.S. Fish and Wildlife Service. Non-game migratory birds are protected under an international treaty. The only animals that do not require a license to hunt are woodchucks and nutria. The nutria is an introduced invasive species that is very injurious to wetlands on the eastern shore of Maryland. Hunting can help control populations of animals, like deer, that no longer have many predators.

- **Loss of habitat** - **Human populations** have increased exponentially reaching more than 7 billion people worldwide now. The rate at which the world population is growing peaked in the mid-1960s at above 2% but is now estimated to be less than 1.2%. That still means that by 2050 there could be 8.9 billion people on Earth. Maryland ranks 6th in population density among US states with a density of 606 people/square mile in 2012

(U.S. Census Bureau). People need places to live, work and recreate, and there has to be enough land to produce food, fuel and other resources to support them.

- **Forests** at one point covered more than 80% of Maryland's land area. The US Forest Service estimates that there has been a net loss of 450,000 acres of forest due to population growth and urban development in the past 50 years. Development breaks up large areas of forest into increasingly smaller patches. This poses a threat to species that require large areas of interior forest such as the scarlet tananger and barred owl. It also exposes forests to more wind, soil compaction and erosion, and incursion by people and invasive species along the edges of the forest (Lister et al. 2008).
- The US EPA estimates that Maryland has lost 73% of its **wetlands** due to drainage, filling and development. Wetlands are crucial for storing and cleaning water, and providing wildlife habitat and protection from erosion along shorelines.

NATURALIST SKILLS

"Naturalists know that what they see on a field trip, whether a day's excursion or a year's residence in a camp or research station, is only a tiny part of what exists around them." - E. O. Wilson in forward to Field Notes on Science and Nature (Canfield, 2011).

As a naturalist, you use your skills to observe nature, record your observations, learn more about what you have observed, and report to others.

Observation - Observation requires patience, persistence, and all your senses. You might first observe the form and placement of an animal or object in the environment. If it is an animal, you watch its movements and behaviors. If it is a plant you might make repeated observations of how its flowers open or its leaves expand. An archaeological find requires particular attention to what layer of soil or rock the object is found in and what other objects might be found in the same layer. Broaden your observations from the individual organism or item itself to its surroundings. What is the weather like, what type of soils is a plant growing in, what interactions does an organism have with its surroundings? It can take a great deal of patience to observe the life cycle of a plant or animal or to search the ground for clues about what has transpired in the near or distant past.

Recording observations - Observations can be recorded through words, drawings, numbers, photographs, video or any number of other formats. They may be stored on paper or electronically. The records kept by both professional and amateur naturalists have proven to be of great importance to future scientists and naturalists. For example, Thomas Jefferson kept detailed records of weather at Monticello in Virginia from 1776 - 1881, "My method is to make two observations a day, the one as early as possible in the morning, the other from 3. to 4.

aclock, because I have found 4. aclock the hottest and day light the coldest point of the 24. hours. I state them in an ivory pocket book in the following form, and copy them out once a week." - Thomas Jefferson from http://www.monticello.org/site/research-and-collections/weather-observations. These observations are compared to recent weather data to look at patterns of climate change.

You can record not only your observations but also your impressions, ideas, and feelings about what you have observed.

- **Nature journals** - In a nature journal the author records not just observations but also their perceptions, feelings and emotions. Journals can record extremely detailed observations or might be more reflective of the author's state of mind at the time.

- **Field notes** - Field notes can be similar to a journal, but tend to have more structure and are intended to be used for research purposes. Field notes can be anything from extensive written observations to recorded columns of data. They can contain drawings and photographs as well.

- **Data sheets** - data sheets are usually designed to record specific information for a research project. You might, for example, record numbers, short descriptions, locations, and dates.

Research and Reporting - You can use research done by others to help you identify a species or to learn more about an ecosystem. You can also contribute to research through your observations. Reporting your observations to others helps to share information and will probably result in your learning more about the topic that interests you. Observations can be shared by giving talks to interested groups, writing about your observations in a newspaper or magazine article, or online in a blog or social media outlet. Or you can simply share with your family, friends and neighbors.

- **Field guides -** Field guides are principally used for identification but sometimes have additional information about a species' behavior, origins, or uses. Often field guides have a binomial key that can help guide you to identify a species based on answering a series of yes/no questions. Other field guides are divided into searchable subsections, for example flower color and shape. Many print field guides are available, and increasingly you can also find field guides online.
- **Scientific literature** - Scientists generally publish their research in journals that are peer-reviewed. Before an article is published, it is sent to other scientists in the same discipline who read it and comment on its accuracy. Only after it has passed this review will a journal publish the paper. You can find scientific journals at university libraries or online. The search engine, scholar.google.com, specializes in searching for scientific literature. If you find these articles too difficult to decipher, there are also a number of

scientists and science writers who have written excellent books summarizing a particular topic. There are also many magazine articles that focus on particular scientific topics that provide good quality information, for example: *Smithsonian*, *Scientific American* and *BioScience*. Always look for the original source of information that a popular article is based on so you can make a judgement on its objectivity and accuracy.

- **Online databases** - Increasingly naturalists are contributing their observations to online databases that can be accessed by scientists worldwide for research projects. Below are just a few of the many databases to which you may contribute:
    - iNaturalist, http://www.inaturalist.org/ - This site allows anyone to record where and when different species were observed and includes photographs and other information about different species. You can form project groups if you are interested in certain types of observations or a particular geographic area. For example, in Maryland there is a project for Maryland Master Naturalists on the Coastal Plain to record their observations, and another project to create a checklist of plants and animals that live in the Eastport neighborhood of Annapolis.
    - Project BudBurst, http://budburst.org/ - Project BudBurst uses volunteers to collect data on when particular species of plants begin to flower and leaf out in spring to follow plant responses to climate change.
    - Feeder Watch, http://www.birds.cornell.edu/pfw/ - The Cornell Lab of Ornithology collects data from people who watch which birds come to their bird feeders in winter. The data is used to track the movements of birds in winter and their population dynamics over time.
    - NASA, http://science.nasa.gov/citizen-scientists/ - NASA has numerous citizen science projects that use volunteer observations of images and the night sky to collect data. For example, the GLOBE at Night project, http://www.globeatnight.org/, raises awareness of light pollution by having citizens measure light in the night sky. Light pollution can affect wildlife behavior and human health.
    - Mid-Atlantic Early Detection Network, http://www.eddmaps.org/midatlantic/ - This network records observations of introduced species in the Mid-Atlantic region to help find new invasions quickly and to better manage and coordinate control efforts. Data entered on this network are verified by experts in the region.

The term "citizen science" has been used to describe a range of ideas, from a philosophy of public engagement in scientific discourse to the work of scientists driven by a social conscience. In North America, citizen science typically refers to research collaborations between scientists and volunteers, particularly (but not exclusively) to expand opportunities for scientific data collection and to provide access to scientific information for community members. As a working definition, we offer the following: projects in which volunteers partner with scientists to answer

real-world questions. Often, online data collection as outlined above is part of a "citizen science" project.

NATURALISTS IN MARYLAND

Many remarkable naturalists have lived and worked in Maryland. Below are a few examples. Who else do you know who should be listed as a significant Maryland naturalist?

Hugh Jones (~1671-1702) - Hugh Jones was a Welshman sent to collect plants, insects and fossils and to serve as minister to Christ Church Parish in Calvert County in 1696. Unfortunately, at first he was not very successful as a naturalist because many of his specimens arrived back in London unsorted, unlabeled or dead. Two additional collectors were sent to Maryland, David Krieg, a Prussian, and William Vernon, from England. They were sponsored by collectors in England and collected mostly along Maryland's coastal plain in 1698. The collections made by Hugh Jones were described in a paper on natural history of Maryland by one of the English collectors, James Petiver. It was published in *Philosophical Transactions* in 1698. Another collector, Plukenet, also published descriptions based on the collections by Jones and Krieg in 1700 in a volume on botany.

Benjamin Banneker (1731-1806) - Born on a farm in Baltimore County as a free African-American, Banneker became a scientist, surveyor and writer. Largely self-taught, he became interested in astronomy and wrote a series of almanacs. The almanacs included predictions of solar and lunar eclipses, weather predictions, and tide tables.

John, Andrew and Joseph Ellicott (1739-1794;1733-1809; 1732-1780) - The Ellicott brothers established Ellicott Mills near Elkridge, MD in 1772. They encouraged farmers to plant wheat instead of tobacco because tobacco had rapidly depleted soils. They also introduced to farmers in the region the idea of using fertilizer to replace nutrients lost in growing crops.

Charles Wilson Peale (1741-1827). Born in Chester, MD, Peale studied painting and had a great interest in natural history. He organized the first U.S. Scientific Expedition in 1801 to southeastern New York to excavate mastodon bones. He then established the first public arts and science museum in Philadelphia, PA to display his collections. The museum contained many bird specimens that Peale himself had taxidermied. It was also one of the first museums to adopt Linnaean taxonomy.

André Michaux (1746-1804) - Michaux explored the mid-Atlantic region and Carolinas as a botanist. Appointed by the King of France, Michaux headed a French scientific mission to explore North American forests for useful plants.

Almira Hart Licoln Phelps (1793-1884) - While living with her sister in Vermont, a male student attending Middlebury College boarded at their home and tutored Phelps on his lessons.

Realizing the discrepancy between educational opportunities offered to men and women, she spent her life improving women's educational opportunities. She published ten textbooks focusing on botany, chemistry, geology and women's education and in 1841 became the head of the Patapsco Women's Institute in Ellicott City, MD. She transformed the curriculum of the institution to focus on natural history, sciences and mathematics.

Mary Elizabeth Banning (1822 - 1903) - Born near Oxford, Maryland, Banning showed an early interest in plants and fungi. In 1845 her family moved to Baltimore, where she began working on her book, *Fungi of Maryland*. In her book she described 175 species, 23 of which were new to science. Extensive field notes accompanied the drawings.

George Huntington Williams (1856-1894) - Williams was a geology professor at John Hopkins University from 1885 to 1894. He was the editor-in-chief of "Maryland: Its Resources, Industries and Institutions" published in 1893 by the World's Fair Commission along with many other publications on geology of Maryland and the world.

Rachel Carson (1907-1964) - Rachel Carson was born in Pennsylvania and earned a Masters degree in Zoology at John Hopkins University. She became the second full-time professional woman hired by the U.S Bureau of Fisheries, working as an aquatic biologist in 1932. She wrote natural history articles on the Chesapeake Bay published in the *Baltimore Sun* and other newspapers. In 1952 she resigned to start writing full time. Her book *Silent Spring*, serialized by the New Yorker beginning in 1962, criticized the overuse of pesticides (particularly DDT), and was read by millions of people. It eventually led to a ban on the use of DDT in the United States. She died of cancer in Silver Springs, MD at age 56.

Chandler S. Robbins (1918-). Chandler "Chan" Robbins began working for the US Fish and Wildlife Service in Patuxent, MD in 1945 as a junior biologist. His research on the effect of DDT on breeding bird populations was used by Rachel Carson in *Silent Spring*, and his research on the effects of forest fragmentation on woodland birds informed environmental regulations to protect the Chesapeake Bay. He is co-author of *Birds of North America*, the first comprehensive field guide to all North American birds and the first to include sonograms of bird songs. Robbins developed the methodology for the Breeding Bird Survey, begun in 1966 to track the health of bird populations. He is Senior Editor of the *Atlas of the Breeding Birds of Maryland and the District of Columbia,* published in 1996. Robbins is also famous for being the first to band a Laysan Albatross on Midway Atoll (in the North Pacific Ocean) in 1956. This same bird has been followed for many years each time she returns to breed. In 2011, the tsunami associated with the Japanese earthquake washed away her nest. Dubbed "Widsom," she returned to nest successfully in 2012 -- at age 62! Robbins retired from the Patuxent Wildlife Research Station in 2005, but is still active as Editor in Chief of "Maryland Bird Life," the Maryland Ornithological Society research journal.

George Abbe (1943-) - George Abbe surveyed blue crabs and oysters in the Chesapeake Bay for 41 years. He worked as a research scientist at the Morgan State University Estuarine Research Center until retiring in 2009. The survey began in 1968 near the Calvert Cliffs to study the potential impacts of cooling water discharges from power plants. The research evolved into assessing crab stocks and oyster growth and mortality. His research contributed greatly to state regulations protecting stocks of crabs and oysters and to a better understanding of how to restore crab and oyster populations.

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