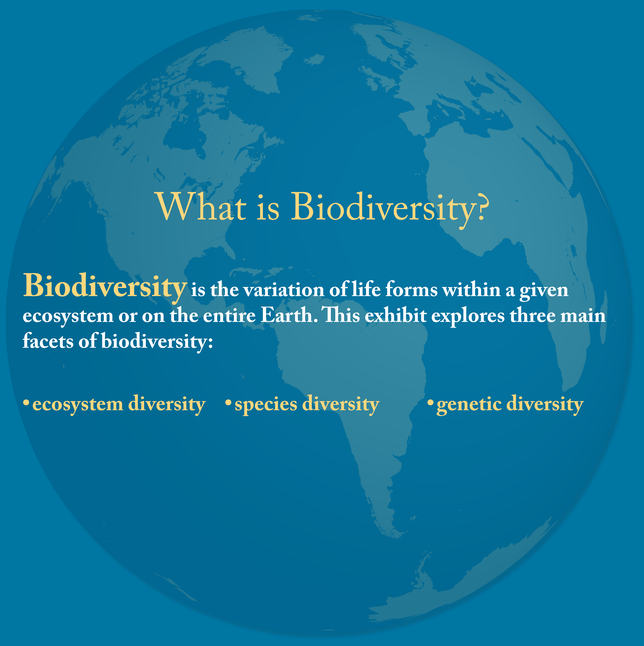
DOCUMENTING Diversity



What is Biodiversity?

Biodiversity is the variation of life forms within a given ecosystem or on the entire Earth. This exhibit explores three main facets of biodiversity:

- ecosystem diversity
- species diversity
- genetic diversity

Genetic Diversity

Genetics plays an important role in biodiversity, even at the species level. Genetic diversity allows species to adapt to almost every type of environment. Because of genetics, each individual is unique!

It's Good to be Different

The total number of inherited characteristics (genes) in a species make up its genetic diversity. In many plants and most animals, variation within a species comes from reproduction. Offspring inherit one set of genes from each parent.

The moths and butterflies in these cases belong to a single species, but their color and patterns vary somewhat in each individual.

The dog (*Canis lupus familiaris*) is a domesticated subspecies of the grey wolf. All dogs are members of the same species, and yet a wide variety of characteristics can be seen among "man's best friend."

There are over 150 breeds registered with the American Kennel Club, ranging in height from the 6-inch-tall (15.2 cm) Chihuahua to the 35-inch (88.9 cm) Irish Wolfhound (shoulder height). By intentionally breeding dogs, humans have helped to diversify the dog species.

The large dog is an Afghan hound and the small dog is a Chihuahua, among the smallest of domestic dog breeds. Dogs differ in size, fur length and texture, skull shape, and leg length.

Why is genetic diversity important?

Humans have long used this variation to breed plants and animals with preferred traits. Thoroughbred race horses are bred to be fast. Dogs are often bred with a specific job in mind such as hunting, service, and drug or bomb sniffing.

Crop plants are bred to resist disease or produce better flavor. Broccoli, cauliflower, cabbage, kale, brussels sprouts, and kohlrabi all belong to the same species, but people have bred different varieties for different tastes, producing strikingly different looking plants.

Photos from www.flickr.com creative commons. Photographer usernames from left to right: xrry, Katie Harbath, thehlog, KaCey97007, Brantford Selections.

The survival of species depends on genetic variation. Slight genetic variations in form or behavior make it possible for the species to adapt to environmental changes. A species with more genetic variation is more likely to survive a change.

Where Is Biodiversity the Greatest?

The Tropics

Practically every place on Earth has life but there are big differences in the diversity of life in different locations. The frozen climate of Antarctica or the dry air of Earth's deserts are very low in diversity. In contrast, tropical rainforests and coral reefs are the most diverse ecosystems on Earth.

Tropical Rainforests

- are the most complex land-based ecosystem on Earth, containing over 30 million species of plants and animals.
- cover roughly eight percent of the Earth yet contain about half of the Earth's wildlife and two-thirds of its plant species.
- are home to more species than all other biomes combined—an estimated 80 percent of the world's biodiversity.

Why are tropical rainforests so diverse?

Tropical rainforests are fueled by a warm, humid climate and the efficient re-use of nutrients through food webs and decay. In addition, tropical rainforests support considerable specialization in ecological roles. Within the numerous habitats, species evolve to have special adaptations just for their niche in the habitat.

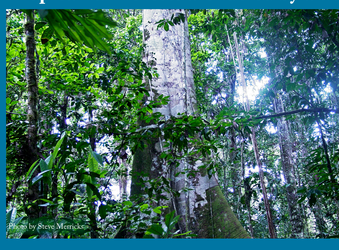


Photo by Steve Mercier

Coral Reefs: "Tropical Rainforests of the Sea"

Coral reefs can be found worldwide, but mainly near coastlines and between 30 degrees north and south of the equator. The relatively warm, shallow waters along coastlines support a mutually beneficial ecosystem and provide the essential environmental conditions for coral reef building.

Coral reefs

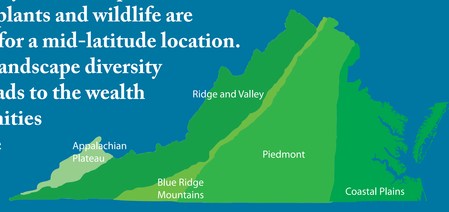
- are the oldest ecosystem and largest living structures on Earth.
- cover less than one percent of the surface area of the oceans yet support over one quarter of the fish species in the ocean.
- host 32 of the 34 recognized animal phyla compared to 9 phyla in tropical rainforests.

Why are coral reefs so diverse?

One of the reasons coral reefs are so diverse is that they are among the oldest and most stable kinds of ecosystems. Some of today's reefs began forming 2.5 million years ago. The reef builds from the skeletons of the coral animals. The reef structure protects the inner side of the reef from waves. Within the reef are many caves and crevices. The variety of places to live also means many different kinds of animals can live there. Although only a low level of nutrients are present in reef waters, they are efficiently recycled by the plants and animals living there creating a stable ecosystem.

Virginia's Biodiversity: from the Mountains to the Bay

Virginia boasts a variety of landscapes and considerable differences in climate. Virginia's plants and wildlife are exceptionally diverse for a mid-latitude location. This combination of landscape diversity and biotic richness leads to the wealth of ecological communities found throughout the Commonwealth.



Burke's Garden

At an elevation of 3,086 feet above sea level (941 meters), Burke's Garden is the highest valley in Virginia. Its unique geology has made it home to some of the most fertile land in the state. Surrounded by mountain ridges, Burke's Garden includes woodlands, grasslands, and marsh habitat. And beneath all that, there are caves that are home to reptile and amphibian species not found anywhere else on Earth.

The Chesapeake Bay

The Chesapeake Bay is an estuary— a body of water where fresh and salt water mix. It is the largest of the 130 estuaries in the United States, and it has around 11,684 miles of shoreline (18,800 kilometers)—more than the entire U.S. West Coast. The Chesapeake Bay supports over 2,700 plant species and provides food, water, cover, and nesting or nursery areas to more than 3,000 migratory and resident wildlife species.

The Bay has a number of diverse habitats:

- forests
- wetlands
- streams and rivers
- shallow waters
- tidal marshes
- aquatic reefs
- open waters

The Bay's many habitats contribute to the overall health of the Bay.

Earth's Family Tree

Diversity of life is not random. A common history and ancestry unite all living things. Comparative biologists have studied biology and behavior of living things for the last 200 years.

They focus on

- descriptions of organisms, based on their similarities and differences.
- the relationship patterns of the organisms over time.
- their geographic history and distribution.

Living organisms belong to one of five kingdoms based on major differences in their cells and other features. They are then further categorized into smaller groups, or taxonomic ranks.

Kingdom
Phylum
Class
Order
Family
Genus
Species

Diversity occurs in each rank. Each of the above groups can also have smaller sub-categories. The next three sides of this case provide examples.

How many species?

We still don't know. About 1.5 million have been described. Biologists estimate there could be 5 to 10 million. If microorganisms like bacteria and archaea are counted, estimates go as high as 100 million.

Arthropoda
1,097,289

Mammals
5,490

Fungi
100,000

Bacteria
about 1 million
only 4,000 named

Angiosperms
400,000

Mollusks
93,195

Sipuncula
300

Ctenophora
Comb jellies
100

Phylum

Arthropods Rule

Kingdom
Phylum
Class
Order
Family
Genus
Species

Arthropoda is a phylum of invertebrate animals that can be found in nearly every habitat on Earth. They make up about 85 percent of known animal species.

Arthropods have more variety of shapes than any other group of animals and range in size from microscopic mites and crustaceans to giant spider crabs with legs 3 meters long.

Four major subgroups of arthropods exist:

- **insects**
- **crustaceans** crabs, lobsters, shrimp, barnacles, and sow bugs
- **arachnids** spiders, mites, ticks, scorpions, and daddy long-legs
- **myriapods** millipedes and centipedes

Crustaceans are most diverse and abundant in the ocean while the other groups are most diverse on land.

Echinoderms: Stars of the Sea

Echinodermata is a phylum of invertebrate animals that live in marine environments, except for a few species which inhabit brackish (somewhat salty) waters.

The species living today are generally classified into five subgroups:

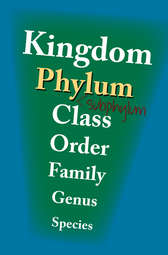
- **crinoidea** sea lilies and feather stars
- **asteroidea** starfish or sea stars
- **ophiuroidea** brittlestars and basket stars
- **holothuroidea** sea cucumbers
- **echinoidea** sea urchins, sea biscuits, and sand dollars

This sea star demonstrates radial symmetry. Echinoderms share a body plan displaying radial symmetry, often made up of five sets of body parts surrounding a central disk.

Echinoderms inhabit depths ranging from shallow waters to the deep sea. Although echinoderms are not the largest of the animal phyla in terms of numbers of species, they are among the most diverse in terms of anatomy.

Subphylum

Reptiles and Amphibians are subgroups of the vertebrates (Phylum Chordata)— animals with backbones. Both reptiles and amphibians are cold blooded vertebrates, but the two groups differ in other ways.



Amphibians

Amphibians are the oldest four-legged animals, emerging about 350 million years ago. All have permeable skin, which means they can breathe and sometimes drink through it. Amphibian means double life—life on both land and water.

There are more than 6,600 species of amphibians, classified into three different orders:

- 5,973 species of frogs and toads
- 606 species of salamanders and newts
- 186 species of wormlike caecilians

Amphibians live in almost every type of habitat except for open oceans, polar regions, and some extremely dry deserts. Tropical areas of the world have the greatest diversity of amphibians. The tropical country of Ecuador has 485 species of amphibians. That's more than all of the U.S. and Canada combined.

Reptiles

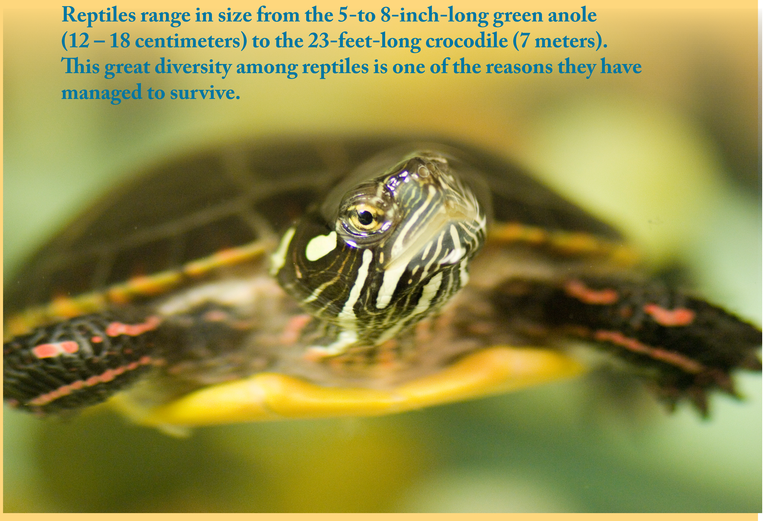
Reptiles have scaly waterproof skin and water-resistant eggs, which means they can live in places and ways that amphibians cannot.

There are over 8, 700 recognized species of reptiles:

- over 5,000 species of lizards
- over 3,000 species of snakes
- 300 species of turtles
- 23 species of crocodiles
- 178 species of amphisbaenians ("worm lizards")

Although most abundant in the tropics and subtropics, the nearly 8,000 species of living reptiles inhabit every continent except Antarctica.

Reptiles range in size from the 5-to 8-inch-long green anole (12 – 18 centimeters) to the 23-feet-long crocodile (7 meters). This great diversity among reptiles is one of the reasons they have managed to survive.



Kingdom Plantae

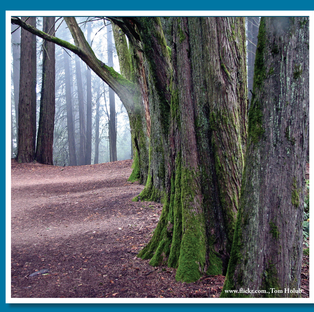
Kingdom
Phylum
Class
Order
Family
Genus
Species

Plants have made Earth what it is today.

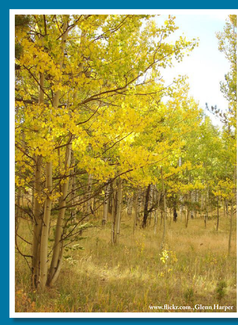
O_2 Without green plants there would be no oxygen for animals, including humans, to breathe.

Plants make their own food and convert carbon dioxide to oxygen during photosynthesis.

They range in size from very small and short-lived like the *Arabidopsis* that completes its entire life cycle in six weeks



to the very large and long-lived like redwoods that average 500-700 years but that have lived up to 2000 years old.



Certain plants are thought to be the largest genetic individuals in the world.

Plants are grouped into 12 phyla, shown here in the order of their living species diversity.

Number of species	*Phyla*
1	ginkgo
3	whisk ferns
15	horsetails
70	gnetophytes
100	hornworts
185	cycads
550	conifers
1,000	lycophytes
6,000	liverworts
10,000	mosses
12,000	ferns
400,000	flowering plants

How Do We Study Biodiversity?

Scientists study biodiversity through three main ways: systematics, ecology, and paleontology.

Systematics is the study of biodiversity and the evolutionary relationships among organisms. Originally systematists based their studies on morphology and anatomy. Today we also use behavioral, genetic and ecological differences among organisms to determine their relationships.

Scientists are still searching for unknown species. This photograph shows Dr. Judith Winston, VMNH curator of marine biology , taking pictures of a new species in a threatened mangrove habitat in Belize.

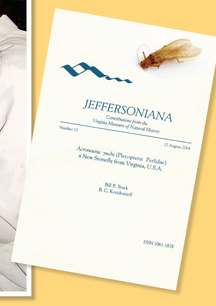
We aren't done yet — estimates of the number of species still to be described range from 3 million to 10 million. Scientists estimate that half of earth's biological diversity will be lost by 2100.

Taxonomy is the part of systematics which includes

identification — referring a specimen to a previously classified and named group.

classification — ordering organisms into groups based on their similarities and differences.

Scientists describe a new species in a technical publication with a narrative physical description, photos, and drawings. The specimen used for the description becomes the type specimen and is housed in a natural history collection. This publication is the formal description of a new kind of stonefly. The type specimen pictured, Acroneuria yuchi, *is housed in VMNH's recent invertebrates collection.*



Biological nomenclature is the system of scientific naming of organisms. It was devised so every kind of organism can have a unique name. It consists of two parts: genus and species.

Dasymutilla occidentalis

red velvet ants
cow killers
mule stingers

Persea americana

avocado
alligator pear
ahuacatl
palta
manzana del invierno

Marmota monax

groundhog
woodchuck
land-beaver
whistle pig

Scientific names are necessary to avoid confusion when addressing organisms. Common names often vary based on location, language, dialect, and culture.

Red ant, avocado, and groundhog photos are from www.flickr.com creative commons.
Photographer usernames from left: Mike_in, JoggeRioBRAZIL, NDomer73.

Museum Collections: Preserving Life's History

Museum collections support research in many disciplines including biology, paleontology, geology, and archaeology studied by VMNH curators.

Collections are

- non-renewable resources.
- cost-effective.
- important to medicine, public health, and security.
- used to monitor climate change and predict its effects on species success.
- used to demonstrate biological differences and/or changes in genetic diversity within a species or population.
- educational tools.
- an important part of the training of new systematists.
- the foundation for taxonomic research and the study of biodiversity.

What do you see when looking at the specimen in the photo?

If a specimen is properly maintained, new technologies can be used to re-analyze it later. University of Maryland researchers drilled a small hole in this fossil bone to obtain material for a chemical analysis of this muskox's diet.

Scientists examine this specimen and learn

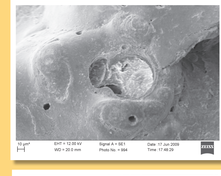
- the type of animal.
- the age of the animal.
- the time it lived.
- its location.
- the diet of the animal.

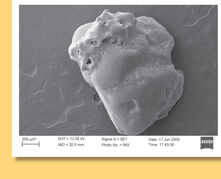
This information can then be used to

- study past and present ecosystems… which animals ate which plants, which animals eat/ate them.
- examine seasonal differences in diet.
- identify marine, versus terrestrial, versus freshwater component of diet.

What do you see when looking at this specimen?

Below are Scanning Electron Microscope images of an interstitial bryozoan on a grain of sand.





Scientists examine this specimen and learn

- the type of animal.
- where it lived.
- how long it lived.
- its location.
- how it reproduced.

This information can then be used to

- discover a new ecosystem for encrusting marine animals: attached to sand grains on subtidal sand shoals.
- learn what role these animals played in the community.
- explore new locations to look for other similar communities.
- identify and describe many new species in this group.

Ecology: The Study of Home

Ecological diversity is another important aspect of biological diversity. Ecologists study the interactions of organisms and their environments.

VMNH Curator Dr. Judith Winston collects specimens near the Philpott Dam.

A woman uses a secchi disk to measure water clarity in a Chesapeake Bay tributary during an algae bloom called a "mahogany tide."

Ecological diversity is the variety of biological communities, such as forests, deserts, grasslands, and streams, that interact with one another and with their physical and chemical (nonliving) environments.

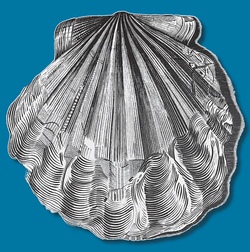
Woodland

Stream

Paleontology: the Long View of Life

Paleontology is the study of the history of life on earth. Paleontologists study the fossil forms of all life, animals and plants, and their environments.

Paleontologists contribute to the study of biodiversity by



- **discovering and describing fossil organisms.**
- **studying the events in the Earth's history that have resulted in increases in diversity and those that have resulted in great losses such as mass extinctions.**
- **using present day environments to interpret past environments and use past patterns to predict future events.**

One observation paleontologists have made is that many of the same ecosystems that are found today were also present in the distant past, and they contain most of the same phyla of animals, but the details of the ecosystems change. Phyla that are rare today are sometimes very common in the past, and the individual species in those phyla are often completely different.

These samples show marine organisms that lived almost 450 million years apart, in similar environments. Notice how most of the same phyla are present, but different phyla are more common in each period, and the species are different.

Paleontology: Moon Snails

Paleontologist use present environments to understand those of the past.

Moon snails are predatory marine snails who have fed on other mollusks since the Cretaceous Period (145.5 – 65.5 million years ago). They feed by drilling through the shells of their prey. These holes are easy to identify and leave a record of both completed and attempted predation.

Paleontologists examined the fossil record of these moon snails and their prey to study how their feeding patterns and the defenses of their prey changed over time. Scientists expected the shells of the prey mollusks to become thicker over time to protect them from the moon snails. They found that this was true with the species most favored by moon snails developing the thickest shells. Scientists also expected the moon snails to adapt to be able to better drill through thicker shells. Instead, they found that the shells of the moon snails adapted to make them more resistant to their own predators, including larger moon snails.

Marine Invasions:
Drift Plastic Encrusters

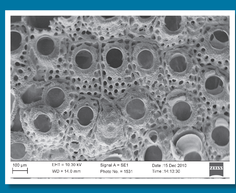
One big problem marine biologists study is the increase and spread of non-native species in marine habitats.

Marine animals reach new places by

- **expanding their range when temperatures change.**
- **larvae being carried in ballast water of ships.**
- **floating on natural and artificial objects.**

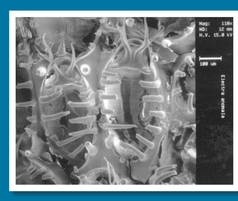
People have greatly increased the amount of habitat for encrusting animals by dumping trash into rivers and oceans. This aids the spread of non-native species to other areas.

The Caribbean bryozoan *Schizoporella pungens* is expanding its range northward along the Florida coast. Its expansion is partly due to warmer seawater temperatures in recent years and partly to its ability to attach to floating trash in the Caribbean that is carried by the currents to Florida.



***SEM image of* Hippoporina indica**

Two bryozoans, *Hippoporina indica* and *Electra bengalensis*, native to Asia, have invaded warm water bays and harbors in the southeastern U.S. and the Gulf of Mexico in recent years. They are now found in many ports around the world.



SEM image of
Electra bengalensis

How do scientists know if a species is an invader?

An inventory of species that live in an area is needed. Then, scientists must periodically survey to see what new species are found. Later, they must study the area again to see if they have been able to establish themselves.

Didymosphenia geminata, commonly known as rock snot, is an invasive or nuisance species that forms large mats on the bottom of lakes, rivers, and streams. One of the first places it was noticed in the eastern U.S. was in the Smith River near Philpott Dam (2006).

The diatom is native to northern Europe, but is now found in many parts of the U.S. and seems to be able to live in both cold clear and warm nutrient rich waters. It has already invaded places as far away as Chile and New Zealand. It can take away habitat for fish food sources and can make the bottom slippery and dangerous for wading fishermen. The diatoms themselves are unicellular and microscopic, but they produce long slimy stalks that develop into rapidly into tan colored slimy mats.

Forensic Flight: the Life of Crime Scene First Responders

Decomposition following the death of an animal is driven by saprophagous insects (literally, body eating).

The diversity of insects on a dead body can help investigators pinpoint the time between death and body discovery, or postmortem interval.

Female blow flies, for example, deposit eggs on bodies within minutes following death during warm seasons.

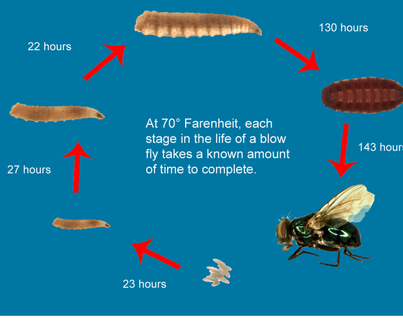
Entomologists can estimate the postmortem interval by examining the age of the eggs, larvae (maggots), or pupae on a body. This information helps with timelines during investigations.

The black blow fly, Phormia regina, *is frequently found at crime scenes throughout North America.*

How do entomologists do this?

- They determine which species are present using technical literature and museum collections.
- Larvae are examined to determine age by examining aspects of the body that change over time.
- Temperature data are used to determine how long it took the maggots to reach the development stage they were in at the time of collection and approximate time of death.

The time intervals noted represent the time between each individual stage of the life cycle of the blow fly.



Succession

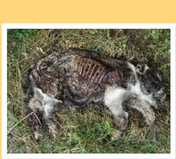
During warm months, maggots may only require a week or so to grow from stage 1 to stage 3 and then form a pupa. After this point, aging eggs, maggots, and pupae is less precise. However, insects arrive at bodies in distinctive waves. Insect succession can help approximate how long a body has been exposed to insect activity.

As bodies decompose, they go through four distinctive phases illustrated below with images of a decaying pig. Each phase has a specific suite of insects.

Fresh:
The body appears normal.

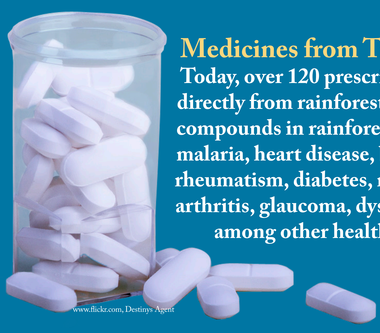
Bloat:
Bacteria in the body form gasses causing swelling.

Active decay:
The beginnings of skeletonization occurs.



Dry remains:
The body has dried out.

Medicine



www.flickr.com, Destinys Agent

Medicines from Tropical Rainforests

Today, over 120 prescription drugs are derived directly from rainforest plants. Some of the compounds in rainforest plants are used to treat malaria, heart disease, bronchitis, hypertension, rheumatism, diabetes, muscle tension, body aches, arthritis, glaucoma, dysentery and tuberculosis, among other health problems.

- Quinine, an aid in the cure of malaria, is an alkaloid extracted from the bark of the cinchona tree found in Latin America and Africa.
- The alkaloid d-tubocuarine, from the bark of various curare vines, is used to treat multiple sclerosis, Parkinson's disease and other muscular disorders. It is also used in anesthesia for surgeries.
- Madagascar's rosy periwinkle provides two important anti-tumor agents. One provides for a 99 percent chance of remission in cases of lymphocytic leukemia. The other offers a life in remission to 58 percent of Hodgkin's disease sufferers.

Medicines from Tropical Coral Reefs

New drugs are expected to come from coral reefs. Many coral reef animals protect themselves by producing chemicals that are poisonous or that make them taste bad. These chemicals have uses in medicine for humans. Possible new drugs in development derive from sponges, sea squirts (tunicates), bryozoans, sea fans, and bacteria from reef animals.

- Spongothymidine, discovered in 1945 in a Caribbean sponge, *Tectitethya crypta*, led to the development of a series of cancer and antiviral drugs used today.
- AZT fights HIV/AIDS virus.
- Ara-C is used to treat leukemia and non-Hodgkins lymphomas.
- Acyclovir is used to treat chickenpox sores, shingles, and herpes viruses.
- The neurotoxin produced by the cone shell snail, *Conus magus*, to kill its prey has been developed into a drug for chronic pain.

Why Care? Life Depends On It.

All living things depend on healthy biodiversity. As humans, our lives and health depend on it, too. Increased biodiversity allows us to have a more stable food supply and makes us less vulnerable to natural disasters.

Benefits of a Healthy Biosphere

- A larger number of plant species means a greater variety of crops.
- Greater species diversity ensures natural sustainability for all life forms.
- Healthy ecosystems can better withstand and recover from a variety of disasters.

While the loss of one species on our planet may seem inconsequential, each species in an ecosystem depends on a variety of other species in order to survive. This creates an interconnected web between all living things. The more variety of species within each ecosystem, the stronger that web of life will be.

An ecosystem can stand strong if all of the components are in balance.

If a species is removed, the entire structure can become unstable.

Each species plays a critical role in maintaining structure.

Each species relies on the components around it to avoid collapse.

The Demand for Resources Can Endanger Ecosystems

Expanding areas of population and increased development threaten fragile ecosystems and in doing so threaten biodiversity and the well-being of the surrounding communities that rely on the natural resources for their economic prosperity and livelihoods.

Globally

Every second, an area of tropical rainforest the size of a football field is destroyed or converted for agricultural use.

Increasing demand for fish has resulted in over-fishing of deep-water commercial fish and key coral reef species.

The United States makes up 4.6 percent of the world's population, but produces about 33 percent of the world's solid waste.

Adapted from an image by D'Arcy Norman, www.flickr.com

Locally

In the time it takes you to read this panel, over 36,000 pounds (over 16,000 kilograms) of sediment will have entered the Chesapeake Bay, totaling 18.7 billion pounds (almost 8.5 billion kilograms) per year. This excess of sediment is a result of erosion, due to over-development of the land surrounding the bay.

In the last hour, 14 acres of Virginia's rural land was converted to non-renewable uses. That's over 300 acres per day and over 100,000 per year.

Every year, 2 million seabirds and 100,000 marine mammals die from ingesting debris and becoming entangled in litter that washed out of rivers and streams (including Virginia's) into the ocean.

www.flickr.com, ingridtaylar

What Can I Do to Help?

Despite all the bad news in regard to deforestation and habitat destruction, there are encouraging initiatives from individuals, corporations, and government agencies that are helping. You too can make a difference!

Join or support an effective rainforest or coral reef conservation organization.

Be a smart consumer and live sustainably. Practice the 3 Rs—Reduce, Reuse, Recycle. Find out where the products you buy came from and what environmental policies the businesses practice.

Educate others. Give a presentation. Teach a class. Share your favorite conservation causes on Facebook. Subscribe to conservation YouTube channels.

Act locally. Join a local stewardship group such as a local chapter of the Virginia Master Naturalist Program, Virginia Master Gardeners, or a local Virginia watershed program such as the Dan River Basin Association.

Virginia Master Naturalist
Southwestern Piedmont Chapter

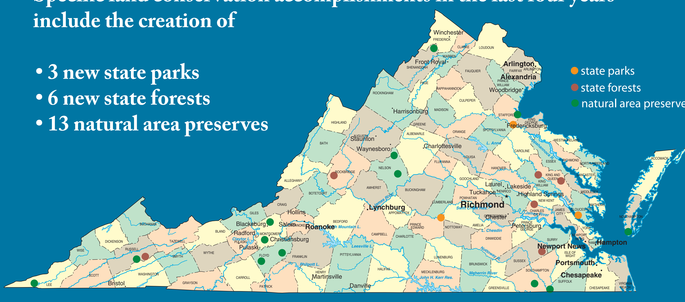
How Can We Protect Virginia's Biodiversity?

Several widespread efforts to improve Virginia's waters and protect Virginia's land are underway across the Commonwealth, from the mountains to the bay. The efforts are led by Virginia and Federal government agencies, private non-profit organizations, communities, and volunteers.

These successful improvement efforts include:
Virginia Land Conservation Foundation efforts have helped to protect over 7.14 million acres — about 28 percent of Virginia's land. When land is set aside and development on that land is prohibited, the habitats and species living there are protected as well. So, as we conserve more land, we contribute to the survival of Virginia's habitats and species.

Specific land conservation accomplishments in the last four years include the creation of

- **3 new state parks**
- **6 new state forests**
- **13 natural area preserves**



Clean Virginia Waterways is a statewide non-profit organization dedicated to citizen stewardship of Virginia's water resources. The organization coordinates the annual Virginia Waterways cleanup, and over 43,000 Virginians have volunteered for the event since 1995.

Over 1.6 million pounds of trash have been collected by clean-up volunteers between 1995 and 2007. Pictured, Friends of Wilson Park pose after cleaning J. Frank Wilson Park behind the museum.