Aquatic
Plants and Animals

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Chapter- 1

Aquatic Plant

Nymphaea alba, a species of water lily

Aquatic plants are plants that have adapted to living within aquatic environments. They are also referred to as **hydrophytes** or **aquatic macrophytes**. These plants require special adaptations for living submerged in water or at the water's surface. Aquatic plants can only grow in water or in soil that is permanently saturated with water. Aquatic vascular plants can be ferns or angiosperms (from a variety of families, including among the monocots and dicots). Seaweeds are not vascular plants but multicellular marine

algae, and therefore not typically included in the category of aquatic plants. As opposed to plant types such as mesophytes and xerophytes, hydrophytes do not have a problem in retaining water, due to the abundance of water in their environment. This means that aquatic plants have less need to regulate transpiration, which would require more energy and be of little benefit to the plant.

Characteristics of aquatic plants:

- A thin cuticle. Cuticles primarily discourage water loss; thus most hydrophytes have no need for cuticles.
- Stomata that are open most of time because water is abundant and therefore there is no need for it to be retained in the plant. This means that guard cells on the stomata are generally inactive.
- An increased number of stomata, that can be on either side of leaves.
- A less rigid structure: water pressure supports them.
- Flat leaves on surface plants for flotation.
- Air sacs for flotation.
- Smaller roots: water can diffuse directly into leaves.
- Feathery roots: no need to support the plant.
- Specialized roots able to take in oxygen.

For example, some species of buttercup (genus *Ranunculus*) float slightly submerged in water; only the flowers extend above the water. Their leaves and roots are long and thin and almost hair-like; this helps spread the mass of the plant over a wide area, making it more buoyant. Long roots and thin leaves also provide a greater surface area for uptake of mineral solutes and oxygen.

Wide flat leaves in water lilies (family Nymphaeaceae) help distribute weight over a large area, thus helping them float near surface.

Many fish keepers keep aquatic plants in their tanks to control phytoplankton and moss by removing metabolites.

Many species of aquatic plant are invasive species. Aquatic plants make particularly good weeds because they reproduce vegetatively from fragments.

Adaptations

- Floating plants: In an outdoor body of water, these receive more sunlight than submerged plants do. They also rarely have to compete with one another for sunlight
- Submerged plants: The leaves of submerged plants receive lower levels of sunlight because light energy diminishes while passing through a water column.

All floating plants

- Either have air spaces trapped in their roots, or else air spaces in their bodies (aerenchyma) to help them to float, thus receiving adequate sunshine
- Have hair on their leaves that traps air
- Structural adaptations

Duckweed, water cabbage

- Chloroplast found on the top surface of the leaves
- Upper Surface has a thick, waxy cuticle to repel water and to help keep the stomata open and clear
- Structural adaptation
- Small and light

Water lily

- Structural material to reach higher points and receive more sunlight
- Structural adaptation

Floating heart, water lily, lotus, yellow pond lily, water-shield

- Their leaves tend to be broader without major lobing, to remain flat on water surface, to enlarge their surface area, and to make use of as much sunlight as possible. Their chloroplasts are found on the tops of their leaves.
- Structural/ behavioral adaptations

Most partially-submerged ("emersed") plants

- Air spaces within their tissues to keep them buoyant so that their leaves can reach the top of the body of water, in order to receive an adequate amount of sunlight
- Structural adaptation

Dissected: Parrot's Feather, Hornwort
Thread-like: ditch-grass, quillwort

- Highly dissected/ divided leaves or thread-like ones, allows for a bigger surface area (surface to volume ratio)
- Structural adaptation

Hydrilla

- Elongates rapidly to reach water surface and branches out at water surface; more light can be obtained at water surface
- Structural/ behavioral adaptation
- Xylem tubes are absent

Human nutrition

Many aquatic plants are used by humans as a food source. Note that especially in (South-east) Asia edible but uncooked hydrophytes are implicated in the transmission of fasciolopsiasis.

- Wild rice (*Zizania*)
- Water caltrop (*Trapa natans*)
- Chinese water chestnut (*Eleocharis dulcis*)
- Indian Lotus (*Nelumbo nucifera*)
- Water spinach (*Ipomoea aquatica*)
- Watercress (*Rorippa nasturtium-aquaticum*)
- Watermimose, Water mimosa ? (*Neptunia natans*)
- Taro (*Colocasia esculenta*)
- Rice (*Oryza*) is originally not an aquatic plant.
- Bullrush, Cattail, (*Typha*)
- Water-pepper (*Polygonum hydropiper*)
- Wasabi (*Wasabia japonica*)

Animal nutrition

Some examples of aquatic plants

- Water hyacinth (*Eichhornia*)
- Duckweed: *Lemna, Spirodela and Wolffia*
- *Trichanthera gigantea*

Some examples of aquatic plants

- Most algae, and all seaweed and kelp

- *Utricularia* (from the Latin, *utriculus*, a little bag or bottle) is a genus of slender aquatic plants, the leaves of which contain floating air bladders. They are called bladderworts.

- Water lettuce

Chapter- 2

Lemnaoideae

Lemnaoideae

Close up of two different duckweeds: *Spirodela polyrrhiza* and *Wolffia globosa*. The latter are less than 2 mm long.

Scientific classification	
Kingdom:	Plantae
(unranked):	Angiosperms
(unranked):	Monocots
Order:	Alismatales
Family:	Araceae
Subfamily:	**Lemnoideae**

Genus

- *Spirodela*
- *Landoltia*
- *Lemna*
- *Wolffiella*
- *Wolffia*

Duckweeds, or water lentils, are aquatic plants which float on or just beneath the surface of still or slow-moving fresh water bodies. They arose from within the arum or aroid family, (Araceae), and therefore, often are classified as the subfamily **Lemnoideae** within the Araceae. Classifications created prior to the approximate end of the twentieth century tend to classify them as a separate family, **Lemnaceae**.

These plants are very simple, lacking an obvious stem or leaves. They consist of a small 'thalloid' or plate-like structure that floats on or just under the water surface, with or without simple rootlets. The plants are highly reduced from their earlier relatives in Araceae.

Reproduction is mostly by asexual budding, but occasionally three tiny 'flowers' consisting of two stamens and a pistil are produced and sexual reproduction occurs. Some view this 'flower' as a pseudanthium, or reduced inflorescence, with three flowers that are distinctly either female or male and which are derived from the spadix in Araceae. Anatomical research regarding the mechanics of this process has not been completed or remains ambiguous due to considerable evolutionary reduction of these plants from their earlier relatives. The flower of *Wolffia* is the smallest known flower in the world, measuring merely 0.3 mm long. The fruit produced through this occasional sexual reproduction is a *utricle*, and a seed is produced in a sac containing air that facilitates flotation.

Duckweed in various environments

Duckweed is an important high-protein food source for waterfowl and also is eaten by humans in some parts of Southeast Asia (as *khai-nam*). As it contains more protein than soybeans, it is sometimes cited as a significant potential food source.

Some duckweeds are introduced into freshwater aquariums and ponds where they may spread rapidly. This introduction may be deliberate or unintended and once established in a large pond, may be difficult to eradicate. Occurring naturally by being carried on the feathers, shells, and coats of native species, the plant is introduced readily by birds, turtles, reptiles, and aquatic mammals visiting multiple ponds, rivers, and lakes. In water bodies with constant currents or overflow, the plants are carried down the water channels and do not proliferate greatly. In some locations a cyclical pattern driven by weather patterns exists in which the plants proliferate greatly during low water flow periods, yet are carried away as rainy periods ensue.

The tiny plants provide cover for fry of many aquatic species. The plants are used as shelter by pond water species such as bullfrogs and bluegills. They also provide shade and, although frequently confused with them, can reduce certain light-generated growths of photoautotrophic algae.

The plants can provide nitrate removal, if cropped, and the duckweeds are important in the process of bioremediation because they grow rapidly, absorbing excess mineral nutrients, particularly nitrogen and phosphates. For these reasons they are touted as water purifiers of untapped value.

The Swiss *Department of Water and Sanitation in Developing Countries*, SANDEC, associated with the Swiss Federal Institute for Environmental Science and Technology, asserts that as well as the food and agricultural values, duckweed also may be used for waste water treatment to capture toxins and for odor control, and, that if a mat of duckweed is maintained during harvesting for removal of the toxins captured thereby, it prevents the development of algae and controls the breeding of mosquitoes. The same publication provides an extensive list of references for many duckweed-related topics.

These plants also may play a role in conservation of water because a cover of duckweed will reduce evaporation of water when compared to the rate of a similar size water body with a clear surface.

Taxonomy

The duckweeds long have been a taxonomic mystery, and usually have been considered to be their own family, Lemnaceae. They primarily reproduce asexually. Flowers, if present at all, are small. Roots are either very much reduced, or absent entirely. They were suspected of being related to the Araceae as long ago as 1876, but until the advent of molecular phylogeny it was difficult to test this hypothesis. Starting in 1995 studies

began to confirm their placement in the Araceae and since then, most systematists consider them to be part of that family.

Their position within their family has been slightly less clear, but several twenty-first century studies place them in the position shown below. They are not closely related to *Pistia*, however, which also is an aquatic plant in the family Araceae.

Research

In July 2008 the U.S. Department of Energy (DOE) Joint Genome Institute announced that the Community Sequencing Program would fund the sequencing the genome of the giant duckweed, *Spirodela polyrhiza*. This was a priority project for DOE in 2009. The research is intended to facilitate new biomass and bio-energy programs.

Duckweed is being studied by researchers around the world as a possible source of clean energy. In the United States, in addition to being the subject of study by the DOE, both Rutgers University and North Carolina State University have ongoing projects to determine if duckweed might be a source of cost-effective, clean, renewable energy.. In Rutgers duckweed is being studied under Rutgers' Waksman Students Scholar Program where high school students contribute to the genotyping of the duckweed. Currently 50 schools, along with Rutgers, are participating. The Frisch School is among those fifty schools participating in sequencing the genome. Students at the Frisch School sequencing the Duckweed include Kate Fishbein, the team leader, Aaron Dardik and Eric Tepper. Duckweed is a good candidate as a biofuel because as a biomass it grows rapidly, has 5 to 6 times as much starch as corn, and does not contribute to global warming. Duckweed is considered a carbon neutral energy source, because unlike most fuels, it actually *removes* carbon dioxide from the atmosphere.

Duckweed also functions as a bioremediator by effectively filtering contaminants such as bacteria, nitrogen, phosphates, and other nutrients from naturally occurring bodies of water, constructed wetlands and waste water. One study in Australia surrounding aquaculture suggests that although duckweed is initially effective as a nutrient filter, over time some nutrient build-up returns.

Common duckweed in Galicia, Spain

Lemna minor

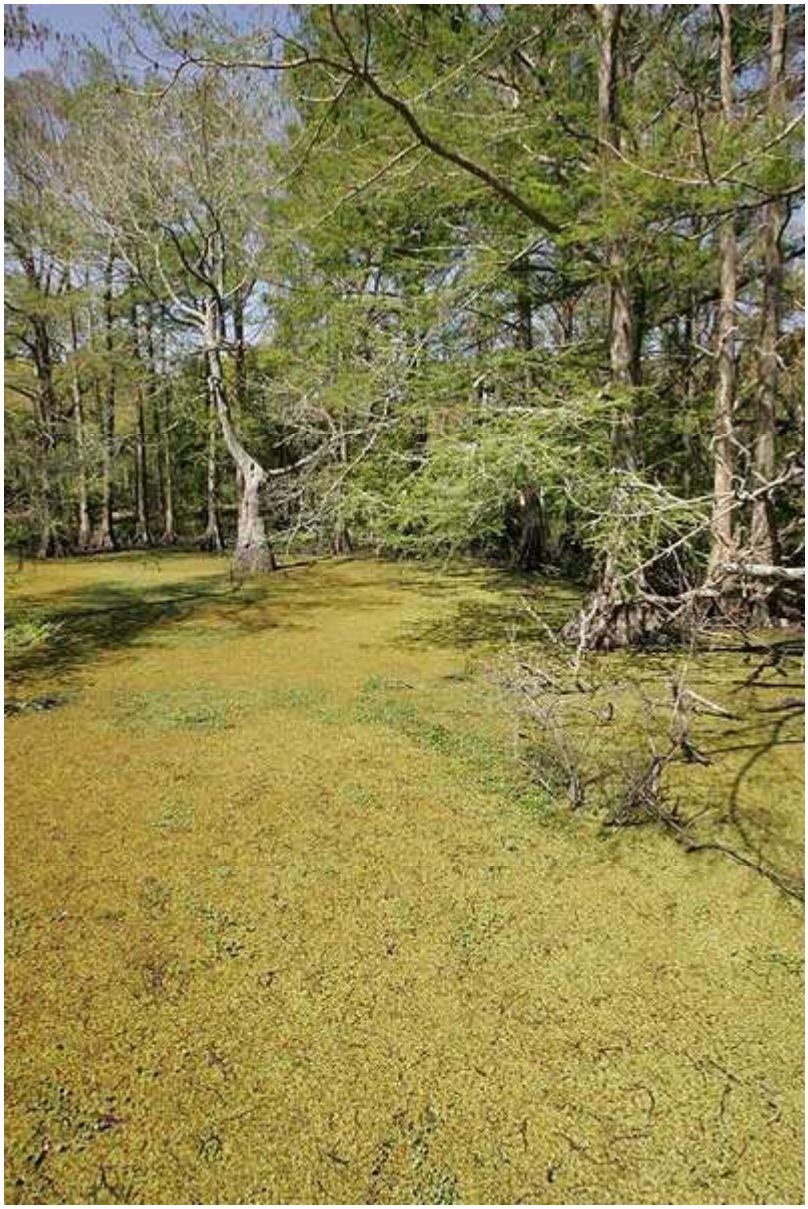
Lemna trisulca

Lemna gibba.

Turning the canals of the Poitevin Marsh (Marais Poitevin, France) into the "Green Venice":

Spirodela polyrhiza

Canal green with duckweed



Duckweed-covered water edged with several bald cypress trees

Chapter- 3

Pistia and Nelumbo

Pistia

Pistia

Scientific classification
Kingdom: Plantae
(unranked): Angiosperms
(unranked): Monocots
Order: Alismatales
Family: Araceae
Subfamily: Aroideae
Tribe: Pistieae
Genus: ***Pistia*** L.
Species: ***P. stratiotes***
Binomial name
Pistia stratiotes L.

Pistia is a genus of aquatic plant in the family Araceae, comprising a single species, ***Pistia stratiotes***, often called **water cabbage** or **water lettuce**. Its native distribution is uncertain, but probably pantropical; it was first described from the Nile near Lake Victoria in Africa. It is now present, either naturally or through human introduction, in nearly all tropical and subtropical fresh waterways.

Description

19th century illustration of *Pistia stratiotes*

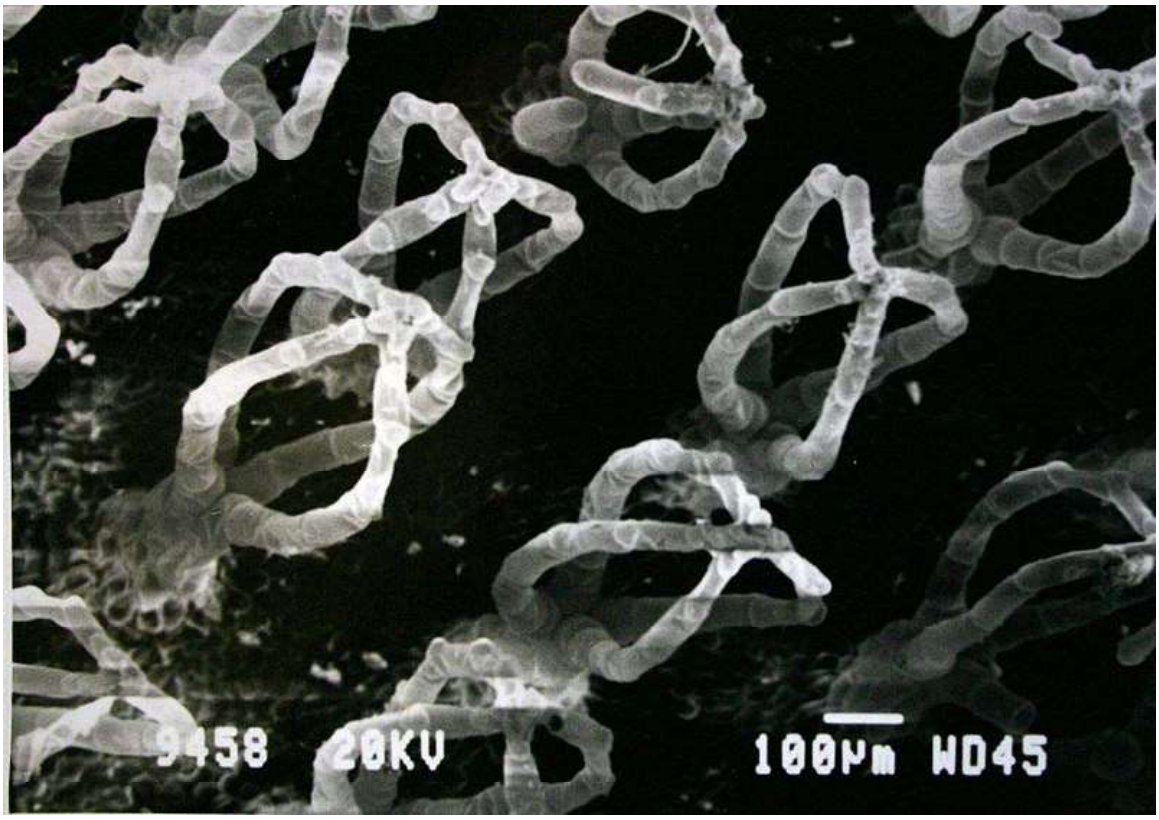
It is a perennial monocotyledon with thick, soft leaves that form a rosette. It floats on the surface of the water its roots hanging submersed beneath floating leaves. The leaves can be up to 14 cm long and have no stem. They are light green, with parallel veins, wavy margins and are covered in short hairs which form basket-like structures which trap air bubbles, increasing the plant's buoyancy. The flowers are dioecious, and are hidden in the middle of the plant amongst the leaves. Small green berries form after successful fertilization. The plant can also undergo asexual reproduction. Mother and daughter plants are connected by a short stolon, forming dense mats.

Ecology

The growth habit can make it a weed in waterways. It is a common aquatic weed in the United States, particularly in Florida where it may clog waterways. It has the potential to reduce the biodiversity of a waterway. Mats of *Pistia* block gas exchange at the air-water

interface, reducing the oxygen in the water and killing fish. They also block light, killing native submerged plants, and alter immersed plant communities by crushing them.

Pistia can be controlled by mechanical harvesters that remove the water lettuce from the water and transport it to disposal on shore. Aquatic herbicides may also be used. Two insects are also being used as a biological control. Adults and larvae of the South American weevil *Neohydronomous affinis* feed on *Pistia* leaves, and the larvae of moth *Spodoptera pectinicornis* from Thailand. Both are proving to be useful tools in the management of *Pistia*.



SEM image of basket-like structures on surface of leaf

Water lettuce is often used in tropical aquariums to provide cover for fry and small fish. It is also helpful as it outcompetes algae for nutrients in the water, thereby preventing massive algal blooms.

Public health importance

Mosquitoes of the genus *Mansonioides* complete their life cycle only in the presence of aquatic plants like *Pistia*, *Eihcornia*, *Salvinia*, etc. These mosquitoes lay their eggs under the *Pistia* leaf.It will appear just like rosette. The emerging larva fall into the water with in 24 houurs and stay attached to the *Pistia* root (which is rich with air sacs) with the help of a serrated siphon tube for respiration and develop into pupa. The pupa is also attached

to the pistia root with the serrated piercing siphon tube. The egg to adult mosquito development will be completed with in 7 days. These mosquitoes transmit the *Brugia malayi* type of Lymphatic filariasis in Kerala, India.

Nelumbo

Nelumbo

Nelumbo nucifera

Scientific classification	
Kingdom:	Plantae
Division:	Angiosperms
(unranked):	Eudicots
Order:	Proteales
Family:	**Nelumbonaceae**
Genus:	***Nelumbo*** Adans.

Species

- †*Nelumbo aureavallis*
- *Nelumbo lutea*
- *Nelumbo nucifera*

Nelumbo is a genus of aquatic plants with large, showy, water lily-like flowers commonly known as **lotus**. The generic name is derived from the Sinhalese word *Nelum*. There are two living species in the genus, the better known of which, the Sacred Lotus (*N. nucifera*), is the national flower of Egypt, India and Vietnam. An extinct species, *Nelumbo aureavallis* has been described from leaves found in the Golden Valley Formation in North Dakota, USA.

There is residual disagreement over which family the genus should be placed in. Traditional classification systems recognized *Nelumbo* as part of the Nymphaeaceae (water lily) family, but traditional taxonomists were likely misled by evolutionary convergences associated with an evolutionary shift from a terrestrial to an aquatic lifestyle. In the older classification systems it was recognized under the biological order Nymphaeales or Nelumbonales. *Nelumbo* is currently recognized as its own family, Nelumbonaceae, as one of several distinctive families in the eudicot order Proteales. Its closest living relatives are shrubs or trees (Proteaceae and Platanaceae).

These plants are unrelated to the bird's-foot trefoils and deer-vetches of the genus *Lotus*.

Species

- †*Nelumbo aureavallis* Hickey – Eocene (North Dakota)

- *Nelumbo lutea* Willd. – American Lotus (Eastern United States, Mexico, Greater Antilles, Honduras)

- *Nelumbo nucifera* Gaertn. – Sacred or Indian Lotus, also known as the Rose of India and the Sacred Water Lily of Hinduism and Buddhism. It is the national flower of India and Vietnam. Its roots and seeds are also used widely in Asian cooking.

Classification

Most academic botanists recognize *Nelumbo* in the family Nelumbonaceae, comprising only the single genus, *Nelumbo*, with probably two species of aquatic plants, found in North America and Asia (and perhaps some adjacent areas, but widely cultivated elsewhere).

The leaves of *Nelumbo* can be distinguished from those of genera in the Nymphaeaceae as they are peltate, that is they have fully circular leaves. *Nymphaea*, on the other hand, has a single characteristic notch from the edge in to the center of the lily pad. The seedpod of *Nelumbo* is very distinctive.

APG

The APG II system of 2003, recognizes Nelumbonaceae as a distinct family and places it in the order Proteales, in the eudicot clade.

Earlier classification systems

The Cronquist system of 1981, recognizes the family but places it in the water lily order Nymphaeales. The Dahlgren system of 1985 and Thorne system (1992) both recognize the family and place it in its own order, Nelumbonales.

Thermoregulation

N. nucifera regulates its temperature in order to benefit insects that are needed for it to reproduce. When the plant flowers, it heats its blossoms to above 30 °C (86 °F) for as long as four days even when the air is as cool as 10 °C (50 °F). The heat releases an aroma that attracts certain insects, which fly into the flower to feed on nectar and pollen. According to Roger Seymour and Paul Schultze-Motel of Australia's University of Adelaide, the heat also rewards insects with a stable environment that enhances their ability to eat, mate, and prepare for flight.

Different views & aspects

Nelumbo lutea

Nelumbo nucifera- A lotus blossom in full bloom.

Nelumbo nucifera- A lotus blossom in full bloom.

Nelumbo nucifera- An example of the lotus effect after rain.

Lotus bud

Nelumbo nucifera- A blossom opening.

Young seed pod

Dried seed pod

Chapter- 4

Nuphar lutea and Hydrilla

Nuphar lutea

Nuphar lutea

Nuphar lutea

Scientific classification	
Kingdom:	Plantae
(unranked):	Angiosperms
Order:	Nymphaeales
Family:	Nymphaeaceae
Genus:	*Nuphar*
Species:	***N. lutea***

Binomial name

Nuphar lutea
(L.) Sm.

Nuphar lutea, the **spatterdock**, **yellow water-lily**, **cow lily**, or **yellow pond-lily**, is an aquatic plant of the family Nymphaeaceae, native to Eurasia and North America. It grows in eutrophic freshwater beds, with its roots fixed into the ground and its leaves floating on the water's surface.

Growth

The plant's inflorescence is a solitary, terminal hermaphrodite flower, pollinated by insects, which blooms from June to September in the Northern Hemisphere. The flower is followed by achenes which are distributed by the water current. It can grow in water up to 40 cm (16 in) deep.

Medicinal and food uses

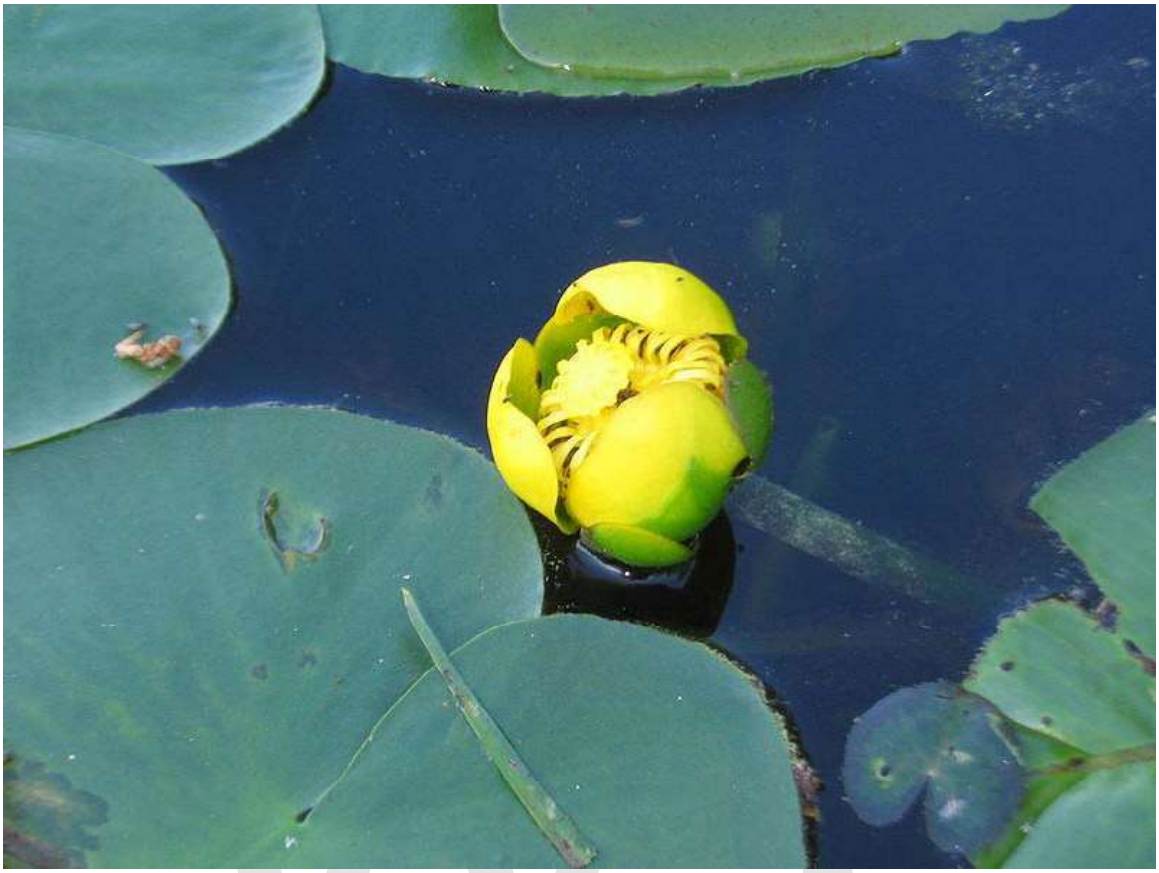
Spatterdock was long used in traditional medicine, with the root applied to the skin and/or both the root and seeds eaten for a variety of conditions. The seeds are edible, and can be ground into flour. The root is edible too, but can prove to be incredibly bitter in some plants.

Synonyms

Possible botanical synonyms include

- *Nuphar luteum* (L.) Sibth. & Sm.
- *Nuphar advena* Ait.
- *Nuphar variegata* Durand

Floating leaf habit



A Nuphar flower, New Hampshire

On Eglinton Loch, North Ayrshire, Scotland

Detail of leaf structure

Hydrilla

Hydrilla

Scientific classification	
Kingdom:	Plantae
(unranked):	Monocots
Order:	Alismatales
Family:	Hydrocharitaceae
Genus:	***Hydrilla*** Rich.
Species:	***H. verticillata***

Binomial name

Hydrilla verticillata
(L.f.) Royle

Hydrilla (**Esthwaite Waterweed** or **Hydrilla**) is an aquatic plant genus, usually treated as containing just one species, *Hydrilla verticillata*, though some botanists divide it into several species. Synonyms include *H. asiatica*, *H. japonica*, *H. lithuanica*, and *H. ovalifolica*. It is native to the cool and warm waters of the Old World in Asia, Europe, Africa and Australia, with a sparse, scattered distribution; in Europe, it is reported from Ireland, Great Britain, Germany, and the Baltic States, and in Australia from Northern Territory, Queensland, and New South Wales.

It has off-white to yellowish rhizomes growing in sediments at the water bottom at up to 2 m depth. The stems grow up to 1–2 m long. The leaves are arranged in whorls of two to eight around the stem, each leaf 5–20 mm long and 0.7–2 mm broad, with serrations or small spines along the leaf margins; the leaf midrib is often reddish when fresh. It is monoecious (sometimes dioecious), with male and female flowers produced separately on a single plant; the flowers are small, with three sepals and three petals, the petals 3–5 mm long, transparent with red streaks. It reproduces primarily vegetatively by fragmentation and by rhizomes and turions (overwintering buds), and flowers are rarely seen.

Hydrilla has a high resistance to salinity (>9-10ppt) compared to many other freshwater associated aquatic plants.

The name Esthwaite Waterweed derives from its occurrence in Esthwaite Water in northwestern England, the only English site where it is native, but now presumed extinct, having not been seen since 1941. *Hydrilla* closely resembles some other related aquatic plants, including *Egeria* and *Elodea*.

Status as an invasive plant

Foliage detail

in Lotus Pond, Hyderabad, India.

Hydrilla is naturalised and invasive in the United States following release in the 1960s from aquariums into waterways in Florida. It is now established in the southeast from Connecticut to Texas, and also in California. By the 1990s control and management were costing millions of dollars each year.

Hydrilla can be controlled by the application of aquatic herbicides and it is also eaten by grass carp, itself an invasive species in North America. Insects used as biological pest control for this plant include weevils of genus *Bagous* and the Asian hydrilla leaf-mining fly (*Hydrellia pakistanae*). Tubers pose a problem to control as they can lay dormant for a number of years. This has made it even more difficult to remove from waterways and estuaries.

As an invasive species in Florida, Hydrilla has become the most serious aquatic weed problem for Florida and most of the U.S. Because it was such a threat as an invasive species, restrictions were placed, only allowing a single type of chemical, fluridone, to be used as an herbicide. This was done to prevent the evolution of multiple mutants. The result is fluridone resistant Hyrdilla. “As hydrilla spread rapidly to lakes across the southern United States in the past, the expansion of resistant biotypes is likely to pose significant environmental challenges in the future.”

Phytoremediation

This abundant source of biomas is a known bioremediation hyperaccumulator of Mercury, Cadmium, Chromium and Lead, and as such can be used in phytoremediation.

- Hyperaccumulators table – 3

Chapter- 5

Water Hyacinth and Lemna

Water hyacinth

Water Hyacinth

Common Water Hyacinth (*E. crassipes*)

Scientific classification	
Kingdom:	Plantae
(unranked):	Angiosperms
(unranked):	Monocots
(unranked):	Commelinids
Order:	Commelinales
Family:	Pontederiaceae
Genus:	***Eichhornia*** Kunth

Species

Seven species, including:
E. azurea - Anchored Water Hyacinth
E. crassipes - Common Water Hyacinth

E. diversifolia - Variableleaf Water Hyacinth
E. paniculata - Brazilian Water Hyacinth

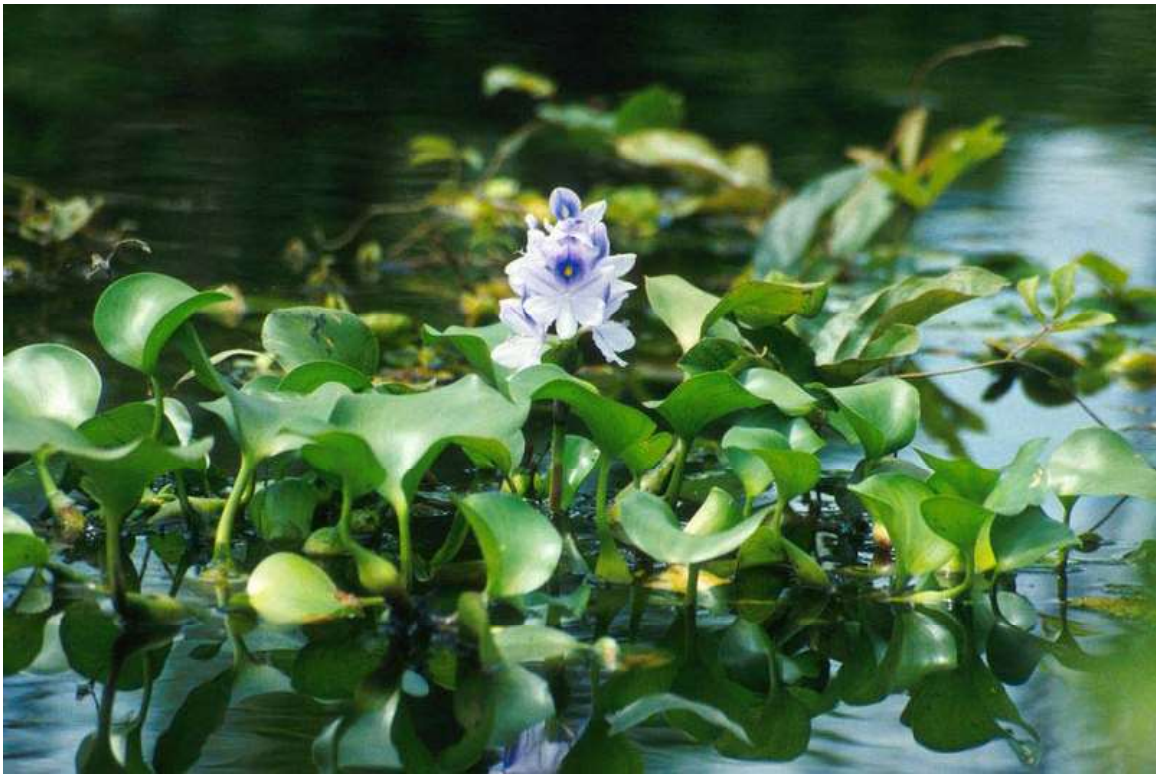
The seven species of **water hyacinth** comprise the genus ***Eichhornia***. Water hyacinth are a free-floating perennial aquatic plant native to tropical and sub-tropical South America. With broad, thick, glossy, ovate leaves, water hyacinth may rise above the surface of the water as much as 1 meter in height. The leaves are 10–20 cm across, and float above the water surface. They have long, spongy and bulbous stalks. The feathery, freely hanging roots are purple-black. An erect stalk supports a single spike of 8-15 conspicuously attractive flowers, mostly lavender to pink in colour with six petals. When not in bloom, water hyacinth may be mistaken for frog's-bit (*Limnobium spongia*).

One of the fastest growing plants known, water hyacinth reproduces primarily by way of runners or stolons, which eventually form daughter plants. It also produces large quantities of seeds, and these are viable up to thirty years. The common water hyacinth (*Eichhornia crassipes*) are vigorous growers known to double their population in two weeks.

In Assamese they are known as ***Meteka***. In Sinhala they are known as **Japan Jabara** due to their use in World War II to fool Japanese pilots into thinking lakes were fields usable to land their aircraft, leading to crashes. In Burmese they are known as ***Baydar***.

In Southern Pakistan, they are the provincial flower of Sindh.

Invasiveness as an exotic plant



Common water hyacinth in flower

Water hyacinth has been widely introduced throughout North America, Asia, Australia and Africa. They can be found in large water areas such as Louisiana, or in the Kerala Backwaters in India. In many areas it, particularly *E. crassipes*, is an important and pernicious invasive species. First introduced to North America in 1884, an estimated 50 kilograms per square metre of hyacinth once choked Florida's waterways, although the problem there has since been mitigated. When not controlled, water hyacinth will cover lakes and ponds entirely; this dramatically impacts water flow, blocks sunlight from reaching native aquatic plants, and starves the water of oxygen, often killing fish (or turtles). The plants also create a prime habitat for mosquitos, the classic vectors of disease, and a species of snail known to host a parasitic flatworm which causes schistosomiasis (snail fever). Directly blamed for starving subsistence farmers in Papua New Guinea, water hyacinth remains a major problem where effective control programs are not in place. Water hyacinth is often problematic in man-made ponds if uncontrolled, but can also provide a food source for gold fish, keep water clean and help to provide oxygen to man-made ponds.

Water hyacinth often invades bodies of water that have been impacted by human activities. For example, the plants can unbalance natural lifecycles in artificial reservoirs or in eutrophied lakes that receive large amounts of nutrients.

They are being found for the abundant plants, such as for cattle food and in biogas production. Recently, they have also begun to be used in wastewater treatment due to their fast growth and ability to tolerate high levels of pollution. Parts of the plant are also used in the production of traditional handicrafts in Southeast Asia. In Bangladesh, farmers have started producing fertilizer using Water Hyacinth or Kochuripana as it is known there locally.

As chemical and mechanical removal is often too expensive and ineffective, researchers have turned to biological control agents to deal with water hyacinth. The effort began in the 1970s when USDA researchers released three species of weevil known to feed on water hyacinth into the United States, *Neochetina bruchi*, *N. eichhorniae*, and the water hyacinth borer *Sameodes albiguttalis*. Although meeting with limited success, the weevils have since been released in more than 20 other countries. However, the most effective control method remains the control of excessive nutrients and prevention of the spread of this species.

In 2010 the insect Megamelus scutellaris was released by the Agricultural Research Service as a biological control for the invasive species *Eichhornia crassipes*, more commonly known as waterhyacinth. (United States Department of Agriculture, Agricultural Research Service,)

In May of 2010 the USDA's Agricultural Research Service released *Megamelus scutellaris* as a biological control insect for the invasive waterhyacinth species. *Megamelus scutellaris* is a small planthopper insect native to Argentina. Researchers have been studying the effects of the biological control agent in extensive host-range studies since 2006 and concluded that the insect is highly host-specific and will not pose a threat to any other plant population other than the targeted water hyacinth. Researchers also hope that the biological control will be more resilient than existing biological controls to the herbicides that are already in place to combat the invasive water hyacinth.

Water hyacinth in Lake Victoria, Africa

Hyacinth-choked lakeshore at Ndere Island, Lake Victoria, Kenya

Botanists and gardeners carry plants with them in their travels, and experts suspect that this is how the water hyacinth came to East Africa in the 1980s. Its flowers are beautiful; it was probably brought over as an ornamental for garden ponds (United Nations News, 2000). The consensus is that Water Hyacinth entered Lake Victoria from Rwanda via the river Kagera (Ambrose 1997). The exact time and place of introduction has been debated, but the plant is native to South America, and therefore reached Lake Victoria due to human activity. It has spread prolifically, due to lack of natural enemies, an abundance of space, agreeable temperature conditions, and abundant nutrients (Opande et al., 2004). It increased rapidly between 1992-1998, was greatly reduced by 2001, and has since resurged to a lesser degree. Management techniques include (hyacinth-eating) insect controls and manual beach cleanup efforts (Kateregga/Sterner 2007). A water hyacinth infestation is seldom totally eradicated. Instead, it is a situation that must be continually managed (LVEMP, 2004) (United Nations News, 2000)).

Water Hyacinth affects the Lake Victorian population in many negative ways. There are economic impacts when the weed blocks boat access. The effects on transportation and fishing are immediately felt. Where the weed is prolific, there is a general increase in several diseases, as the weed creates excellent breeding areas for mosquitoes and other insects. There are increased incidents of skin rash, cough, malaria, encephalitis,

bilharzias, gastro intestinal disorders, and schistosomiasis. Water hyacinth also interferes with water treatment, irrigation, and water supply (Opande et al., 2004)). It can smother aquatic life by deoxygenating the water, and it reduces nutrients for young fish in sheltered bays. It has blocked supply intakes for the hydroelectric plant, interrupting electrical power for entire cities. The weed also interrupts local subsistence fishing, blocking access to the beaches (LVEMP, 2004).

Industrial utilization

Since the plant has abundant nitrogen content, it can be used a substrate for biogas production and the sludge obtained from the biogas. However, due to easy accumulation of toxins, the plant is prone to get contaminated when used as feed.

Exogenous

The plant is extremely tolerant of, and has a high capacity for, the uptake of heavy metals, including Cd, Cr, Co, Ni, Pb and Hg, which could make it suitable for the biocleaning of industrial wastewater ' ' ' . In addition to heavy metals, *Eichhornia crassipes* can also remove other toxins, such as cyanide, which is environmentally beneficial in areas that have endured gold mining operations .

Water hyacinth is also observed to enhance nitrification in waste water treatment cells of living technology. Their root zones are superb micro-sites for bacterial communities.

Lemna

Lemna

Common Duckweed (*Lemna minor*)

Scientific classification	
Kingdom:	Plantae
(unranked):	Angiosperms
(unranked):	Monocots
Order:	Alismatales
Family:	Araceae

Subfamily:	Lemnoideae
Tribe:	Lemneae
Genus:	***Lemna*** L.

Species

About 13, including:

- *Lemna gibba* : Gibbous Duckweed
- *Lemna minor* : Common Duckweed
- *Lemna minuta* : Least Duckweed
- *Lemna trisulca* : Ivy Duckweed
- *Lemna valdiviana* : Valdivia Duckweed

Lemna is a genus of free-floating aquatic plants from the duckweed family. These rapidly-growing plants have found uses as a model system for studies in community

ecology, basic plant biology, in ecotoxicology, in production of biopharmaceuticals, and as a source of animal feeds for agriculture and aquaculture.

Taxonomy and growth habits

The duckweeds have been classified as a separate family, the Lemnaceae, but some researchers (the AGP II) consider the duckweeds members of the Araceae.

Lemna species grow as simple free-floating thalli on or just beneath the water surface. Most are small, not exceeding 5 mm in length, except *Lemna trisulca* which is elongated and has a branched structure. *Lemna* thalli have a single root, which distinguishes them from related genera *Spirodela* and *Landoltia*

The plants grow mainly by vegetative reproduction: two daughter plants bud off from the adult plant. This form of growth allows very rapid colonisation of new water. Duckweeds are flowering plants, and nearly all of them are known to reproduce sexually, flowering and producing seed under appropriate conditions. Certain duckweeds (e.g. *L. gibba*) are long day plants, while others (e.g. *L. minor*) are short day plants.

When *Lemna* invades a waterway, it can be removed mechanically, by the addition of herbivorous fish (e.g. grass carp) or treated with a herbicide.

The rapid growth of duckweeds finds application in bioremediation of polluted waters and as test organisms for environmental studies. It is also being used as an expression system for economical production of complex biopharmaceuticals.

Duckweed meal (dried duckweed) is a good cattle feed. It contains 25-45% proteins (depending on the growth conditions), 4.4% fat, and 8-10% fibre, measured by dry weight.

Assessing the toxicity of chemicals with Lemna

Organisation for Economic Cooperation and Development and U.S. Environmental Protection Agency (US EPA) guidelines describe toxicity testing using *Lemna gibba* or *Lemna minor* as test organisms. Both of these species have been studied extensively for use in phytotoxicity tests. Genetic variability in responses to toxicants can occur in Lemna, and there are insufficient data to recommend a specific clone for testing. The US EPA test uses aseptic technique. The OECD test is not conducted axenically, but steps are taken at stages during the test procedure to keep contamination by other organisms to a minimum. Depending on the objectives of the test and the regulatory requirements, testing may be performed with renewal (semi-static and flow-through) or without renewal (static) of the test solution. Renewal is useful for substances that are rapidly lost from solution as a result of volatilisation, photodegradation, precipitation or biodegradation.

Production of biopharmaceuticals

Lemna has been transformed by molecular biologists to express proteins of pharmaceutical interest. Expression constructs were engineered to cause *Lemna* to secrete the transformed proteins into the growth medium at high yield. Since the *Lemna* is grown on a simple medium, this substantially reduces the burden of protein purification in preparing such proteins for medical use, promising substantial reductions in manufacturing costs. In addition, the host *Lemna* can be engineered to cause secretion of proteins with human patterns of glycosylation, an improvement over conventional plant gene-expression systems. Several such products are being developed, including monoclonal antibodies.

Duckweed farming

High yields of duckweed with a high protein content can be achieved by careful control of growth conditions. Although duckweed can tolerate temperatures ranging from 6 to 33 °C, the optimal growth range is 20 to 28 °C. The acceptable pH range is 5 to 9, but better growth is obtained in the pH range of 6.5 to 7.5. A minimum water depth of 1 ft is desirable to prevent excessive temperature swings. High nitrogen levels, for example 20 mM urea, have provided a protein content in the range of 45% by weight. The water may typically contain 60 mg/L of soluble nitrogen and 1 mg/L of phosphorus. Fertiliser is required on a daily basis for optimal growth.

Duckweed can be farmed organically, with nutrients being supplied from a variety of sources, for example cattle dung, pig waste, biogas plant slurry, or other organic matter in slurry form. Because of the rapid growth of duckweed, daily harvesting is necessary to achieve optimal yields. Harvesting is done such that less than a kilogram per square metre of duckweed remains. Under optimal conditions, a duckweed farm can produce 10 to 30 tons of dried duckweed per hectare per year.

Chapter- 6

Utricularia

Utricularia

Utricularia vulgaris illustration from Jakob Sturm's *"Deutschlands Flora in Abbildungen"*, Stuttgart (1796)

Scientific classification	
Kingdom:	Plantae
(unranked):	Angiosperms
(unranked):	Eudicots
(unranked):	Asterids
Order:	Lamiales
Family:	Lentibulariaceae
Genus:	***Utricularia***

L.

Subgenera

Bivalvaria
Polypompholyx
Utricularia

Diversity

227 species

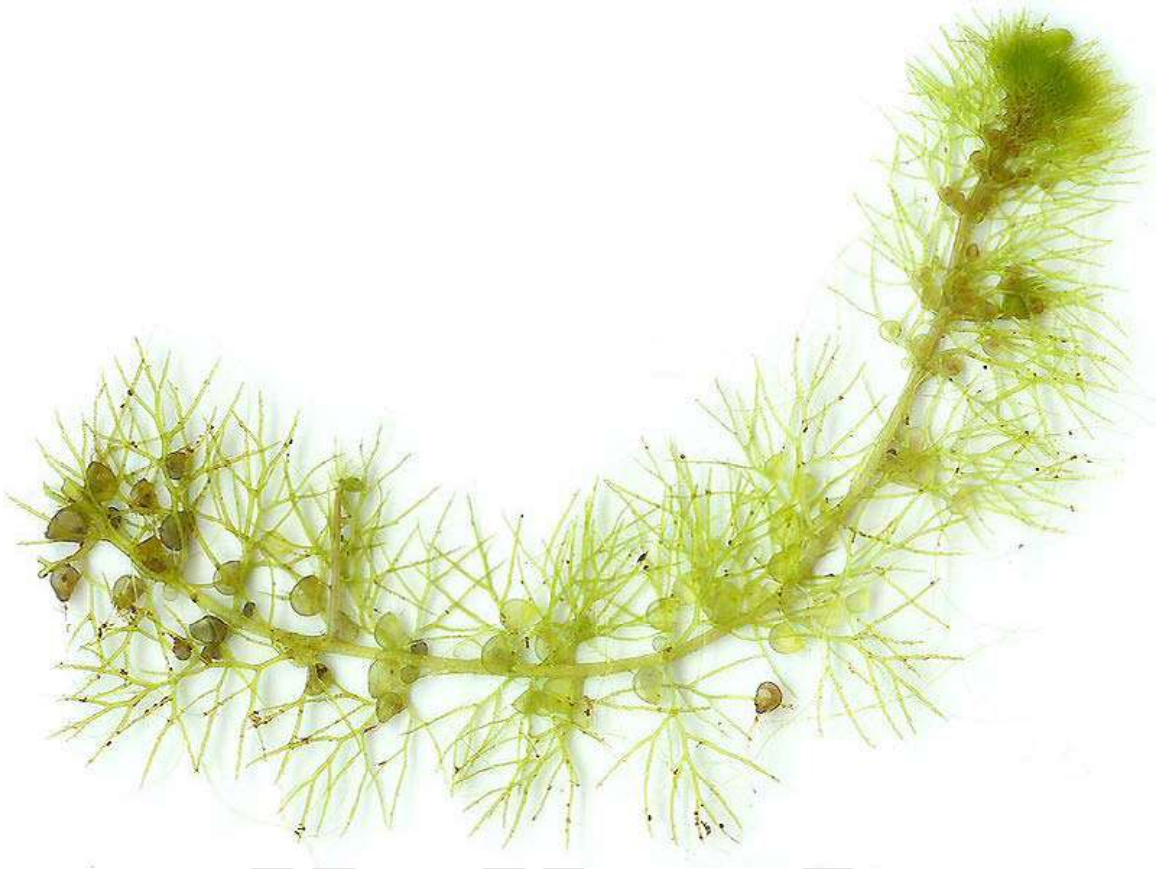
Bladderwort distribution

Utricularia, commonly and collectively called the **bladderworts**, is a genus of carnivorous plants consisting of approximately 227 species (precise counts differ based on classification opinions; one recent publication lists 215 species). They occur in fresh water and wet soil as terrestrial or aquatic species across every continent except Antarctica. *Utricularia* are cultivated for their flowers, which are often compared with those of snapdragons and orchids, and among carnivorous plant enthusiasts.

All *Utricularia* are carnivorous and capture small organisms by means of bladder-like traps. Terrestrial species tend to have tiny traps that feed on minute prey such as protozoa and rotifers swimming in water-saturated soil. The traps can range in size from 0.2 mm to 1.2 cm. Aquatic species, such as *U. vulgaris* (common bladderwort), possess bladders that are usually larger and can feed on more substantial prey such as water fleas *(Daphnia)*, nematodes and even fish fry, mosquito larvae and young tadpoles. Despite their small size, the traps are extremely sophisticated. In the active traps of the aquatic species, prey brush against trigger hairs connected to the trapdoor. The bladder, when "set", is under negative pressure in relation to its environment so that when the trapdoor is mechanically triggered, the prey, along with the water surrounding it, is swept into the bladder. Once the bladder is full of water, the door closes again, the whole process taking only ten to fifteen thousandths of a second.

Bladderworts are unusual and highly specialized plants, and the vegetative organs are not clearly separated into roots, leaves , and stems as in most other angiosperms. The bladder traps, conversely, are recognized as one of the most sophisticated structures in the plant kingdom.

Physical description



The tip of one stolon from a U.K. instance of *U. vulgaris*, showing stolon, branching leaf-shoots and transparent bladder traps.

The main part of a bladderwort plant always lies beneath the surface of its substrate. Terrestrial species sometimes produce a few photosynthetic leaf-shoots which lie unobtrusively flat against the surface of their soil, but in all species only the flowering stems rise above and are prominent. This means that the terrestrial species are generally visible only while they are in flower, although aquatic species can be observed below the surfaces of ponds and streams.

Plant structure

Most species form long, thin, sometimes branching stems or *stolons* beneath the surface of their substrate, whether that be pond water or dripping moss in the canopy of a tropical rainforest. To these stolons are attached both the bladder traps and photosynthetic leaf-shoots, and in terrestrial species the shoots are thrust upward through the soil into the air or along the surface.

The name *bladderwort* refers to the bladder-like traps. The generic name *Utricularia* is similarly derived from the Latin *utriculus*, a word which has many related meanings but

which most commonly means *wine flask* or *leather bottle*. The aquatic members of the genus have the largest and most obvious bladders, and these were initially thought to be flotation devices before their carnivorous nature was discovered.

Flowers and reproduction

Utricularia amethystina flower

Flowers are the only part of the plant clear of the underlying soil or water. They are usually produced at the end of thin, often vertical inflorescences. They can range in size from 2 mm to 10 cm wide, and have two asymmetric labiate (unequal, lip-like) petals, the lower usually significantly larger than the upper. They can be of any colour, or of many colours, and are similar in structure to the flowers of a related carnivorous genus, *Pinguicula*.

The flowers of aquatic varieties like *U. vulgaris* are often described as similar to small yellow snapdragons, and the Australian species *U. dichotoma* can produce the effect of a field full of violets on nodding stems. The epiphytic species of South America, however,

are generally considered to have the showiest, as well as the largest, flowers. It is these species that are frequently compared with orchids.

Certain plants in particular seasons might produce closed, self-pollinating (*cleistogamous*) flowers; but the same plant or species might produce open, insect-pollinated flowers elsewhere or at a different time of year, and with no obvious pattern. Sometimes, individual plants have both types of flower at the same time: aquatic species such as *U. dimorphantha* and *U. geminiscapa*, for example, usually have open flowers riding clear of the water and one or more closed, self-pollinating flowers beneath the water. Seeds are numerous and small and for the majority of species are as small as 0.2 mm to 1 mm long.

Distribution and habitat

Utricularia aurea growing in a rice paddy in Thailand.

Utricularia can survive almost anywhere where there is fresh water for at least part of the year; only Antarctica and some oceanic islands have no native species. The greatest species diversity for the genus is seen in South America, with Australia coming a close second. In common with most carnivorous plants, they grow in moist soils which are poor in dissolved minerals, where their carnivorous nature gives them a competitive advantage; terrestrial varieties of *Utricularia* can frequently be found alongside representatives of the carnivorous genera–*Sarracenia*, *Drosera* and others–in very wet areas where continuously moving water removes most soluble minerals from the soil.

About 80% of the species are terrestrial, and most inhabit waterlogged or wet soils, where their tiny bladders can be permanently exposed to water in the substrate. Frequently they will be found in marshy areas where the water table is very close to the surface. Most of the terrestrial species are tropical, although they occur worldwide.

Approximately 20% of the species are aquatic. Most of these drift freely over the surface of ponds and other still, muddy-bottomed waters and only protrude above the surface when flowering, although a few species are lithophytic and adapted to rapidly moving streams or even waterfalls. The plants are usually found in acidic waters, but they are quite capable of growing in alkaline waters and would very likely do so were it not for the higher level of competition from other plants in such areas. *Utricularia vulgaris* is an aquatic species and grows into branching rafts with individual stolons up to one metre or longer in ponds and ditches throughout Eurasia.

Some South American tropical species are epiphytes, and can be found growing in wet moss and spongy bark on trees in rainforests, or even in the watery leaf-rosettes of other epiphytes such as various *Tillandsia* (a type of bromeliad) species. Rossette-forming epiphytes such as *U. nelumbifolia* put out runners, searching for other nearby bromeliads to colonise.

The plants are as highly adapted in their methods of surviving seasonally inclement conditions as they are in their structure and feeding habits. Temperate perennials can require a winter period in which they die back each year, and they will weaken in cultivation if they are not given it; tropical and warm-temperate species, on the other hand, require no dormancy. Floating bladderworts in cold temperate zones such as the UK and Siberia can produce winter buds called turions at the extremities of their stems: as the autumnal light fails and growth slows down, the main plant may rot away or be killed by freezing conditions, but the turions will separate and sink to the bottom of the pond to rest beneath the coming ice until the spring, when they will return to the surface and resume growth. Many Australian species will grow only during the wet season, reducing themselves to tubers only 10 mm long to wait out the dry season. Other species are annual, returning from seed each year.

Carnivory

Traps of *Utricularia aurea*

Trap of *Utricularia hamiltonii*

Physical description of the trap

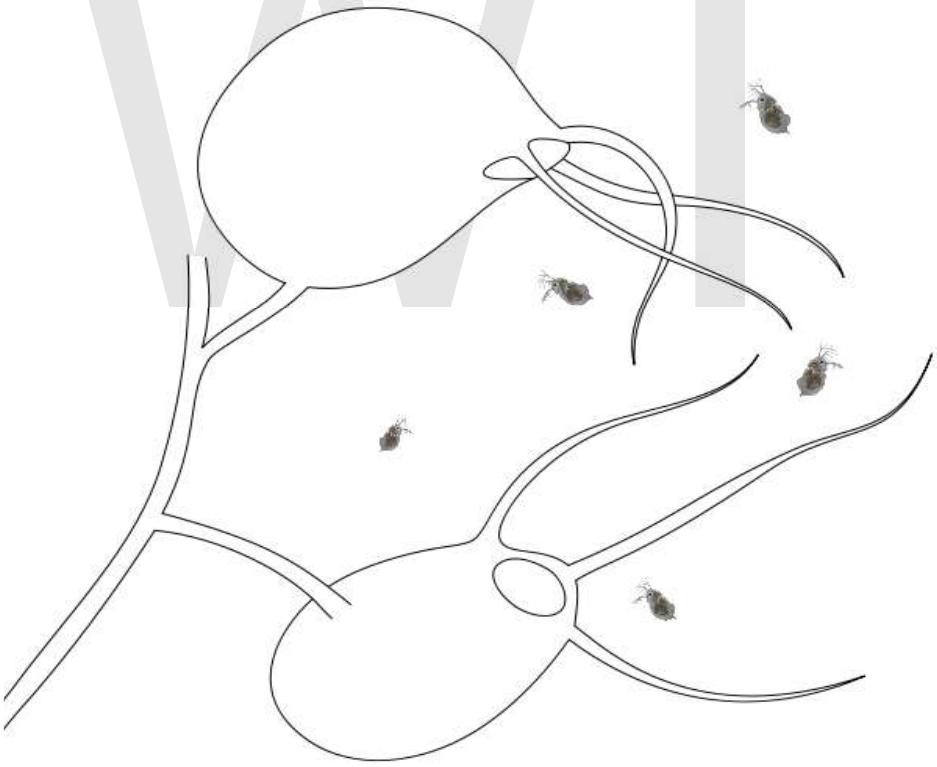
Authorities agree that the vacuum-driven bladders of *Utricularia* are the most sophisticated carnivorous trapping mechanism to be found anywhere in the plant kingdom. The bladders are usually shaped similarly to broad beans (though they come in various shapes) and are to be found attached to the submerged stolons by slender stalks.

The bladder walls are very thin and transparent, but are sufficiently inflexible to maintain the bladder's shape despite the vacuum created within. The entrance, or 'mouth', of the trap is a circular or oval flap whose upper half is joined to the body of the trap by very flexible, yielding cells which form an effective hinge. The door rests on a platform formed by the thickening of the bladder wall immediately underneath. A soft but substantial membrane called the *velum* stretches in a curve around the middle of this platform, and helps seal the door. A second band of springy cells cross the door just above its lower edge, and provide the flexibility for the bottom of the door to become a bendable 'lip' which can make a perfect seal with the velum.

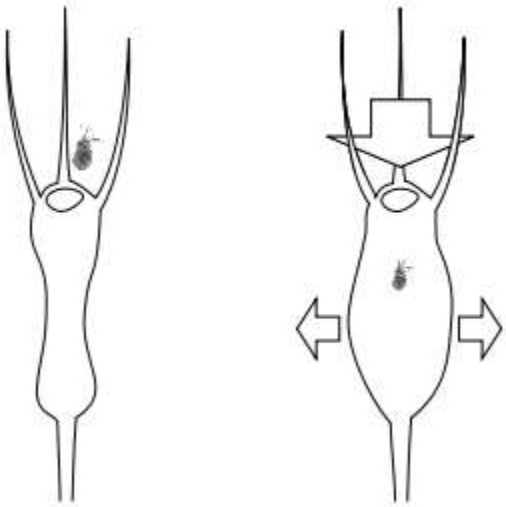
The outer cells of the whole trap excrete mucilage and under the door this is produced in greater quantities and contains sugars. The mucilage certainly contributes towards the seal, and the sugars may help to attract prey.

Terrestrial species generally have tiny traps (sometimes as small as 0.2 mm) with a broad beak-like structure extending and curving down over the entrance; this forms a passageway to the trapdoor and may help prevent the trapping and ingestion of inorganic particles. Aquatic species tend to have larger bladders (up to 1.2 cm), and the mouth of the trap is usually surrounded not by a beak but by branching antennae, which serve both to guide prey animals to the trap entrance and to fend the trap mouth away from larger bodies which might trigger the mechanism needlessly. Epiphytic species have unbranched antennae which curve in front of the mouth and probably serve the same purpose, although it has been observed that they are also capable of holding a pocket of water in front of the mouth by capillary action, and that this assists with the trapping action.

Trapping mechanism



Bladderwort traps: long, usually branching (but here simplified), antennae guide *Daphnia* to the trapdoors of an aquatic bladderwort.



Bladderwort trap mechanism: seen from below, a bladder squeezed by water excretion suddenly swells as its trapdoor is released by an errant *Daphnia*. The bladder sucks in the nearby water, including the unfortunate animal which triggered the trap.

The trapping mechanism of *Utricularia* is purely mechanical; no reaction from the plant (irritability) is required in the presence of prey, in contrast with the triggered mechanisms employed by Venus Flytraps (*Dionaea*), waterwheels (*Aldrovanda*), and many sundews (*Drosera*). The only active mechanism involved is the constant pumping out of water through the bladder walls by active transport.

As water is pumped out, the bladder's walls are sucked inwards by the partial vacuum created, and any dissolved material inside the bladder will become more concentrated. The sides of the bladder bend inwards, storing potential energy like a spring. Eventually, no more water can be extracted, and the bladder trap is 'fully set' (technically, osmotic pressure rather than physical pressure is the limiting factor).

Extending outwards from the bottom of the trapdoor are several long bristle-stiff protuberances that are sometimes referred to as *trigger hairs* or *antennae* but which have no similarity to the sensitive triggers found in *Dionaea* and *Aldrovanda*. In fact, these bristles are simply levers. The suction force exerted by the primed bladder on the door is resisted by the adhesion of its flexible bottom against the soft-sealing velum. The equilibrium depends quite literally on a hair trigger, and the slightest touch to one of the lever hairs will deform the flexible door lip enough to create a tiny gap, breaking the seal.

Once the seal is disturbed, the bladder walls instantly spring back to a more rounded shape; the door flies open and a column of water is sucked into the bladder. The animal which touched the lever, if small enough, is inevitably drawn in, and as soon as the trap is filled, the door resumes its closed position—the whole operation being completed in as little as one-hundredth of a second.

Once inside, the prey will be dissolved by digestive secretions. This generally occurs within a few hours, although some protozoa appear to be highly resistant and have been observed to live for several days inside the trap. All the time, the trap walls continue to pump out water, and the bladder can be ready for its next capture in as little as 15 to 30 minutes.

Lloyd's experiments

In the 1940s Francis Ernest Lloyd conducted extensive experiments with carnivorous plants, including *Utricularia*, and settled many points which had previously been the subject of conjecture. He proved that the mechanism of the trap was purely mechanical by both killing the trigger hairs with iodine and subsequently showing that the response was unaffected, and by demonstrating that the trap could be made ready to spring a second (or third) time immediately after being set off if the bladder's excretion of water were helped by a gentle squeeze; in other words, the delay of at least fifteen minutes between trap springings is due solely to the time needed to excrete water, and the triggers need no time to recover irritability (unlike the reactive trigger hairs of Venus Flytraps, for example).

He tested the role of the velum by showing that the trap will never set if small cuts are made to it; and showed that the excretion of water can be continued under all conditions likely to be found in the natural environment, but can be prevented by driving the osmotic pressure in the trap beyond normal limits by the introduction of glycerine.

The ingestion of larger prey

Lloyd devoted several studies to the possibility, often recounted but never previously accounted for under scientific conditions, that *Utricularia* can consume larger prey such as young tadpoles and mosquito larvae by catching them by the tail, and ingesting them bit by bit.

Prior to Lloyd, several authors had reported this phenomenon and had attempted to explain it by positing that creatures caught by the tail repeatedly set off the trap as they thrash about in an attempt to escape—even as their tails are actively digested by the plant. Lloyd, however, demonstrated that the plant is quite capable of ingestion by stages without the need of multiple stimuli.

The flower stem of the aquatic *Utricularia inflata* is held aloft by a rosette of floats.

He produced suitable artificial "prey" for his experiments by stirring albumen (egg white) into hot water and selecting shreds of an appropriate length and thickness. When caught by one end, the strand would gradually be drawn in, sometimes in sudden jumps, and at other times by a slow and continuous motion. Strands of albumen would often be fully ingested in as little as twenty minutes.

Mosquito larvae, caught by the tail, would be engulfed bit by bit. A typical example given by Lloyd showed that a larva of a size at the upper limit of what the trap could manage would be ingested stage by stage over the course of about twenty-four hours; but that the head, being rigid, would often prove too large for the mouth of the trap and would remain outside, plugging the door. When this happened, the trap evidently formed an effective seal with the head of the larva as it could still excrete water and become flattened, but it would nevertheless die within about ten days "evidently due to overfeeding".

Softer-bodied prey of the same size such as small tadpoles could be ingested completely, because they have no rigid parts and the head, although capable of plugging the door for a time, will soften and yield and finally be drawn in.

Very thin strands of albumen could be soft and fine enough to allow the trapdoor to close completely; these would not be drawn in any further unless the trigger hairs were indeed stimulated again. On the other hand, a human hair, finer still but relatively hard and unyielding, could prevent a seal being formed; these would prevent the trap from resetting at all due to leakage of water.

Lloyd concluded that the sucking action produced by the excretion of water from the bladder was sufficient to draw larger soft-bodied prey into the trap without the need for a second or further touch to the trigger levers. An animal long enough not to be fully engulfed upon first springing the trap, but thin and soft enough to allow the door to return

fully to its set position, would indeed be left partly outside the trap until it or another body triggered the mechanism once again. However, the capture of hard bodies not fully drawn into the trap would prevent its further operation.

Species

Utricularia is the largest genus of carnivorous plants. It is one of the three genera that make up the Bladderwort family (Lentibulariaceae), along with the butterworts *(Pinguicula)* and corkscrew plants *(Genlisea)*.

This genus was considered to have 250 species until Peter Taylor reduced the number to 214 in his exhaustive study *The Genus Utricularia: a taxonomic monograph*, published by HMSO (1989). Taylor's classification is now generally accepted with modifications based on phylogenetic studies.

The genus ***Polypompholyx***, the pink petticoats, contained just two species of carnivorous plant, *Polypompholyx tenella* and *Polypompholyx multifida*, previously distinguished from the otherwise similar genus *Utricularia* by their possession of four calyx lobes rather than two. The genus has now been subsumed into *Utricularia*.

The genus ***Biovularia*** contained the species *Biovularia olivacea* (also known as *B. brasiliensis* or *B. minima*) and *Biovularia cymbantha*. The genus has been subsumed into *Utricularia*.

Chapter- 7

Alternanthera Sessilis and Alisma Subcordatum

Alternanthera sessilis

Alternanthera sessilis

Scientific classification

Kingdom:	Plantae
Division:	Magnoliophyta
Class:	Magnoliopsida
Order:	Caryophyllales
Family:	Amaranthaceae
Subfamily:	Gomphrenoideae
Genus:	*Alternanthera*

Species: ***A. sessilis***

Binomial name

Alternanthera sessilis
(L.) R.Br. ex DC.

Synonyms

Alternanthera glabra
Gomphrena sessilis

Alternanthera sessilis is an aquatic plant known by several common names, including **sessile joyweed** and **dwarf copperleaf**. It is used as an aquarium plant.

The plant occurs around the world.

The leaves are used as a vegetable. Young shoots and leaves are eaten as a vegetable in Southeast Asia. Occasionally it is cultivated for food or for use in herbal medicines.

This species is classified as a weed in parts of the southern States of the USA. It is usually (but not always especially in areas of high humidity where it can even be a garden weed) found in wet or damp spots.

This is a perennial herb with prostrate stems, rarely ascending, often rooting at the nodes. Leaves obovate to broadly elliptic, occasionally linear-lanceolate, 1-15 cm long, 0.3-3 cm wide, glabrous to sparsely villous, petioles 1-5 mm long. Flowers in sessile spikes, bract and bracteoles shiny white, 0.7-1.5 mm long, glabrous; sepals equal, 2.5-3 mm long, outer ones 1-nerved or indistinctly 3-nerved toward base; stamens 5, 2 sterile. In the wild it flowers from December till March.

Aerva lanata is often mistaken for Alternanthera sessilis, which is also of the Amaranthecea family, and looks similar. On careful observation you will notice that flowers of Alternanthera sessilis are situated over the stem and their shape is round. As its flowers look like the eyes of a fish, Alternanthera sessilis is called Matsyakshi, fisheyed. Other Indian names of this plant are Koypa (Marathi), Honganne (Kannada). Leaves along with the flowers and tender stems are used as vegetable in Karnataka. It is diuretic, tonic and cooling. Juice of this plant, deemed beneficial to eyes, is an ingredient in the making of medicinal hairoils and Kajal (kohl). The red variety of this plant is a common garden hedging plant, which is also used as a culinary vegetable.

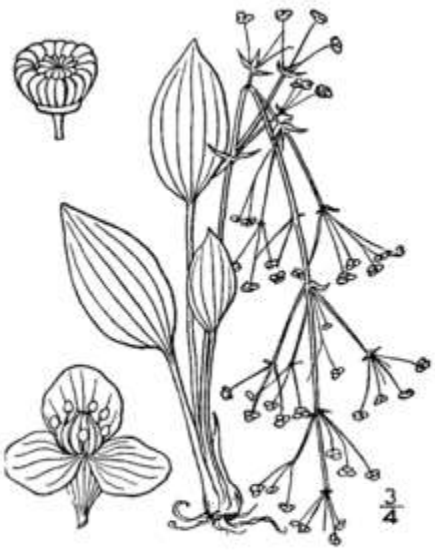
in Rangareddy district of Andhra Pradesh, India.

in Rangareddy district of Andhra Pradesh, India.

in Rangareddy district of Andhra Pradesh, India.

Alisma subcordatum

Alisma subcordatum



Scientific classification	
Kingdom:	Plantae
(unranked):	Angiosperms
(unranked):	Monocots
Order:	Alismatales
Family:	Alismataceae
Genus:	*Alisma*
Species:	***A. subcordatum***

Binomial name

Alisma subcordatum
Raf.

Synonyms

- *Alisma plantago-aquatica* L. ssp. *subcordatum* (Raf.) Hultén
- *Alisma plantago-aquatica* L. var. *parviflorum* (Pursh) Torr.
- *Alisma parviflorum* Pursh

Alisma subcordatum (**American water plantain**) is a perennial aquatic plant in the Water-plantain family (Alismataceae). This plant grows to about 3 feet (1 meter) in height with lance to oval shaped leaves rising from bulbous corms with fibrous roots. Any leaves that form underwater a weak and quick to rot; they rarely remain on adult

plants. A branched inflorescence with white to pink 3 petaled flowers blooms from June to September. The seeds are eaten by waterfowl and upland birds. The species name *subcordatum* means "almost heart-shaped".

American water plantain is native to North America from Massachusetts to Florida and east to Texas and Minnesota. It grows in the mud of still to slow moving water, seeps, and wetlands.

Chapter- 8

Fish

Fish
Fossil range: Ordovician–Neogene

A giant grouper at the Georgia Aquarium, seen swimming among schools of other fish

The ornate lionfish as seen from a head-on view

Scientific classification	
Kingdom:	Animalia
Phylum:	Chordata
(unranked)	Craniata

Included groups
Jawless fish
†Armoured fish
Cartilaginous fish
Ray-finned fish
Lobe-finned fishes

Excluded groups
Tetrapods

A **fish** is any aquatic vertebrate animal that is covered with scales, and equipped with two sets of paired fins and several unpaired fins. Most fish are "cold-blooded", or ectothermic, allowing their body temperatures to vary as ambient temperatures change. Fish are abundant in most bodies of water. They can be found in nearly all aquatic environments, from high mountain streams (e.g., char and gudgeon) to the abyssal and even hadal depths of the deepest oceans (e.g., gulpers and anglerfish). At 31,900 species, fish exhibit greater species diversity than any other class of vertebrates.

Food prepared from animals classified as fish is also referred to as fish, and is an important human food source. Commercial and subsistence fishers hunt fish in wild fisheries or farm them in ponds or in cages in the ocean. They are also caught by recreational fishers and raised by fishkeepers, and are exhibited in public aquaria. Fish have had a role in culture through the ages, serving as deities, religious symbols, and as the subjects of art, books and movies.

Diversity of fish

The term "fish" most precisely describes any non-tetrapod craniate (i.e. an animal with a skull and in most cases a backbone) that has gills throughout life and whose limbs, if any, are in the shape of fins. Unlike groupings such as birds or mammals, fish are not a single clade but a paraphyletic collection of taxa, including hagfishes, lampreys, sharks and rays, ray-finned fish, coelacanths, and lungfish. Indeed, lungfish and coelacanths are closer relatives of tetrapods (such as mammals, birds, amphibians, etc.) than of other fish such as ray-finned fish or sharks, so the last common ancestor of all fish is also an ancestor to tetrapods. As paraphyletic groups are no longer recognised in modern systematic biology, the use of the term "fish" as a biological group must be avoided.

Many types of aquatic animals commonly referred to as "fish" are not fish in the sense given above; examples include shellfish, cuttlefish, starfish, crayfish and jellyfish. In earlier times, even biologists did not make a distinction – sixteenth century natural historians classified also seals, whales, amphibians, crocodiles, even hippopotamuses, as well as a host of aquatic invertebrates, as fish. However, according the definition above, all mammals, including Cetaceans like Whales and Dolphins, are not fish. In some contexts, especially in aquaculture, the true fish are referred to as **finfish** (or **fin fish**) to distinguish them from these other animals.

A typical fish is ectothermic, has a streamlined body for rapid swimming, extracts oxygen from water using gills or uses an accessory breathing organ to breathe atmospheric oxygen, has two sets of paired fins, usually one or two (rarely three) dorsal fins, an anal fin, and a tail fin, has jaws, has skin that is usually covered with scales, and lays eggs.

Fish come in many shapes and sizes. This is a sea dragon, a close relative of the seahorse. Their leaf-like appendages enable them to blend in with floating seaweed.

Each criterion has exceptions. Tuna, swordfish, and some species of sharks show some warm-blooded adaptations—they can heat their bodies significantly above ambient water temperature. Streamlining and swimming performance varies from fish such as tuna, salmon, and jacks that can cover 10–20 body-lengths per second to species such as eels and rays that swim no more than 0.5 body-lengths per second. Many groups of freshwater fish extract oxygen from the air as well as from the water using a variety of different structures. Lungfish have paired lungs similar to those of tetrapods, gouramis have a structure called the labyrinth organ that performs a similar function, while many catfish, such as *Corydoras* extract oxygen via the intestine or stomach. Body shape and the arrangement of the fins is highly variable, covering such seemingly un-fishlike forms as seahorses, pufferfish, anglerfish, and gulpers. Similarly, the surface of the skin may be naked (as in moray eels), or covered with scales of a variety of different types usually defined as placoid (typical of sharks and rays), cosmoid (fossil lungfish and coelacanths), ganoid (various fossil fish but also living gars and bichirs), cycloid, and ctenoid (these last two are found on most bony fish). There are even fish that live mostly on land. Mudskippers feed and interact with one another on mudflats and go underwater to hide in their burrows. The catfish *Phreatobius cisternarum* lives in underground, phreatic habitats, and a relative lives in waterlogged leaf litter.

Fish range in size from the huge 16-metre (52 ft) whale shark to the tiny 8-millimetre (0.3 in) stout infantfish.

Taxonomy

Fish are a paraphyletic group: that is, any clade containing all fish also contains the tetrapods, which are not fish. For this reason, groups such as the "Class Pisces" seen in older reference works are no longer used in formal classifications.

Fish are classified into the following major groups:

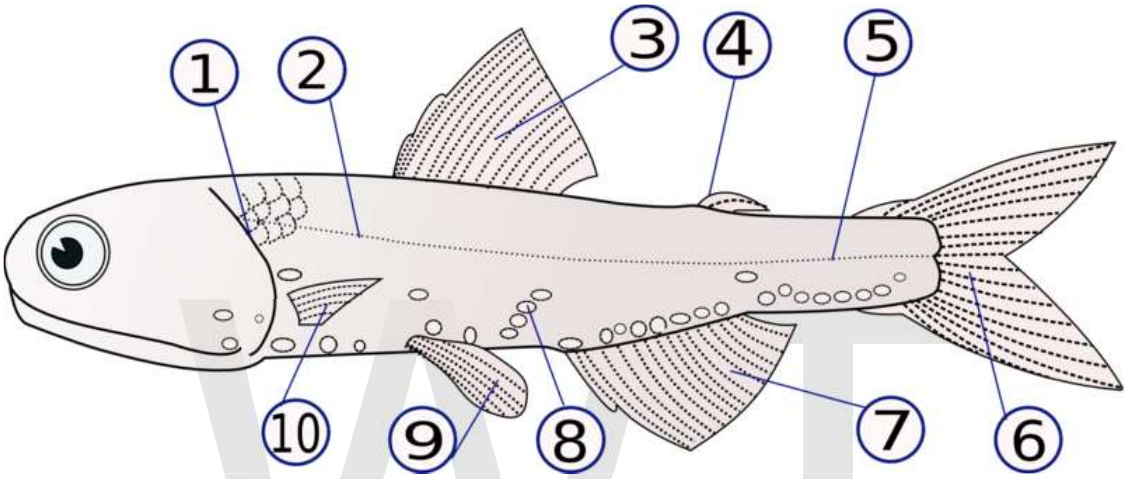
- Class Myxini (hagfish)
- Class Pteraspidomorphi (early jawless fish)
- Class Thelodonti
- Class Anaspida
- Class Petromyzontida or Hyperoartia
    - Petromyzontidae (lampreys)
- Class Conodonta (conodonts)
- Class Cephalaspidomorphi (early jawless fish)
    - (unranked) Galeaspida
    - (unranked) Pituriaspida
    - (unranked) Osteostraci
- Infraphylum Gnathostomata (jawed vertebrates)
    - Class Placodermi (armoured fish, extinct)
    - Class Chondrichthyes (cartilaginous fish)
    - Class Acanthodii (spiny sharks, extinct)
    - Superclass Osteichthyes (bony fish)
        - Class Actinopterygii (ray-finned fish)
            - Subclass Chondrostei
                - Order Acipenseriformes (sturgeons and paddlefishes)
                - Order Polypteriformes (reedfishes and bichirs).
            - Subclass Neopterygii
                - Infraclass Holostei (gars and bowfins)
                - Infraclass Teleostei (many orders of common fish)
        - Class Sarcopterygii (lobe-finned fish)
            - Subclass Coelacanthimorpha (coelacanths)
            - Subclass Dipnoi (lungfish)

Some palaeontologists contend that because Conodonta are chordates, they are primitive fish.

The position of hagfish in the phylum chordata is not settled. Phylogenetic research in 1998 and 1999 supported the idea that the hagfish and the lampreys form a natural group, the Cyclostomata, that is a sister group of the Gnathostomata.

The various fish groups account for more than half of vertebrate species. There are almost 28,000 known extant species, of which almost 27,000 are bony fish, with 970 sharks, rays, and chimeras and about 108 hagfish and lampreys. A third of these species fall within the nine largest families; from largest to smallest, these families are Cyprinidae, Gobiidae, Cichlidae, Characidae, Loricariidae, Balitoridae, Serranidae, Labridae, and Scorpaenidae. About 64 families are monotypic, containing only one species. The final total of extant species may grow to exceed 32,500.

Anatomy



The anatomy of *Lampanyctodes hectoris*
(1) – operculum (gill cover), (2) – lateral line, (3) – dorsal fin, (4) – fat fin, (5) – caudal peduncle, (6) – caudal fin, (7) – anal fin, (8) – photophores, (9) – pelvic fins (paired), (10) – pectoral fins (paired)

Respiration

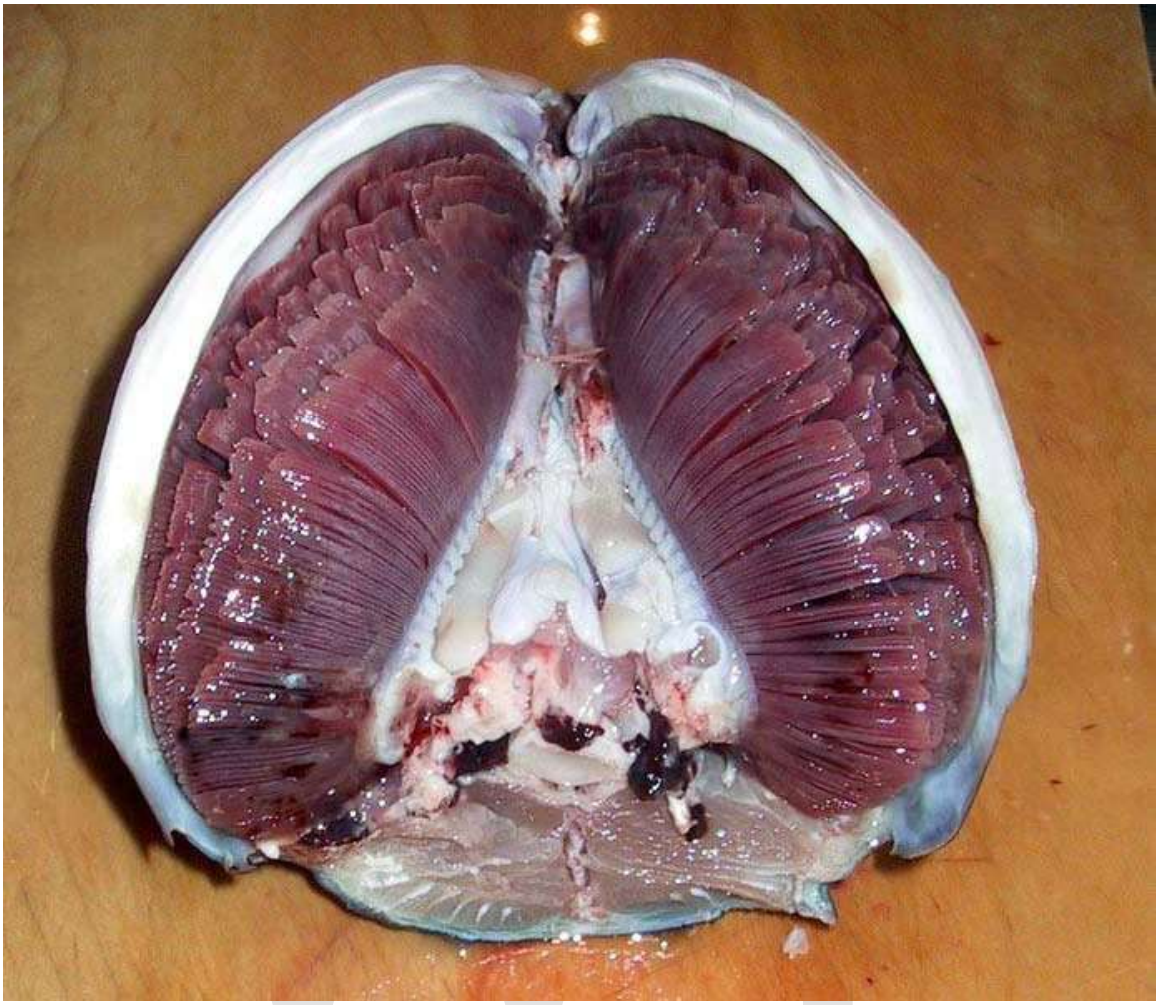
Most fish exchange gases using gills on either side of the pharynx. Gills consist of threadlike structures called filaments. Each filament contains a capillary network that provides a large surface area for exchanging oxygen and carbon dioxide. Fish exchange gases by pulling oxygen-rich water through their mouths and pumping it over their gills. In some fish, capillary blood flows in the opposite direction to the water, causing counter current exchange. The gills push the oxygen-poor water out through openings in the sides of the pharynx. Some fish, like sharks and lampreys, possess multiple gill openings. However, most fish have a single gill opening on each side. This opening is hidden beneath a protective bony cover called an operculum.

Juvenile bichirs have external gills, a very primitive feature that they share with larval amphibians.

Swim bladder of a Rudd (Scardinius erythrophthalmus)

Many fish can breathe air via a variety of mechanisms. The skin of anguillid eels may absorb oxygen. The buccal cavity of the electric eel may breathe air. Catfish of the families Loricariidae, Callichthyidae, and Scoloplacidae absorb air through their digestive tracts. Lungfish, with the exception of the Australian lungfish, and bichirs have paired lungs similar to those of tetrapods and must surface to gulp fresh air through the mouth and pass spent air out through the gills. Gar and bowfin have a vascularized swim bladder that functions in the same way. Loaches, trahiras, and many catfish breathe by passing air through the gut. Mudskippers breathe by absorbing oxygen across the skin (similar to frogs). A number of fish have evolved so-called **accessory breathing organs** that extract oxygen from the air. Labyrinth fish (such as gouramis and bettas) have a labyrinth organ above the gills that performs this function. A few other fish have structures resembling labyrinth organs in form and function, most notably snakeheads, pikeheads, and the Clariidae catfish family.

Breathing air is primarily of use to fish that inhabit shallow, seasonally variable waters where the water's oxygen concentration may seasonally decline. Fish dependent solely on dissolved oxygen, such as perch and cichlids, quickly suffocate, while air-breathers survive for much longer, in some cases in water that is little more than wet mud. At the most extreme, some air-breathing fish are able to survive in damp burrows for weeks without water, entering a state of aestivation (summertime hibernation) until water returns.



Tuna gills inside of the head. The fish head is oriented snout-downwards, with the view looking towards the mouth.

Fish can be divided into **obligate air breathers** and **facultative air breathers**. Obligate air breathers, such as the African lungfish, *must* breathe air periodically or they suffocate. Facultative air breathers, such as the catfish *Hypostomus plecostomus*, only breathe air if they need to and will otherwise rely on their gills for oxygen. Most air breathing fish are facultative air breathers that avoid the energetic cost of rising to the surface and the fitness cost of exposure to surface predators.

Circulation

Fish have a closed-loop circulatory system. The heart pumps the blood in a single loop throughout the body. In most fish, the heart consists of four parts, including two chambers and an entrance and exit. The first part is the sinus venosus, a thin-walled sac that collects blood from the fish's veins before allowing it to flow to the second part, the atrium, which is a large muscular chamber. The atrium serves as a one-way antechamber, sends blood to the third part, ventricle. The ventricle is another thick-walled, muscular

chamber and it pumps the blood, first to the fourth part, bulbous arteriosus, a large tube, and then out of the heart. The bulbus arteriosus connects to the aorta, through which blood flows to the gills for oxygenation.

Digestion

Jaws allow fish to eat a wide variety of food, including plants and other organisms. Fish ingest food through the mouth and break it down in the esophagus. In the stomach, food is further digested and, in many fish, processed in finger-shaped pouches called pyloric caeca, which secrete digestive enzymes and absorb nutrients. Organs such as the liver and pancreas add enzymes and various chemicals as the food moves through the digestive tract. The intestine completes the process of digestion and nutrient absorption.

Excretion

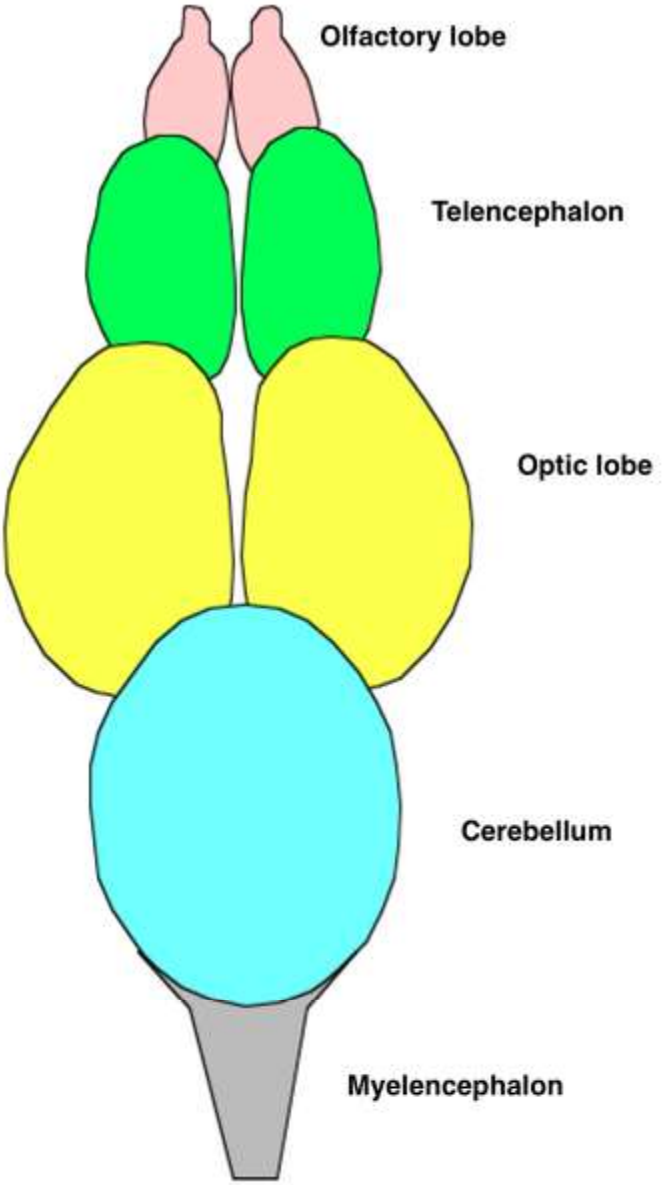
As with many aquatic animals, most fish release their nitrogenous wastes as ammonia. Some of the wastes diffuse through the gills. Blood wastes are filtered by the kidneys.

Saltwater fish tend to lose water because of osmosis. Their kidneys return water to the body. The reverse happens in freshwater fish: they tend to gain water osmotically. Their kidneys produce dilute urine for excretion. Some fish have specially adapted kidneys that vary in function, allowing them to move from freshwater to saltwater.

Scales

The scales of fish originate from the mesoderm (skin); they may be similar in structure to teeth.

Sensory and nervous system



Dorsal view of the brain of the rainbow trout

Central nervous system

Fish typically have quite small brains relative to body size compared with other vertebrates, typically one-fifteenth the brain mass of a similarly sized bird or mammal. However, some fish have relatively large brains, most notably mormyrids and sharks, which have brains about as massive relative to body weight as birds and marsupials.

Fish brains are divided into several regions. At the front are the olfactory lobes, a pair of structures that receive and process signals from the nostrils via the two olfactory nerves.

The olfactory lobes are very large in fish that hunt primarily by smell, such as hagfish, sharks, and catfish. Behind the olfactory lobes is the two-lobed telencephalon, the structural equivalent to the cerebrum in higher vertebrates. In fish the telencephalon is concerned mostly with olfaction. Together these structures form the **forebrain**.

Connecting the forebrain to the **midbrain** is the diencephalon (in the diagram, this structure is below the optic lobes and consequently not visible). The diencephalon performs functions associated with hormones and homeostasis. The pineal body lies just above the diencephalon. This structure detects light, maintains circadian rhythms, and controls color changes.

The midbrain or mesencephalon contains the two optic lobes. These are very large in species that hunt by sight, such as rainbow trout and cichlids.

The **hindbrain** or metencephalon is particularly involved in swimming and balance. The cerebellum is a single-lobed structure that is typically the biggest part of the brain. Hagfish and lampreys have relatively small cerebellae, while the mormyrid cerebellum is massive and apparently involved in their electrical sense.

The **brain stem** or myelencephalon is the brain's posterior. As well as controlling some muscles and body organs, in bony fish at least, the brain stem governs respiration and osmoregulation.

Sense organs

Most fish possess highly developed sense organs. Nearly all daylight fish have color vision that is at least as good as a human's. Many fish also have chemoreceptors that are responsible for extraordinary senses of taste and smell. Although they have ears, many fish may not hear very well. Most fish have sensitive receptors that form the lateral line system, which detects gentle currents and vibrations, and senses the motion of nearby fish and prey. Some fish, such as catfish and sharks, have organs that detect low-level electric current. Other fish, like the electric eel, can produce electric current.

Fish orient themselves using landmarks and may use mental maps based on multiple landmarks or symbols. Fish behavior in mazes reveals that they possess spatial memory and visual discrimination.

Capacity for pain

Experiments done by William Tavolga provide evidence that fish have pain and fear responses. For instance, in Tavolga’s experiments, toadfish grunted when electrically shocked and over time they came to grunt at the mere sight of an electrode.

In 2003, Scottish scientists at the University of Edinburgh and the Roslin Institute concluded that rainbow trout exhibit behaviors often associated with pain in other animals. Bee venom and acetic acid injected into the lips resulted in fish rocking their

bodies and rubbing their lips along the sides and floors of their tanks, which the researchers concluded were attempts to relieve pain, similar to what mammals would do. Neurons fired in a pattern resembling human neuronal patterns.

Professor James D. Rose of the University of Wyoming claimed the study was flawed since it did not provide proof that fish possess "conscious awareness, particularly a kind of awareness that is meaningfully like ours". Rose argues that since fish brains are so different from human brains, fish are probably not conscious in the manner humans are, so that reactions similar to human reactions to pain instead have other causes. Rose had published a study a year earlier arguing that fish cannot feel pain because their brains lack a neocortex. However, animal behaviorist Temple Grandin argues that fish could still have consciousness without a neocortex because "different species can use different brain structures and systems to handle the same functions."

Animal welfare advocates raise concerns about the possible suffering of fish caused by angling. Some countries, such as Germany have banned specific types of fishing, and the British RSPCA now formally prosecutes individuals who are cruel to fish.

Muscular system

Most fish move by alternately contracting paired sets of muscles on either side of the backbone. These contractions form S-shaped curves that move down the body. As each curve reaches the back fin, backward force is applied to the water, and in conjunction with the fins, moves the fish forward. The fish's fins function like an airplane's flaps. Fins also increase the tail's surface area, increasing speed. The streamlined body of the fish decreases the amount of friction from the water. Since body tissue is denser than water, fish must compensate for the difference or they will sink. Many bony fish have an internal organ called a swim bladder that adjusts their buoyancy through manipulation of gases.

Homeothermy

A 3-tonne (3.0 LT; 3.3 ST) great white shark off Isla Guadalupe

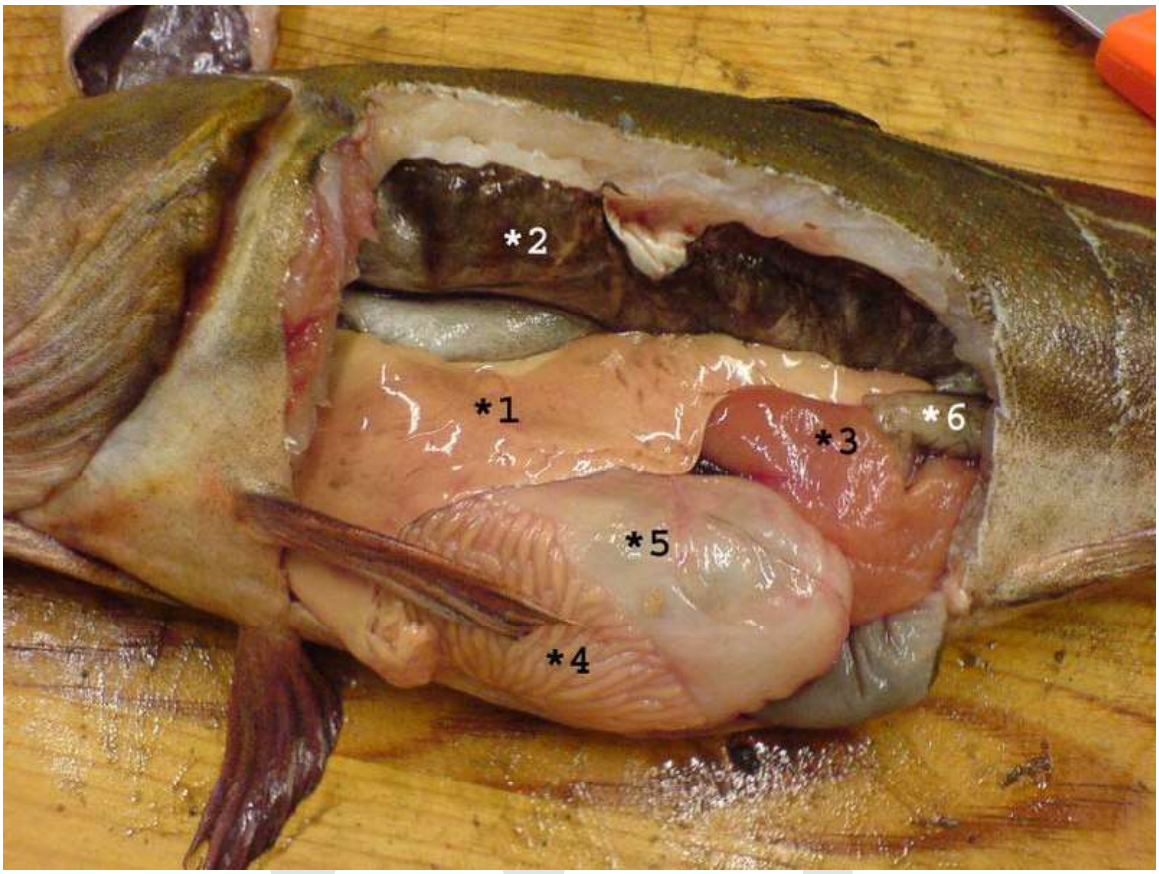
Although most fish are exclusively aquatic and ectothermic, there are exceptions to both cases.

Fish from multiple groups can live out of the water for extended time periods. Amphibious fish such as the mudskipper can live and move about on land for up to several days.

Certain species of fish maintain elevated body temperatures. Endothermic teleosts (bony fish) are all in the suborder Scombroidei and include the billfishes, tunas, and one species of "primitive" mackerel (*Gasterochisma melampus*). All sharks in the family Lamnidae – shortfin mako, long fin mako, white, porbeagle, and salmon shark – are endothermic, and evidence suggests the trait exists in family Alopiidae (thresher sharks). The degree of endothermy varies from the billfish, which warm only their eyes and brain, to bluefin tuna and porbeagle sharks who maintain body temperatures elevated in excess of 20 °C above ambient water temperatures. Endothermy, though metabolically costly, is thought to provide advantages such as increased muscle strength, higher rates of central nervous system processing, and higher rates of digestion.

Reproductive system

Organs



Organs: 1. Liver, 2. Gas bladder, 3. Roe, 4. Pyloric caeca, 5. Stomach, 6. Intestine

Fish reproductive organs include testes and ovaries. In most species, gonads are paired organs of similar size, which can be partially or totally fused. There may also be a range of secondary organs that increase reproductive fitness.

In terms of spermatogonia distribution, the structure of teleosts testes has two types: in the most common, spermatogonia occur all along the seminiferous tubules, while in Atherinomorph fish they are confined to the distal portion of these structures. Fish can present cystic or semi-cystic spermatogenesis in relation to the release phase of germ cells in cysts to the seminiferous tubules lumen.

Fish ovaries may be of three types: gymnovarian, secondary gymnovarian or cystovarian. In the first type, the oocytes are released directly into the coelomic cavity and then enter the ostium, then through the oviduct and are eliminated. Secondary gymnovarian ovaries shed ova into the coelom from which they go directly into the oviduct. In the third type, the oocytes are conveyed to the exterior through the oviduct. Gymnovaries are the primitive condition found in lungfish, sturgeon, and bowfin. Cystovaries characterize

most teleosts, where the ovary lumen has continuity with the oviduct. Secondary gymnovaries are found in salmonids and a few other teleosts.

Oogonia development in teleosts fish varies according to the group, and the determination of oogenesis dynamics allows the understanding of maturation and fertilization processes. Changes in the nucleus, ooplasm, and the surrounding layers characterize the oocyte maturation process.

Postovulatory follicles are structures formed after oocyte release; they do not have endocrine function, present a wide irregular lumen, and are rapidly reabsorbed in a process involving the apoptosis of follicular cells. A degenerative process called follicular atresia reabsorbs vitellogenic oocytes not spawned. This process can also occur, but less frequently, in oocytes in other development stages.

Some fish are hermaphrodites, having both testes and ovaries either at different phases in their life cycle or, as in hamlets, have them simultaneously.

Reproductive method

Over 97% of all known fish are oviparous, that is, the eggs develop outside the mother's body. Examples of oviparous fish include salmon, goldfish, cichlids, tuna, and eels. In the majority of these species, fertilisation takes place outside the mother's body, with the male and female fish shedding their gametes into the surrounding water. However, a few oviparous fish practice internal fertilization, with the male using some sort of intromittent organ to deliver sperm into the genital opening of the female, most notably the oviparous sharks, such as the horn shark, and oviparous rays, such as skates. In these cases, the male is equipped with a pair of modified pelvic fins known as claspers.

Marine fish can produce high numbers of eggs which are often released into the open water column. The eggs have an average diameter of 1 millimetre (0.039 in).

Egg of lamprey

Egg of catshark (mermaids' purse)

Egg of bullhead shark

Egg of chimaera

The newly hatched young of oviparous fish are called larvae. They are usually poorly formed, carry a large yolk sac (for nourishment) and are very different in appearance from juvenile and adult specimens. The larval period in oviparous fish is relatively short (usually only several weeks), and larvae rapidly grow and change appearance and structure (a process termed metamorphosis) to become juveniles. During this transition larvae must switch from their yolk sac to feeding on zooplankton prey, a process which depends on typically inadequate zooplankton density, starving many larvae.

In ovoviviparous fish the eggs develop inside the mother's body after internal fertilization but receive little or no nourishment directly from the mother, depending instead on the

yolk. Each embryo develops in its own egg. Familiar examples of ovoviviparous fish include guppies, angel sharks, and coelacanths.

Some species of fish are viviparous. In such species the mother retains the eggs and nourishes the embryos. Typically, viviparous fish have a structure analogous to the placenta seen in mammals connecting the mother's blood supply with that of the embryo. Examples of viviparous fish include the surf-perches, splitfins, and lemon shark. Some viviparous fish exhibit oophagy, in which the developing embryos eat other eggs produced by the mother. This has been observed primarily among sharks, such as the shortfin mako and porbeagle, but is known for a few bony fish as well, such as the halfbeak *Nomorhamphus ebrardtii*. Intrauterine cannibalism is an even more unusual mode of vivipary, in which the largest embryos eat weaker and smaller siblings. This behavior is also most commonly found among sharks, such as the grey nurse shark, but has also been reported for *Nomorhamphus ebrardtii*.

Aquarists commonly refer to ovoviviparous and viviparous fish as livebearers.

Immune system

Immune organs vary by type of fish. In the jawless fish (lampreys and hagfish), true lymphoid organs are absent. These fish rely on regions of lymphoid tissue within other organs to produce immune cells. For example, erythrocytes, macrophages and plasma cells are produced in the anterior kidney (or pronephros) and some areas of the gut (where granulocytes mature.) They resemble primitive bone marrow in hagfish. Cartilaginous fish (sharks and rays) have a more advanced immune system. They have three specialized organs that are unique to chondrichthyes; the epigonal organs (lymphoid tissue similar to mammalian bone) that surround the gonads, the Leydig's organ within the walls of their esophagus, and a spiral valve in their intestine. These organs house typical immune cells (granulocytes, lymphocytes and plasma cells). They also possess an identifiable thymus and a well-developed spleen (their most important immune organ) where various lymphocytes, plasma cells and macrophages develop and are stored. Chondrostean fish (sturgeons, paddlefish and bichirs) possess a major site for the production of granulocytes within a mass that is associated with the meninges (membranes surrounding the central nervous system.) Their heart is frequently covered with tissue that contains lymphocytes, reticular cells and a small number of macrophages. The chondrostean kidney is an important hemopoietic organ; where erythrocytes, granulocytes, lymphocytes and macrophages develop.

Like chondrostean fish, the major immune tissues of bony fish (or teleostei) include the kidney (especially the anterior kidney), which houses many different immune cells. In addition, teleost fish possess a thymus, spleen and scattered immune areas within mucosal tissues (e.g. in the skin, gills, gut and gonads). Much like the mammalian immune system, teleost erythrocytes, neutrophils and granulocytes are believed to reside in the spleen whereas lymphocytes are the major cell type found in the thymus. In 2006, a lymphatic system similar to that in mammals was described in one species of teleost fish,

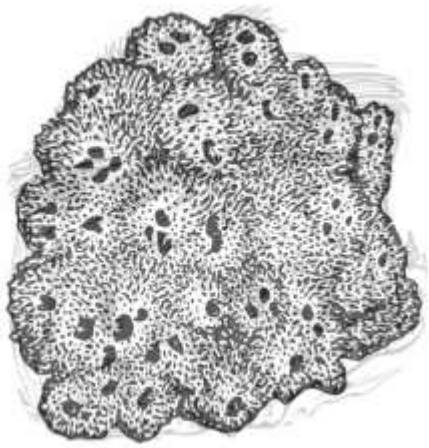
the zebrafish. Although not confirmed as yet, this system presumably will be where naive (unstimulated) T cells accumulate while waiting to encounter an antigen.

Diseases

Like other animals, fish suffer from diseases and parasites. To prevent disease they have a variety of defenses. *Non-specific* defenses include the skin and scales, as well as the mucus layer secreted by the epidermis that traps and inhibits the growth of microorganisms. If pathogens breach these defenses, fish can develop an inflammatory response that increases blood flow to the infected region and delivers white blood cells that attempt to destroy pathogens. Specific defenses respond to particular pathogens recognised by the fish's body, i.e., an immune response. In recent years, vaccines have become widely used in aquaculture and also with ornamental fish, for example furunculosis vaccines in farmed salmon and koi herpes virus in koi.

Some species use cleaner fish to remove external parasites. The best known of these are the Bluestreak cleaner wrasses of the genus *Labroides* found on coral reefs in the Indian and Pacific Oceans. These small fish maintain so-called "cleaning stations" where other fish congregate and perform specific movements to attract the attention of the cleaners. Cleaning behaviors have been observed in a number of fish groups, including an interesting case between two cichlids of the same genus, *Etroplus maculatus*, the cleaner, and the much larger *Etroplus suratensis*.

Evolution



Outdated evolutionary view of continual gradation

Dunkleosteus was a gigantic, 10 meter (33 ft) long prehistoric fish.

Fish do not represent a monophyletic group, and therefore the "evolution of fish" is not studied as a single event.

Proliferation of fish was apparently due to the hinged jaw, because jawless fish left very few descendants. Lampreys may approximate pre-jawed fish. The first jaws are found in Placodermi fossils. It is unclear if the advantage of a hinged jaw is greater biting force, improved respiration, or a combination of factors.

Fish may have evolved from a creature similar to a coral-like Sea squirt, whose larvae resemble primitive fish in important ways. The first ancestors of fish may have kept the larval form into adulthood (as some sea squirts do today), although perhaps the reverse is the case.

Conservation

A Whale shark, the world's largest fish, is classified as Vulnerable.

The 2006 IUCN Red List names 1,173 fish species that are threatened with extinction. Included are species such as Atlantic cod, Devil's Hole pupfish, coelacanths, and great white sharks. Because fish live underwater they are more difficult to study than terrestrial animals and plants, and information about fish populations is often lacking. However, freshwater fish seem particularly threatened because they often live in relatively small water bodies. For example, the Devil's Hole pupfish occupies only a single 3 by 6 metres (10 by 20 ft) pool.

Overfishing

Overfishing is a major threat to edible fish such as cod and tuna. Overfishing eventually causes population (known as stock) collapse because the survivors cannot produce enough young to replace those removed. Such **commercial extinction** does not mean that the species is extinct, merely that it can no longer sustain a fishery.

One well-studied example of fishery collapse is the Pacific sardine *Sadinops sagax caerulues* fishery off the California coast. From a 1937 peak of 790,000 long tons (800,000 t) the catch steadily declined to only 24,000 long tons (24,000 t) in 1968, after which the fishery was no longer economically viable.

The main tension between fisheries science and the fishing industry is that the two groups have different views on the resiliency of fisheries to intensive fishing. In places such as Scotland, Newfoundland, and Alaska the fishing industry is a major employer, so governments are predisposed to support it. On the other hand, scientists and conservationists push for stringent protection, warning that many stocks could be wiped out within fifty years.

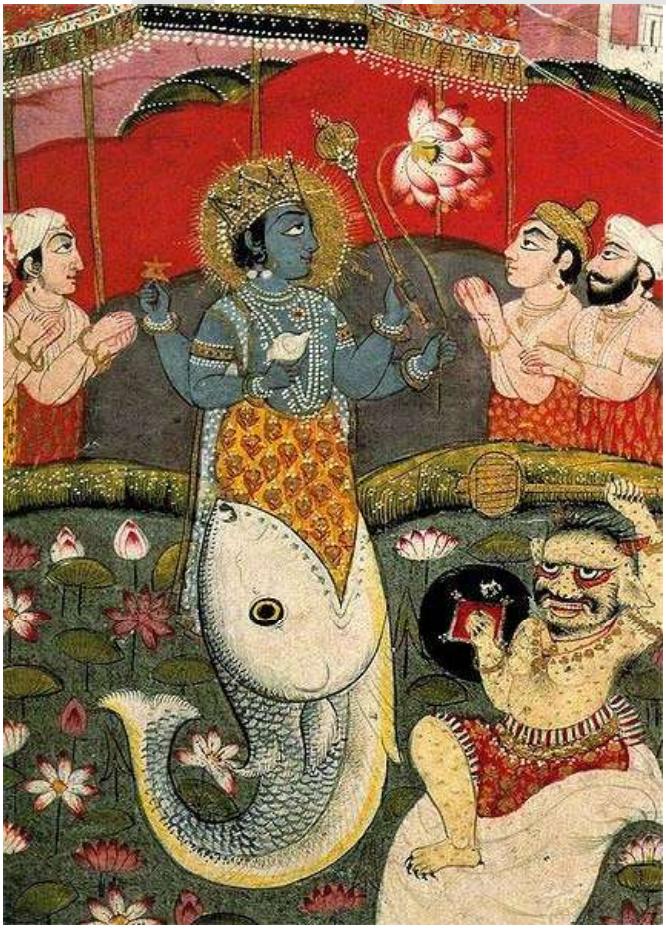
Habitat destruction

A key stress on both freshwater and marine ecosystems is habitat degradation including water pollution, the building of dams, removal of water for use by humans, and the introduction of exotic species. An example of a fish that has become endangered because of habitat change is the pallid sturgeon, a North American freshwater fish that lives in rivers damaged by human activity.

Exotic species

Introduction of non-native species has occurred in many habitats. One of the best studied examples is the introduction of Nile perch into Lake Victoria in the 1960s. Nile perch gradually exterminated the lake's 500 endemic cichlid species. Some of them survive now in captive breeding programmes, but others are probably extinct. Carp, snakeheads, tilapia, European perch, brown trout, rainbow trout, and sea lampreys are other examples of fish that have caused problems by being introduced into a lien environments.

Culture



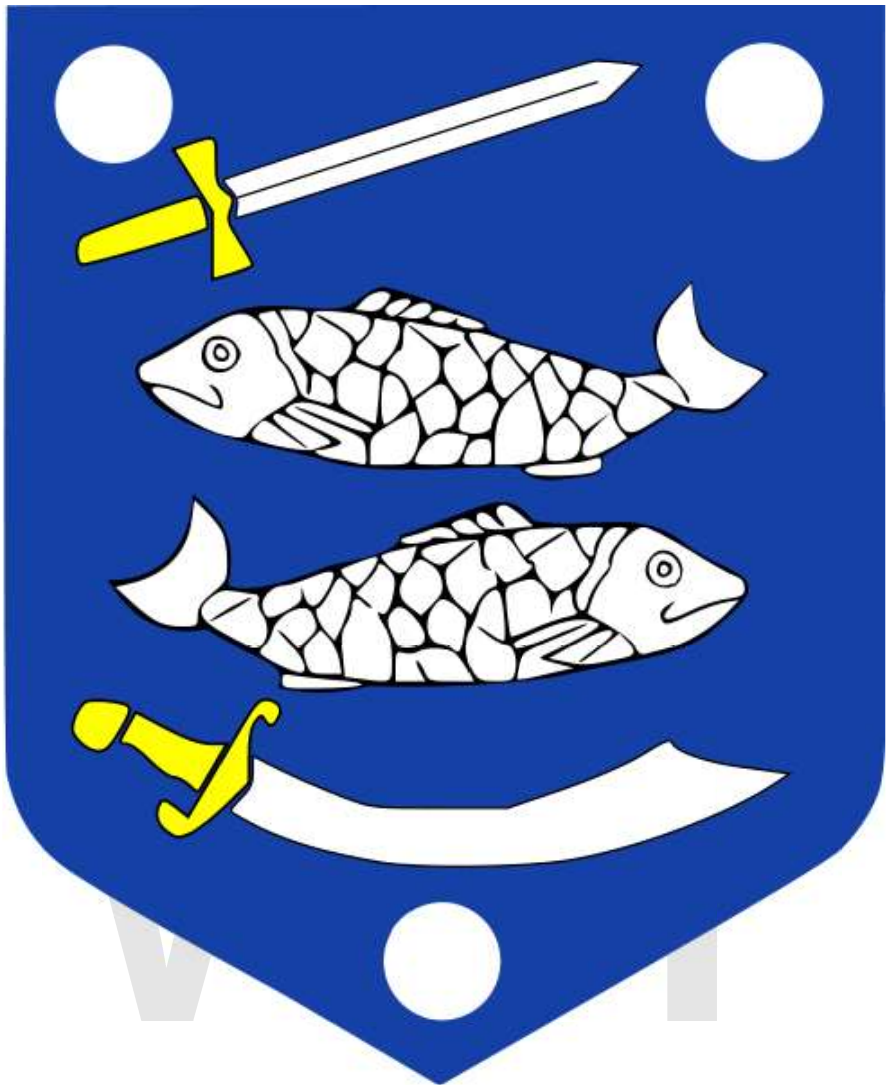
Incarnation of Vishnu as a Merman

In the Book of Jonah a "great fish" swallowed Jonah the Prophet. Legends of half-human, half-fish mermaids have featured in stories like those of Hans Christian Andersen and movies like *Splash*.

Among the deities said to take the form of a fish are Ika-Roa of the Polynesians, Dagon of various ancient Semitic peoples, the shark-gods of Hawai‘i and Matsya of the Dravidas of India. The astrological symbol Pisces is based on a constellation of the same name, but there is also a second fish constellation in the night sky, Piscis Austrinus.

Fish have been used figuratively in many different ways, for example the ichthys used by early Christians to identify themselves, through to the fish as a symbol of fertility among Bengalis.

Coat of arms of Comacchio, Italy



coat of arms of Narva, Estonia

Fish feature prominently in art and literature, in movies such as *Finding Nemo* and books such as *The Old Man and the Sea*. Large fish, particularly sharks, have frequently been the subject of horror movies and thrillers, most notably the novel *Jaws*, which spawned a series of films of the same name that in turn inspired similar films or parodies such as *Shark Tale*, *Snakehead Terror*, and *Piranha*.

In the semiotic of Ashtamangala (buddhist symbolism) the golden fish (Sanskrit: Matsya), represents the state of fearless suspension in samsara, perceived as the harmless ocean, referred to as 'buddha-eyes' or 'rigpa-sight'. The fish symbolizes the auspiciousness of all living beings in a state of fearlessness without danger of drowning in the Samsaric Ocean of Suffering, and migrating from teaching to teaching freely and spontaneously just as fish swim.

Fish riders in a 1920s poster of the Republic of China.

They have religious significance in Hindu, Jain and Buddhist traditions but also in Christianity who is first signified by the sign of the fish, and especially referring to feeding the multitude in the desert. In the dhamma of Buddha the fish symbolize happiness as they have complete freedom of movement in the water. They represent fertility and abundance. Often drawn in the form of carp which are regarded in the Orient as sacred on account of their elegant beauty, size and life-span.

The name of the Canadian city of Coquitlam, British Columbia is derived from *Kwikwetlem*, which is said to be derived from a Coast Salish term meaning "little red fish".

Terminology

Fish or fishes?

Though often used interchangeably, these words have different meanings. ***Fish*** is used either as singular noun or to describe a group of specimens from a single species. ***Fishes*** describes a group of different species.

Shoal or school

These goldband fusiliers are schooling because their swimming is synchronised

A random assemblage of fish merely using some localised resource such as food or nesting sites is known simply as an ***aggregation***. When fish come together in an interactive, social grouping, then they may be forming either a *shoal* or a *school* depending on the degree of organisation. A ***shoal*** is a loosely organised group where each fish swims and forages independently but is attracted to other members of the group and adjusts its behaviour, such as swimming speed, so that it remains close to the other members of the group. ***Schools*** of fish are much more tightly organised, synchronising their swimming so that all fish move at the same speed and in the same direction. Shoaling and schooling behaviour is believed to provide a variety of advantages.

Examples:

- Cichlids congregating at lekking sites form an *aggregation*.
- Many minnows and characins form *shoals*.
- Anchovies, herrings and silversides are classic examples of *schooling* fish.

While school and shoal have different meanings within biology, they are often treated as synonyms by non-specialists, with speakers of British English using "shoal" to describe

any grouping of fish, while speakers of American English often using "school" just as loosely.

Chapter- 9

Sea Snake

Sea snake

Yellow-bellied sea snake, *Pelamis platurus*
Scientific classification
Kingdom: Animalia
Phylum: Chordata
Subphylum: Vertebrata
Class: Reptilia
Order: Squamata
Suborder: Serpentes
Family: **Hydrophiidae** Boie, 1827

Sea snakes are venomous elapid snakes that inhabit marine environments for most or all of their lives. Though they evolved from terrestrial ancestors, most are extensively adapted to a fully aquatic life and are unable to even move on land, except for the genus *Laticauda*, which retain ancestral characteristics which allow limited land movement. They are found in warm coastal waters from the Indian Ocean to the Pacific. All have paddle-like tails and many have laterally compressed bodies that give them an eel-like appearance. Unlike fish, they do not have gills and must surface regularly to breathe. They are among the most completely aquatic of all air-breathing vertebrates. Among this group are species with some of the most potent venoms of all snakes. Some have gentle

dispositions and bite only when provoked, but others are much more aggressive. Currently, 17 genera are described as sea snakes, comprising 62 species.

Description

Adults of most species grow to between 120–150 cm (3.9–4.9 ft) in length, with the largest, *Hydrophis spiralis*, reaching a maximum of 3 m (9.8 ft). Their eyes are relatively small with a round pupil and most have nostrils that are located dorsally. The skulls do not differ significantly from terrestrial elapids, although the dentition is relatively primitive with short fangs and (with the exception of *Emydocephalus*) as many as 18 smaller teeth behind them on the maxilla.

Yellow-lipped sea krait, *Laticauda colubrina*.

Most sea snakes are completely aquatic and have adapted to their environment in many ways, the most characteristic of which is a paddle-like tail that has increased their swimming ability. To a varying degree, the bodies of many species are laterally compressed, especially in the pelagic species. This has often caused the ventral scales to become reduced in size, even difficult to distinguish from the adjoining scales. Their lack of ventral scales means that they have become virtually helpless on land, but as they live out their entire life cycle at sea, they have no need to leave the water.

The only genus that has retained the enlarged ventral scales is the sea kraits, *Laticauda*, with only five species. These snakes are considered to be more primitive, as they still spend much of their time on land, where their ventral scales afford them the necessary grip. *Laticauda* are also the only sea snakes with internasal scales, i.e., their nostrils are not located dorsally.

As it is easier for a snake's tongue to fulfill its olfactory function under water, its action is short compared to that of terrestrial snake species. Only the forked tips protrude from the mouth through a divided notch in the middle of the rostral scale. The nostrils have valves consisting of a specialized spongy tissue to exclude water, and the windpipe can be drawn up to where the short nasal passage opens into the roof of the mouth. This an important adaptation for an animal that must surface to breathe, but may have its head partially submerged when doing so. The lung has become very large and extends almost the entire length of the body, although it is thought that the rear portion developed to aid buoyancy rather than to exchange gas. It is also possible that the extended lung serves to store air for dives.

Most sea snakes are able to respire through their skin. This is unusual for reptiles, because their skin is thick and scaly, but experiments with the black-and-yellow sea snake, *Pelamis platurus* (a pelagic species), have shown that this species can satisfy about 20% of its oxygen requirements in this manner, which allows for prolonged dives.

Blue-lipped sea krait, *Laticauda laticaudata*.

Like other land animals that have adapted to life in a marine environment, sea snakes ingest considerably more salt than their terrestrial relatives through their diet and when sea water is inadvertently swallowed. This meant that they had to evolve a more effective means of regulating the salt concentration of their blood. Mammals have the advantage of being able to pass salt in solution, mostly in the urine, but kidney function in birds and reptiles is too weak to remove salt in sufficient amounts. In birds, such as penguins, salt is removed through nasal glands, just as with the marine iguanas of the Galapagos Islands. Sea turtles have lacrimal glands that allow them to produce very salty tears. In sea snakes, the posterior sublingual glands, located under and around the tongue sheath, evolved to allow them to expel salt with their tongue action.

Scalation among sea snakes is highly variable. As opposed to terrestrial snake species that have imbricate scales to protect against abrasion, the scales of most pelagic sea snakes do not overlap. Reef dwelling species, such as *Aypisurus*, do have imbricate scales to protect against the sharp coral. The scales themselves may be smooth, keeled, spiny or granular, the latter often looking like warts. *Pelamis* has body scales that are "peg-like", while those on its tail are juxtaposed hexagonal plates.

Aipysurus laevis has been found to have photoreceptors in the skin of its tail, allowing it to detect light and presumably aiding it to remain hidden inside coral holes during the day. While other species have not been tested, it is possible that *A. laevis* is not unique among sea snakes in this respect.

Distribution and habitat

Sea snakes are mostly confined to the warm tropical waters of the Indian Ocean and the western Pacific Ocean, with a few species found well out into Oceania. The geographic range of one species, *Pelamis platurus*, is wider than that of any other reptile species, save for a few species of sea turtles. It extends from the east coast of Africa, from Djibouti in the north to Cape Town in the south, across the Indian Ocean, the Pacific, south as far as the northern coast of New Zealand, all the way to the western coast of the Americas, where it occurs from northern Peru in the south (including the Galápagos Islands) to the Gulf of California in the north. Isolated specimens have been found as far north as San Clemente in the United States.

Sea snakes do not occur in the Atlantic Ocean. It is thought that *Pelamis* would be found there were it not for the cold currents off Namibia and western South Africa that keep it from crossing into the eastern South Atlantic, or south of 5° latitude along the South American west coast. Sea snakes do not occur in the Red Sea*, believed to be due to its increased salinity, so there is no danger of them crossing through the Suez Canal. Salinity, or rather a lack thereof, is also thought to be the reason why *Pelamis* has not crossed into the Caribbean via the Panama Canal.

Despite their marine adaptations, most sea snakes prefer shallow waters near land, around islands, and especially waters that are somewhat sheltered, as well as near estuaries. They may swim up rivers and have been reported as far as 160 km (99 mi) from the sea. Others, such as *Pelamis platurus*, are pelagic and are found in drift lines; slicks of floating debris brought together by surface currents. Some sea snakes inhabit mangrove swamps and similar brackish water habitats and there are two landlocked fresh water forms: *Hydrophis semperi* occurs in Lake Taal in the Philippines, and *Laticauda crockeri* in Lake Te Nggano on Rennell Island in the Solomon Islands.

Behavior

Stidworthy (1974) describes all sea snake species as being reluctant to bite, and Fichter (1982) adds that they are quite docile. Spawls and Branch (1994) also claims they are mainly non-aggressive. The US Navy describes sea snakes as generally mild tempered, although there is variation among species and individuals. Mehrtens (1987) suggests that species such as *Pelamis platurus*, that feed by simply gulping down their prey, are more likely to bite when provoked because they seem to use their venom more for defence. This is in contrast to others, such as *Laticauda*, that use their venom for prey immobilization; these snakes are frequently handled with impunity by local fishermen. Species that have been reported as much more aggressive include *Aipysurus laevis*, *Astrotia stokesii*, *Enhydrina schistosa* and *Hydrophis ornatus*.

Olive sea snake, *Aipysurus laevis*.

Ditmars (1933) mentions that when they are taken out of the water, their movements become very erratic. They crawl awkwardly in these situations and can become quite aggressive, striking wildly at anything that moves. Yet they are frequently caught in nets by fishermen, who unravel and throw them back barehanded, usually suffering no harm. On land, sea snakes are unable to coil and strike like terrestrial snakes.

Observations suggest that sea snakes are active both day and night. In the morning, and sometimes late in the afternoon, they can be seen at the surface basking in the sunlight. When disturbed, they dive below. Sea snakes have been reported swimming at depths of over 90 m (300 ft). They can remain submerged for as long as a few hours, possibly depending on temperature and degree of activity.

Huge aggregations of sea snakes have been reported. For example, in 1932 millions of *Astrotia stokesii*, a relative of *Pelamis*, were seen from a steamer in the Strait of Malacca, off the coast of Malaysia, and formed a line of snakes 3 m (9.8 ft) wide and 100 km (62 mi) long. The cause of this phenomenon is unknown, although it likely has to do with reproduction. Ditmars (1933) mentions that, in that same area, sea snakes can sometimes be seen swimming in schools of several dozen, and that after typhoons many dead specimens can be found on the beaches.

Feeding

Most sea snake species prey on fish, especially eels. The latter, when bitten, stiffen and die within seconds. One species prefers molluscs and crustaceans, such as prawns, while a few others feed only on fish eggs, which is unusual for a venomous snake. Some reef dwelling species have small heads and thin necks, making it possible for them to extract small eels from the soft bottom where they hide. Stidworthy (1974) states that sea snakes will sometimes take bait from a fishing line.

Reproduction

Except for a single genus, all sea snakes are ovoviviparous; the young are born alive in the water where they live their entire life cycle. In some species, the young are quite large: up to half as long as the mother. The one exception is the genus *Laticauda*, which is oviparous; its five species all lay their eggs on land.

Venom

Like their cousins in the Elapidae family, the majority of sea snakes are highly venomous; however, when bites occur, it is rare for much venom to be injected, so that envenomation symptoms usually seem non-existent or trivial. For example, *Pelamis platurus* has a venom more potent than any other terrestrial snake species in Costa Rica, but despite its abundance in the waters off its western coast, few human fatalities have been reported. Nevertheless, all sea snakes should be handled with great caution.

Bites in which envenomation does occur are usually painless and may not even be noticed when contact is made. Teeth may remain in the wound. There is usually little or no swelling, and it is rare for any nearby lymph nodes to be affected. The most important symptoms are rhabdomyolysis (rapid breakdown of skeletal muscle tissue) and paralysis. Early symptoms include headache, a thick-feeling tongue, thirst, sweating, and vomiting. Symptoms that can occur after 30 minutes to several hours post-bite include generalized aching, stiffness, and tenderness of muscles all over the body. Passive stretching of the muscles is also painful, and trismus, which is similar to tetanus, is common. This is followed later on by symptoms typical of other elapid envenomations: a progressive flaccid paralysis, starting with ptosis and paralysis of voluntary muscles. Paralysis of muscles involved in swallowing and respiration can be fatal. After 3–8 hours, myoglobin as a result of muscle breakdown may start to show up in the blood plasma, which can cause the urine to turn a dark reddish, brown, or black color, and eventually lead to acute renal failure. After 6 to 12 hours, severe hyperkalemia, also the result of muscle breakdown, can lead to cardiac arrest.

Taxonomy

Sea snakes were at first regarded as a unified and separate family, the Hydrophiidae, that later came to comprise two subfamilies: the Hydrophiinae, or true/aquatic sea snakes

(now 16 genera with 57 species), and the more primitive Laticaudinae, or sea kraits (1 genus, *Laticauda*, with 5 species). Eventually, as it became clear just how closely related the sea snakes are to the elapids, the taxonomic situation became less well-defined. Some taxonomists responded by moving the sea snakes to the Elapidae, thereby creating the subfamilies Elapinae, Hydrophiinae and Laticaudinae, although the latter may be omitted if *Laticauda* is included in the Hydrophiinae. No one has yet been able to convincingly work out the phylogenetic relationships between the various elapid subgroups, and the situation is still unclear. Therefore, others opted to either continue to work with the older traditional arrangements, if only for practical reasons, or to lump all of the genera together in the Elapidae, with no taxonomic subdivisions, to reflect the work that remains to be done.

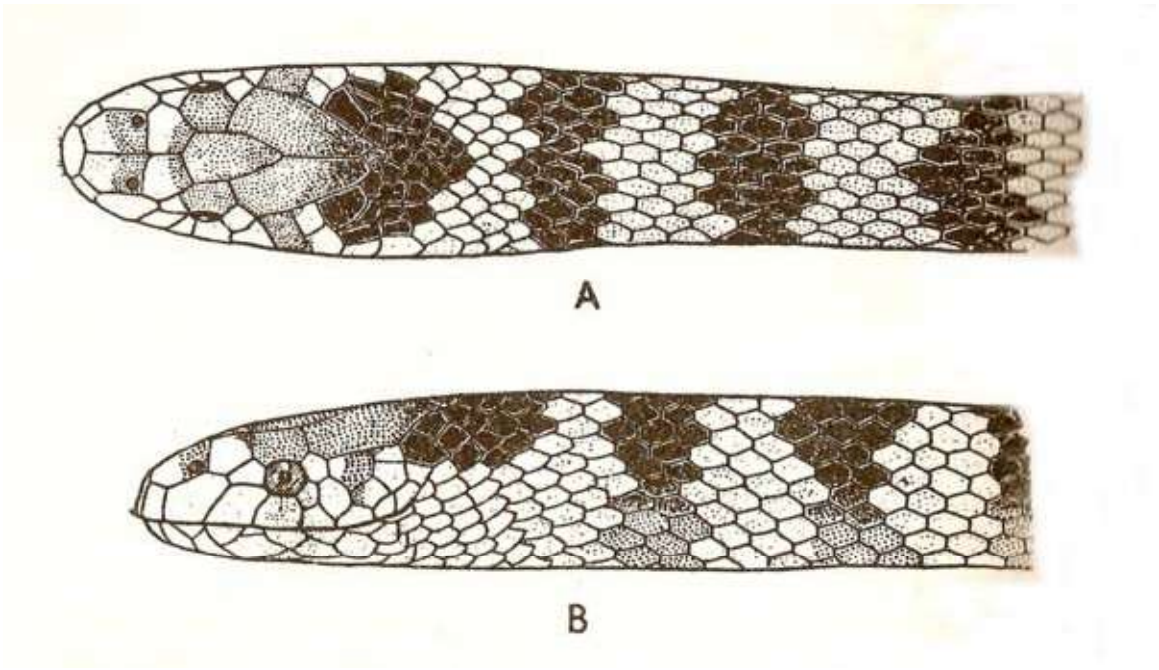
Genus	Taxon author	Species	Subsp.*	Common name	Geographic range
Acalyptophis	Boulenger, 1869	1	0	Spiny-headed Sea Snake or Horned Sea Snake	Gulf of Thailand, South China Sea, the Strait of Taiwan, and the coasts of Guangdong, Indonesia, Philippines, New Guinea, New Caledonia, Australia (Northern Territory, Queensland, Western Australia)
Aipysurus	Lacépède, 1804	7	1	Olive sea snakes	Timor Sea, South China Sea, Gulf of Thailand, and coasts of Australia (North Territory, Queensland, West Australia), New Caledonia, Loyalty Islands, southern New Guinea, Indonesia, western Malaysia and Vietnam.
Astrotia	Fischer, 1855	1	0	Stoke's sea snake	Coastal areas from west India and Sri Lanka through Gulf of Thailand to China Sea, west Malaysia, Indonesia east to New Guinea, north and east coasts of Australia, Philippines
Emydocephalus	Krefft, 1869	2	0	Turtlehead sea snakes	The coasts of Timor (Indonesian sea), New Caledonia, Australia (North Territory, Queensland, West Australia), and in the Southeast Asian Sea along the coasts of China, Taiwan,

					Japan, and the Ryukyu Island.
Enhydrina	Gray, 1849	2	0	Beaked sea snakes	In the Persian Gulf (Oman, United Arab Emirates, etc.), south to the Seychelles and Madagascar, SE Asian Sea (Pakistan, India, Bangladesh, Myanmar, Thailand, Vietnam), Australia (North Territory, Queensland), New Guinea and Papua New Guinea.
Ephalophis	M.A. Smith, 1931	1	0	Grey's mudsnake	North-western Australia
Hydrelaps	Boulenger, 1896	1	0	Port Darwin mudsnake	Northern Australia, southern New Guinea
Hydrophis	Latreille *In* Sonnini & Latreille, 1801	34	3	Sea snakes	Indoaustralian and Southeast Asian waters.
Kerilia	Gray, 1849	1	0	Jerdon's sea snake	Southeast Asian waters.
Kolpophis	M.A. Smith, 1926	1	0	Bighead sea snake	Indian Ocean.
Lapemis	Gray, 1835	2	0	Spine-bellied Sea Snake, Shaw's Sea Snake	Persian Gulf to Indian Ocean, South China Sea, Indo-Australian archipelago and the western Pacific.
Laticauda	Laurenti, 1768	5	0	Sea kraits	Southeast Asian and Indoaustralian waters.
Parahydrophis	Burger & Natsuno, 1974	1	0	Northern mangrove sea snake	Northern Australia, southern New Guinea
Parapistocalamus	Roux, 1934	1	0	Hediger's snake	Bougainville Island, Solomons
Pelamis	Daudin, 1803	1	0	Yellow bellied sea	Indian and Pacific Oceans

				snake	
Praescutata	Wall, 1921	1	0		From the Persian Gulf to the Indian Ocean, the South Chinese Sea, and northeast to the coastal region of Fujian and Strait of Taiwan.
Thalassophis	P. Schmidt, 1852	1	0	Anomalous sea snake	South Chinese Sea (Malaysia, Gulf of Thailand), Indian Ocean (Sumatra, Java, Borneo)

**) Not including the nominate subspecies.*

Captivity



Hydrophis cyanocinctus

At best, these snakes make difficult captives. Ditmars (1933) described them as nervous and delicate captives that usually refuse to eat, preferring only to hide in the darkest corner of the tank. Over 50 years later, Mehrtens (1987) wrote that although they were rarely displayed in western zoological parks, some species were regularly on display in Japanese aquariums. Available food supply is one factor that limits the number of species that can be kept in captivity, since some have diets that are too specialized. Another is that some species appear too intolerant to handling, or even being removed from the water. Regarding their facilities, the *Laticauda* species need to be able to exit the water somewhere and bask, while the other strictly aquatic genera do not, basically requiring only a tank of filtered (synthetic) sea water maintained at about 29°C, along with a

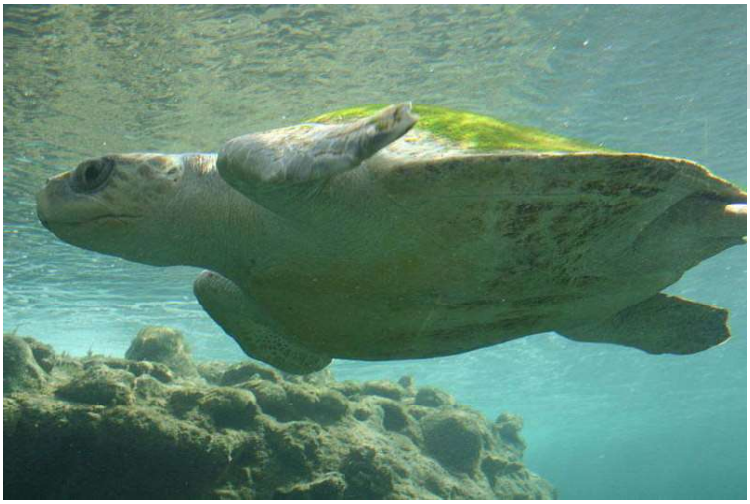
submerged shelter. Species that have done relatively well in captivity include the ringed sea snake, *Hydrophis cyanocinctus*, which feed on fish and eels in particular. *Pelamis platurus* has done especially well in captivity, accepting small fish, including goldfish. However, care has to be taken to house them in round or oval tanks, or in rectangular tanks with corners that are well-rounded, to prevent the snakes from damaging their snouts by swimming into the sides.

Conservation status

Most sea snakes are not on the CITES protection lists. Only one species, *Laticauda crockeri*, is classified as vulnerable (VU) according to the IUCN Red List of Threatened Species.

Chapter- 10

Sea Turtle

Sea turtles

An olive ridley sea turtle
Conservation status

Endangered (IUCN 3.1)
Scientific classification

Kingdom:	Animalia
Phylum:	Chordata
Class:	Reptilia
Order:	Testudines
Suborder:	Cryptodira
Superfamily:	**Chelonioidea** Bauer, 1893

Genera

- Family **Cheloniidae** (Oppel, 1811)
  - *Caretta*
  - *Chelonia*
  - *Eretmochelys*
  - *Lepidochelys*
  - *Natator*
- Family Dermochelyidae
  - *Dermochelys*
- Family Protostegidae (extinct)
- Family Toxochelyidae (extinct)
- Family Thalassemyidae (extinct)

Sea turtles (superfamily **Chelonioidea**) are marine reptiles that inhabit all of the world's oceans except the Arctic.

Distribution

The superfamily Chelonioidea has a world-wide distribution; sea turtles can be found in all oceans except for the polar regions. Some species travel between oceans. The flatback sea turtle is found solely on the northern coast of Australia.

Biology

Respiration

A Green sea turtle breaks the surface to breathe.

Sea turtles are almost always submerged in water, and, therefore, have developed an anaerobic system of respiration. Although all sea turtles breathe air, under dire circumstances they may divert to anaerobic respiration for long periods of time. When surfacing to breathe, a sea turtle can quickly refill its lungs with a single explosive exhalation and rapid inhalation. Their large lungs have adapted to permit rapid exchange of oxygen and to avoid trapping gases during deep dives. However, sea turtles must emerge while breeding, given the extra level of activity.

Life history

Hawksbill sea turtle swims at Black Hills, Honduras

A feeding green sea turtle, *Chelonia mydas*

According to SeaWorld Parks & Entertainment, a lifespan of 80 years is feasible for sea turtles.

It takes decades for sea turtles to reach sexual maturity. After mating at sea, adult female sea turtles return to land to nest at night. Different species of sea turtles exhibit various levels of philopatry. In the extreme case, females return to the beach where they hatched. This can take place every two to four years in maturity. They make from one to eight nests per season.

The mature nesting female hauls herself onto the beach, nearly always at night, and finds suitable sand on which to create a nest. Using her hind flippers, she digs a circular hole 40 to 50 centimetres (16 to 20 in) deep. After the hole is dug, the female then starts filling the nest with a clutch of soft-shelled eggs one by one until she has deposited around 50 to 200 eggs, depending on the species. Some species have been reported to lay 250 eggs, such as the hawksbill. After laying, she re-fills the nest with sand, re-sculpting and smoothing the surface until it is relatively undetectable visually. The whole process takes thirty to sixty minutes. She then returns to the ocean, leaving the eggs untended.

The hatchling's gender depends on the sand temperature. Lighter sands maintain higher temperatures, which decreases incubation time and results in more female hatchlings.

Incubation takes about two months. The eggs in one nest hatch together over a very short period of time. When ready, hatchlings tear their shells apart with their snout and dig

through the sand. Again, this usually takes place at night, when predators such as seagulls cannot fly. Once they reach the surface, they instinctively head towards the sea. If, as happens on rare occasions, hatching takes place during daylight, only a very small proportion of each hatch (usually 0.01%) succeed, because local opportunist predators, such as the common seagull, gorge on the new sea turtles. Thus there is an obvious evolutionary drive to hatch at night, when survival rates on the beach are much higher.

The hatchlings then proceed into the ocean, where a variety of marine predators await them. In 1987, Carr discovered that the young of *Chelonia mydas* and *Caretta caretta* spent a great deal of their pelagic lives in floating sargassum beds, where there are thick mats of unanchored seaweed. Within these beds, they found ample shelter and food. In the absence of sargassum beds, sea turtle young feed in the vicinity of upwelling "fronts". In 2007, Reich determined that green sea turtle hatchlings spend the first three to five years of their lives in pelagic waters. In the open ocean, pre-juveniles of this particular species were found to feed on zooplankton and smaller nekton before they are recruited into inshore seagrass meadows as obligate herbivores.

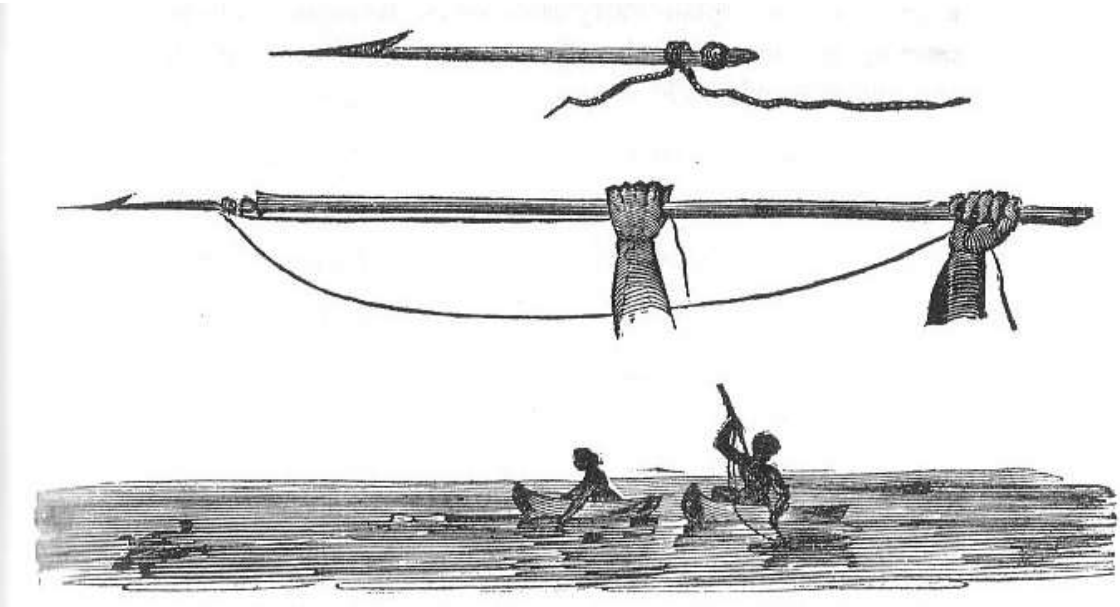
Instead of nesting individually like the other species, Ridley sea turtles come ashore en masse, known as an "arribada" (arrival). With the Kemp's ridley sea turtles this occurs during the day.

Salt gland

Sea turtles possess a salt excretory gland at the corner of the eye, in the nostrils, or in the tongue, depending on the species; chelonian salt glands are found in the corner of the eyes in leatherback sea turtles. Due to the iso-osmotic makeup of jellyfish and the other gelatinous prey upon which sea turtles subsist, sea turtle diets are high in salt; chelonian salt gland excretions are almost entirely composed of sodium chloride 1500-1800 mosmoll-1 (Marshall and Cooper, 1988; Nicolson and Lutz, 1989; Reina and Cooper, 2000).

Importance to humans

Moche Sea Turtle. 200 A.D. Larco Museum Collection, Lima, Peru



"Manner in which Natives of the East Coast strike turtle". Near Cooktown, Australia. From Phillip Parker King's Survey. 1818.

Marine sea turtles are caught worldwide, although it is illegal to hunt most species in many countries. A great deal of intentional marine sea turtle harvests worldwide are for food.

Many parts of the world have long considered sea turtles to be fine dining. Ancient Chinese texts dating to the fifth century B.C. describe sea turtles as exotic delicacies. Many coastal communities around the world depend on sea turtles as a source of protein, often harvesting several sea turtles at once and keeping them alive on their backs until needed. Coastal peoples gather sea turtle eggs for consumption.

Sea turtles are popular in Mexico as boot material and food.

To a much lesser extent, specific species of marine sea turtles are targeted not for their flesh, but for their shells. Tortoiseshell, a traditional decorative ornamental material used in Japan and China, comes from the carapace scutes of the hawksbill sea turtle. Ancient Greeks and ancient Romans processed sea turtle scutes (primarily from the hawksbill) for various articles and ornaments used by their elites, such as combs and brushes. The skin of the flippers are prized for use as shoes and assorted leather goods.

The Moche people of ancient Peru worshipped the sea and its animals. They often depicted sea turtles in their art.

Sea turtles enjoy immunity from the sting of the deadly box jellyfish and regularly eat them, helping keep tropical beaches safe for humans.

Sea turtles, especially green sea turtles, are one of the few animals that eat sea grass. Sea grass needs to be constantly cut short to help it grow across the sea floor. Sea turtles act as grazing animals that cut the grass short and help maintain the health of the sea grass beds. Sea grass beds provide breeding and developmental grounds for numerous species of fish, shellfish and crustaceans. Without sea grass beds, many marine species humans harvest would be lost, as would the lower levels of the food chain. The reactions could result in many more marine species eventually becoming endangered or extinct.

Beaches and dune systems do not get many nutrients. Sea turtles use beaches and the lower dunes to nest and lay their eggs. Sea turtles lay around 100 eggs in a nest and lay between 3 and 7 nests during the summer nesting season. Along a 20-mile stretch of beach on the east coast of Florida sea turtles lay over 150,000 lbs of eggs in the sand. Dune vegetation is able to grow and become stronger with the presence of nutrients from sea turtle eggs, unhatched nests, eggs and trapped hatchlings. As the dune vegetation grows stronger and healthier, the health of the entire beach/dune ecosystem becomes better. Stronger vegetation and root systems helps to hold the sand in the dunes and helps protect the beach from erosion.

Beach towns, such as Tortuguero, Costa Rica, have transitioned from a tourism industry that made profits from selling sea turtle meat and shells to an ecotourism-based economy. Tortuguero is considered to be the founding location of sea turtle conservation. In the 1960s the cultural demand for sea turtle meat, shells, and eggs were quickly killing once abundant sea turtle populations that nested on the beach. The Caribbean Conservation Corporation began working with villagers to promote ecotourism as a permanent substitute to sea turtle hunting. Sea turtle nesting grounds became sustainable. Since the creation of a sea turtle, ecotourism-based economy, Tortugero annually houses thousands of tourists who visit the protected 22-mile beach that hosts sea turtle walks and nesting grounds.

Conservation

All species of sea turtles are listed as threatened or endangered. The leatherback, Kemp's Ridley, and hawksbill sea turtles are critically endangered. The Olive Ridley and green sea turtles are endangered, and the loggerhead is threatened. The flatback's conservation status is unclear due to lack of data.

One of the most significant threats now comes from bycatch due to imprecise fishing methods. Long-lining has been identified as a major cause of accidental sea turtle death. There is also black-market demand for tortoiseshell for both decoration and supposed health benefits.

Sea turtles must surface to breathe. Caught in a fisherman's net, they are unable to surface and thus suffocate. In early 2007, almost a thousand sea turtles were killed inadvertently in the Bay of Bengal over the course of a few months after netting.

However, some relatively inexpensive changes to fishing techniques, such as slightly larger hooks and traps from which sea turtles can escape, can dramatically cut the mortality rate. Turtle Excluder Devices (TEDs) have reduced sea turtle bycatch in shrimp nets by 97 percent. Another danger comes from marine debris, especially from abandoned fishing nets in which they can become entangled.

Beach development is another area which threatens sea turtles. Since many sea turtles return to the same beach each time to nest, development can disrupt the cycle. There has been a movement to protect these areas, in some cases by special police. In some areas, such as the east coast of Florida, conservationists dig up sea turtle eggs and relocate them to fenced nurseries to protect them from beach traffic.

Since hatchlings find their way to the ocean by crawling towards the brightest horizon, they can become disoriented on developed stretches of coastline. Lighting restrictions can prevent lights from shining on the beach and confusing hatchlings. Sea turtle-safe lighting uses red or amber LED light, invisible to sea turtles, in place of white light.

Another major threat to sea turtles is black-market trade in eggs and meat. This is a problem throughout the world, but especially a concern in the Philippines, India, Indonesia and the coastal nations of Latin America. Estimates reach as high as 35,000 sea turtles killed a year in Mexico and the same number in Nicaragua. Conservationists in Mexico and the United States have launched "Don't Eat Sea Turtle" campaigns in order to reduce this trade in sea turtle products. These campaigns have involved figures such as Dorismar, Los Tigres del Norte and Maná. Sea turtles are often consumed during the Catholic season of Lent, even though they are reptiles, not fish. Consequently, conservation organizations have written letters to the Pope asking that he declare sea turtles meat.

Loggerhead sea turtle exits from fishing net through a turtle excluder device (TED)

Climate change may also cause a threat to sea turtles. Since sand temperature at nesting beaches defines the sex of a sea turtle while developing in the egg, there is concern that rising temperatures may produce too many females. However, more research is needed to understand how climate change might affect sea turtle gender distribution and what other possible threats it may pose.

Fibropapillomatosis disease causes tumors in sea turtles.

Injured sea turtles are sometimes rescued and rehabilitated by professional organizations, such as the Mote Marine Laboratory in Sarasota, Florida, the Marine Mammal Center in Northern California, the ClearWater Marine Aquarium in Clearwater, Florida, and the Sea Turtle Inc. organization in South Padre Island, Texas. One such sea turtle, named Nickel for the coin that was found lodged in her throat, lives at the Shedd Aquarium in Chicago.

In the Caribbean, researchers are having some success in assisting a comeback. In September 2007, Corpus Christi, Texas, wildlife officials found 128 Kemp's ridley sea turtle nests on Texas beaches, a record number, including 81 on North Padre Island (Padre Island National Seashore) and four on Mustang Island. Wildlife officials released 10,594 Kemp's ridleys hatchlings along the Texas coast this year.

Also in 2007, the U.S. Fish and Wildlife Service and the National Marine Fisheries Service issued a determination that the leatherback, the hawksbill and the Kemp's Ridley populations were endangered while that of green sea turtles and olive ridleys were threatened.

In Southeast Asia, the Philippines has had several initiatives dealing with the issue of sea turtle conservation. In 2007, the province of Batangas in the Philippines declared the catching and eating of Pawikans illegal. However, the law seems to have had little effect as Pawikan eggs are still in demand in Batangan markets. In September 2007, several Chinese poachers were apprehended off the Turtle Islands in the country's southernmost province of Tawi-Tawi. The poachers had collected more than a hundred sea turtles, along with 10,000 sea turtle eggs.

Sea turtles are very vulnerable to oil pollution, both because of their tendency to linger on the water's surface, and because oil can effect them at every stage of their life cycle. Oil can poison the sea turtles upon entering their digestive system,

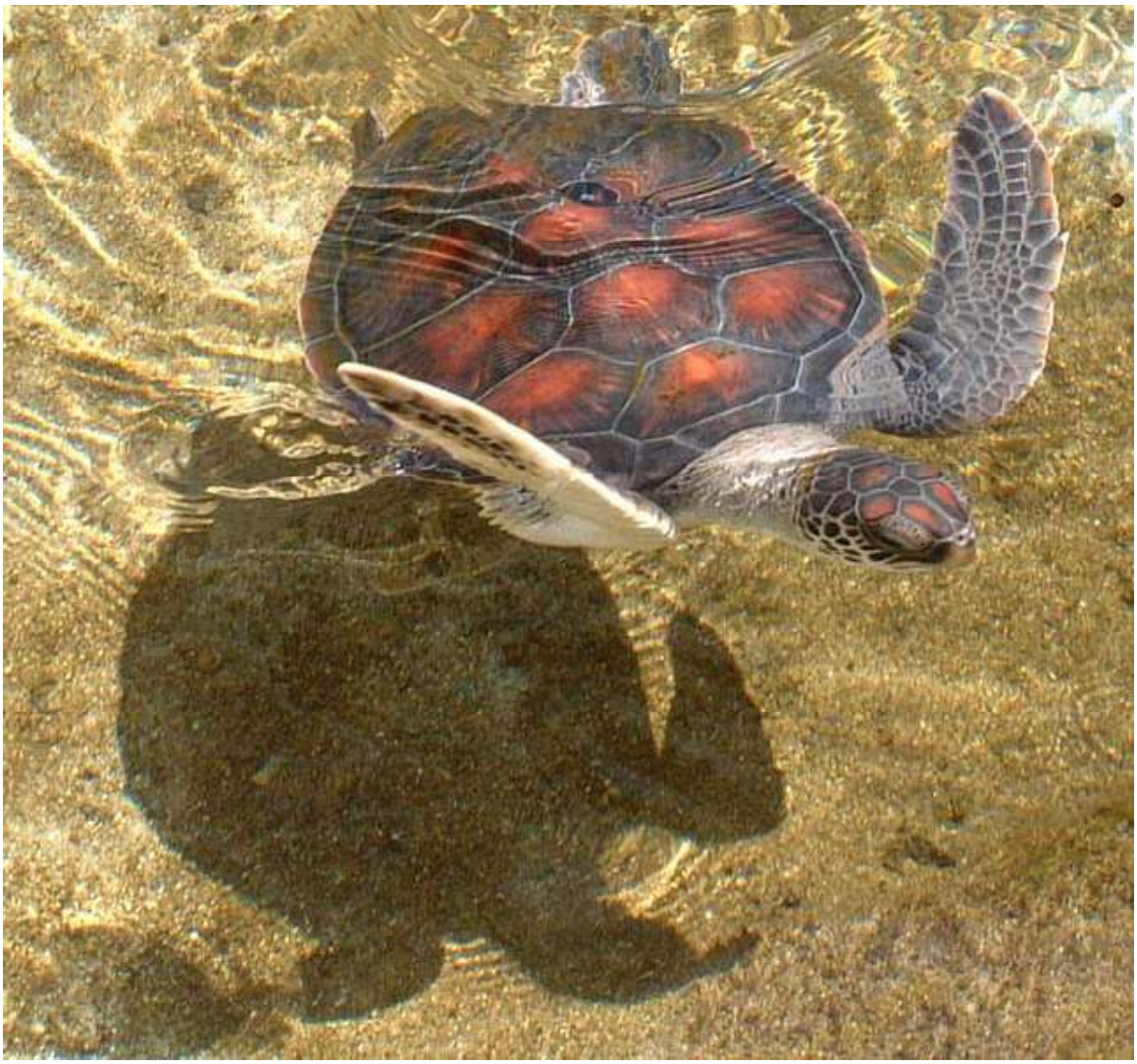
Fragile ecosystems

Sea turtles on a beach in Hawaii

Sea turtles play key roles in two ecosystem types that are critical to them as well as to humans—oceans and beaches/dunes. In the oceans, for example, sea turtles, especially green sea turtles, are one of very few creatures (manatees are another) that eat the sea grass that grows on the sea floor. Sea grass must be kept short to remain healthy, and beds of healthy sea grass are essential breeding and development areas for many species of fish and other marine life. A decline or loss of sea grass beds would damage these populations, triggering a chain reaction and negatively impacting marine and human life.

Beaches and dunes form a fragile ecosystem that depends on vegetation to protect against erosion. Eggs, hatched or unhatched, and hatchlings that fail to make it into the ocean are nutrient sources for dune vegetation. Every year, sea turtles lay countless eggs on beaches. Along one twenty-mile (32 km) stretch of beach in Florida alone, for example, more than 150,000 pounds of eggs are laid each year.

Taxonomy and evolution



Immature Hawaiian Green sea turtle in shallow waters

Eurysternum wagneri fossil at the Museum für Naturkunde, Berlin

Sea turtles, along with other turtles and tortoises, are part of the order Testudines.

The seven living species of sea turtles are: flatback sea turtle, green sea turtle, hawksbill sea turtle, Kemp's ridley sea turtle, leatherback sea turtle, loggerhead sea turtle and olive ridley sea turtle. All species except the leatherback are in the family Cheloniidae. The leatherback belongs to the family Dermochelyidae and is its only member.

The species are primarily distinguished by their anatomy: for instance, the prefrontal scales on the head, the number of and shape of scutes on the carapace, and the type of inframarginal scutes on the plastron. The leatherback is the only sea turtle that does not have a hard shell; instead, it bears a mosaic of bony plates beneath its leathery skin. It is the largest sea turtle, measuring 6 to 7 feet (1.8 to 2.1 m) in length at maturity, and 3 to 5 feet (0.91 to 1.5 m) in width, weighing up to 1,300 pounds (590 kg). Other species are smaller, being mostly 2 to 4 feet (0.61 to 1.2 m) and proportionally narrower.

Sea turtles constitute a single radiation that became distinct from all other turtles at least 110 million years ago.

From *SWOT Report*, vol. 1:

- **Family Cheloniida**
  - *Chelonia mydas* or green sea turtle

    - *Eretmochelys imbricata* or hawksbill sea turtle
    - *Natator depressus* or flatback sea turtle
    - *Caretta caretta* or Loggerhead sea turtle
    - *Lepidochelys kempii* or Kemp's ridley sea turtle
    - *Lepidochelys olivacea* or olive ridley sea turtle
- **Family Dermochelyidae**
    - *Dermochelys coriacea* or leatherback sea turtle

Chapter- 11

Cetacea

Cetaceans Temporal range: 55–0 Ma Early Eocene - Present

Humpback Whale breaching
Scientific classification
Kingdom: Animalia
Phylum: Chordata
Class: Mammalia
Infraclass: Laurasiatheria
(unranked): Cetartiodactyla
Order: **Cetacea** Brisson, 1762
Suborders
Mysticeti Odontoceti †Archaeoceti

The order **Cetacea** includes the marine mammals commonly known as whales, dolphins, and porpoises. *Cetus* is Latin and is used in biological names to mean "whale"; its original meaning, "large sea animal", was more general. It comes from Ancient Greek κῆτος (*kētos*), meaning "whale" or "any huge fish or sea monster". In Greek mythology the monster Perseus defeated was called Ceto, which is depicted by the constellation of Cetus. Cetology is the branch of marine science associated with the study of cetaceans.

Cetaceans are the mammals best adapted to aquatic life. Their body is fusiform (spindle-shaped). The forelimbs are modified into flippers. The tiny hindlimbs are vestigial; they do not attach to the backbone and are hidden within the body. The tail has horizontal flukes. Cetaceans are nearly hairless, and are insulated from the cooler water they inhabit by a thick layer of blubber. Some species are noted for their high intelligence.

Respiration

A dolphin in the Strait of Gibraltar

Cetaceans breathe air. They surface periodically to exhale carbon dioxide and inhale a fresh supply of oxygen. During diving, a muscular action closes the blowholes (nostrils), which remain closed until the cetacean next breaks the surface; when it surfaces, the muscles open the blowholes and warm air is exhaled.

Cetaceans' blowholes have evolved to a position at the top of the head, simplifying breathing in sometimes rough seas. When the stale air, warmed from the lungs, is exhaled, it condenses as it meets colder external air. As with a terrestrial mammal breathing out on a cold day, a small cloud of 'steam' appears. This is called the 'blow' or 'spout' and varies by species in terms of shape, angle and height. Species can be identified at a distance using this characteristic.

Cetaceans can remain under water for much longer periods than other mammals, (approximately 7–30 minutes, varying by species) due to large physiological differences. Two studied advantages of cetacean physiology let this order (and other marine mammals) forage underwater for extended periods without breathing:

- Mammalian myoglobin concentrations in skeletal muscle have much variation. New Zealand white rabbits have 0.08 grams (0.0028 oz) +/- 0.6 grams (0.021 oz) myoglobin in 100 grams (3.5 oz) of wet muscle, whereas a Northern Bottlenose Whale has 6.34 grams (0.224 oz). Myoglobin, by nature, has a higher oxygen affinity than hemoglobin. The higher the myoglobin concentration in skeletal muscle, the longer the animal can stay underwater.

- Increased body size also increases maximum dive duration. Greater body size implies increased muscle mass and increased oxygen stores. Cetaceans also obey Kleiber's law, which states that mass and metabolic rate are inversely related. I.e., larger animals consume less oxygen than smaller animals per unit mass.

Vision, hearing and echolocation

Cetacean eyes are set on the side rather than the front of the head. This means that only cetaceans with pointed 'beaks' (such as dolphins) have good binocular vision forward and downward. Tear glands secrete greasy tears, which protect the eyes from the salt in the water. The lens is almost spherical, which is most efficient at focusing the minimal light that reaches deep water. Cetaceans make up for their generally poor vision (with the exception of the dolphin) with excellent hearing.

As with the eyes, cetacean ears are also small. Life in the sea accounts for the cetacean's loss of its external ears, whose function is to collect and focus airborne sound waves. However, water conducts sound better than air, so the external ear is unneeded: it is a tiny hole in the skin, just behind the eye. The highly developed inner ear can detect sounds from dozens of miles away and discern from which direction the sound comes.

Odontoceti are generally capable of echolocation. From this, Odontoceti can discern the size, shape, surface characteristics, distance and movement of an object. With this ability cetaceans can search for, chase and catch fast-swimming prey in total darkness. Echolocation is so advanced in most Odontoceti that they can distinguish between prey and non-prey (such as humans or boats); captive Odontoceti can be trained to distinguish between, for example, balls of different sizes or shapes. Mysticeti have little need of

echolocation, because they prey upon tiny fish such as krill that are impractical to locate with echolocation.

Cetaceans also use sound to communicate, whether it be groans, moans, whistles, clicks or the complex 'singing' of the Humpback Whale.

Feeding

The toothed whales such as the sperm whale, beluga, dolphins and porpoises, have teeth that they use for catching fish, squid or other marine life. They do not chew but swallow prey whole. When they catch large prey, such as when the orca (*Orcinus orca*) catches a seal, they bite off and swallow one chunk at a time.

Mysticeti instead have baleen plates made of keratin (the same substance as human fingernails) which hang from the upper jaw. These plates filter small animals (such as krill and fish) from the seawater. Cetaceans included in this group include the Blue, Humpback, Bowhead and Minke whales.

Not all Mysticeti feed on plankton: the larger species eat small shoaling fish, such as herring and sardine, called micronecton. The gray whale (*Eschrichtius robustus*), is a benthic feeder, primarily eating sea floor crustaceans.

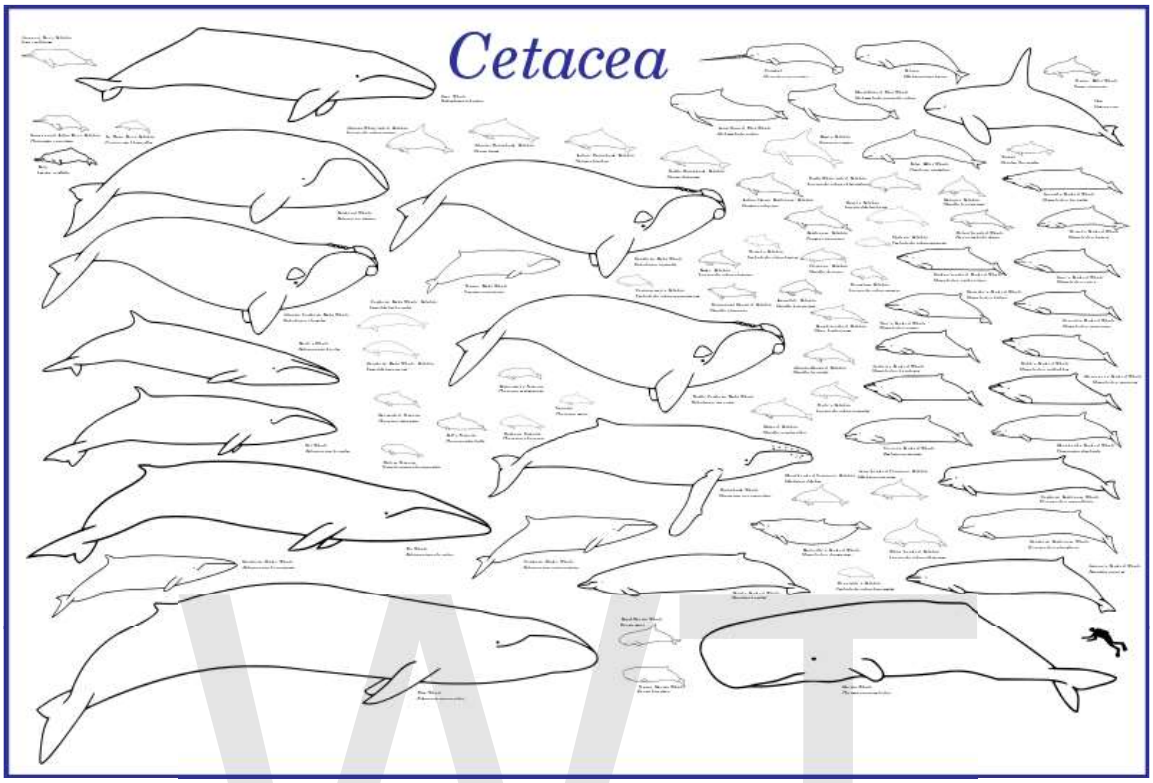
Mammalian nature

Cetaceans are mammals, that is, members of the class Mammalia. The closest living relatives of cetaceans are the even-toed ungulates, such as the hippopotamus and deer.

Mammalian characteristics include warm-bloodedness, breathing air through their lungs, and suckling their young, and growing hair, although very little of it.

Another way of distinguishing a cetacean from a fish is by the shape of the tail. Fish tails are vertical and move from side to side when the fish swims. Cetacea tails—called a fluke—are horizontal and move up and down, because cetacea spines bend in the same manner as a human spine.

Taxonomy



Size comparison of all known extant cetacean species. Note the human diver at lower right for scale.

The order Cetacea contains about ninety species, all marine except for four species of freshwater dolphins. The order contains two suborders, Mysticeti (baleen whales) and Odontoceti (toothed whales, which includes dolphins and porpoises). The species range in size from Commerson's Dolphin, smaller than a human, to the Blue Whale, the largest animal ever known to have lived.

Mysticeti vs Odontoceti

Fossils indicate that before evolving baleen, Mysticeti also had teeth, so defining the Odontoceti via teeth alone is problematic, and paleontologists have instead identified other features uniting fossil and modern odontocetes that are not shared by Mysticetes.

Characteristic	**Odontoceti**	**Mysticeti**
Feeding	Echolocation, fast	Filter feeder, not fast
Size	Smaller (except Sperm whale)	Larger
Blowhole	One	Two
Dentition	Teeth	Baleen plates
Melon	Ovoid, in anterior facial	Vestigial or none

	region	
Skull and facial tissue	Dorsally asymmetric	Symmetric
Sexual dimorphism	Some species have larger males	Females always larger
Mandible	Symphyseal	Nonsymphyseal
Pan bone of lower jaw	Yes	No
Maxillae projection	Outward over expanded supraorbital processes	Under eye orbit, with bony protuberance anterior to eye orbit
Tympanic bulla and periotic bone	Fused, equal sized	Larger, separate tympanic

Tree

The classification here closely follows Dale W. Rice, *Marine Mammals of the World: Systematics and Distribution* (1998), which has become the standard taxonomy reference in the field. There is very close agreement between this classification and that of *Mammal Species of the World: 3rd Edition* (Wilson and Reeder eds., 2005). Any differences are noted using the abbreviations "Rice" and "MSW3" respectively. Further differences due to recent discoveries are also noted.

Discussion of synonyms and subspecies are relegated to the relevant genus and species articles.

- **ORDER CETACEA**
  - **Suborder Mysticeti**: Baleen whales
    - Family Balaenidae: Right whales and Bowhead Whale
      - Genus *Balaena*
        - Bowhead Whale, *Balaena mysticetus*
      - Genus *Eubalaena*
        - North Atlantic Right Whale, *Eubalaena glacialis*
        - North Pacific Right Whale, *Eubalaena japonica*
        - Southern Right Whale, *Eubalaena australis*
    - Family Balaenopteridae: Rorquals
      - Subfamily Balaenopterinae
        - Genus *Balaenoptera*
          - Common Minke Whale, *Balaenoptera acutorostrata*
          - Antarctic Minke Whale, *Balaenoptera bonaerensis*
          - Sei Whale, *Balaenoptera borealis*
          - Bryde's Whale, *Balaenoptera brydei*
          - Eden's Whale *Balaenoptera edeni* - Rice lists this as a separate species, MSW3 does not

            - *Balaenoptera omurai* - MSW3 lists this is a synonym of Bryde's Whale but suggests this may be temporary.
            - Blue Whale, *Balaenoptera musculus*
            - Fin Whale, *Balaenoptera physalus*
        - Subfamily Megapterinae
            - Genus *Megaptera*
                - Humpback Whale, *Megaptera novaeangliae*
    - Family Eschrichtiidae
        - Genus *Eschrichtius*
            - Gray Whale, *Eschrichtius robustus*
    - Family Neobalaenidae: Pygmy Right Whale
        - Genus *Caperea*
            - Pygmy Right Whale, *Caperea marginata*
- **Suborder Odontoceti**: toothed whales
    - Family Delphinidae: Dolphin
        - Genus *Cephalorhynchus*
            - Commerson's Dolphin, *Cephalorhyncus commersonii*
            - Chilean Dolphin, *Cephalorhyncus eutropia*
            - Heaviside's Dolphin, *Cephalorhyncus heavisidii*
            - Hector's Dolphin, *Cephalorhyncus hectori*
        - Genus *Delphinus*
            - Long-beaked Common Dolphin, *Delphinus capensis*
            - Short-beaked Common Dolphin, *Delphinus delphis*
            - Arabian Common Dolphin, *Delphinus tropicalis*. Rice recognises this as a separate species. MSW3 does not.
        - Genus *Feresa*
            - Pygmy Killer Whale, *Feresa attenuata*
        - Genus *Globicephala*
            - Short-finned Pilot Whale, *Globicephala macrorhyncus*
            - Long-finned Pilot Whale, *Globicephala melas*
        - Genus *Grampus*
            - Risso's Dolphin, *Grampus griseus*
        - Genus *Lagenodelphis*
            - Fraser's Dolphin, *Lagenodelphis hosei*
        - Genus *Lagenorhynchus*
            - Atlantic White-sided Dolphin, *Lagenorhynchus acutus*
            - White-beaked Dolphin, *Lagenorhynchus albirostris*
            - Peale's Dolphin, *Lagenorhynchus australis*
            - Hourglass Dolphin, *Lagenorhynchus cruciger*

        - Pacific White-sided Dolphin, *Lagenorhynchus obliquidens*
        - Dusky Dolphin, *Lagenorhynchus obscurus*
    - Genus *Lissodelphis*
        - Northern Right Whale Dolphin, *Lissodelphis borealis*
        - Southern Right Whale Dolphin, *Lissodelphis peronii*
    - Genus *Orcaella*
        - Irrawaddy Dolphin, *Orcaella brevirostris*
            - Australian Snubfin Dolphin, *Orcaella heinsohni*. 2005 discovery, thus not recognized by Rice or MSW3 and subject to revision.
    - Genus *Orcinus*
        - Killer Whale, *Orcinus orca*
    - Genus *Peponocephala*
        - Melon-headed Whale, *Peponocephala electra*
    - Genus *Pseudorca*
        - False Killer Whale, *Pseudorca crassidens*
    - Genus *Sotalia*
        - Tucuxi, *Sotalia fluviatilis*
        - Costero, *Sotalia guianensis*
    - Genus *Sousa*
        - Pacific Humpback Dolphin, *Sousa chinensis*
        - Indian Humpback Dolphin, *Sousa plumbea*
        - Atlantic Humpback Dolphin, *Sousa teuszii*
    - Genus *Stenella*
        - Pantropical Spotted Dolphin, *Stenella attenuata*
        - Clymene Dolphin, *Stenella clymene*
        - Striped Dolphin, *Stenella coeruleoalba*
        - Atlantic Spotted Dolphin, *Stenella frontalis*
        - Spinner Dolphin, *Stenella longirostris*
    - Genus *Steno*
        - Rough-toothed Dolphin, *Steno bredanensis*
    - Genus *Tursiops*
        - Indian Ocean Bottlenose Dolphin, *Tursiops aduncus*
        - Common Bottlenose Dolphin, *Tursiops truncatus*
- Family Monodontidae
    - Genus *Delphinapterus*
        - Beluga, *Delphinapterus leucas*
    - Genus *Monodon*
        - Narwhal, *Monodon monoceros*
- Family Phocoenidae: Porpoises
    - Genus *Neophocaena*
        - Finless Porpoise, *Neophocaena phocaenoides*

        - Genus *Phocoena*
            - Spectacled Porpoise, *Phocoena dioptrica*
            - Harbour Porpoise, *Phocoena phocaena*
            - Vaquita, *Phocoena sinus*
            - Burmeister's Porpoise, *Phocoena spinipinnis*
        - Genus *Phocoenoides*
            - Dall's Porpoise, *Phocoenoides dalli*
    - Family Physeteridae: Sperm Whale family
        - Genus *Physeter*
            - Sperm Whale, *Physeter catodon* (syn. *P. macrocephalus*)
    - Family Kogiidae - MSW3 treats *Kogia* as a member of Physeteridae
        - Genus *Kogia*
            - Pygmy Sperm Whale, *Kogia breviceps*
            - Dwarf Sperm Whale, *Kogia sima*
    - **Superfamily Platanistoidea**: River dolphins
        - Family Iniidae
            - Genus *Inia*
                - Amazon River Dolphin, *Inia geoffrensis*
                    - Bolivian River Dolphin, *Inia boliviensis*
        - † Family Lipotidae - MSW3 treats *Lipotes* as a member of *Iniidae*
            - † Genus *Lipotes*
                - † Baiji, *Lipotes vexillifer*
        - Family Pontoporiidae - MSW3 treats *Pontoporia* as a member of *Iniidae*
            - Genus *Pontoporia*
                - La Plata Dolphin, *Pontoporia blainvillei*
        - Family Platanistidae
            - Genus *Platanista*
                - Ganges and Indus River Dolphin, *Platanista gangetica*. MSW3 treats *Platanista minor* as a separate species, with common names Ganges River Dolphin and Indus River Dolphin, respectively.
    - Family Ziphidae, Beaked whales
        - Genus *Berardius*
            - Arnoux's Beaked Whale, *Berardius arnuxii*
            - Baird's Beaked Whale (North Pacific Bottlenose Whale), *Berardius bairdii*
        - Subfamily Hyperoodontidae
            - Genus *Hyperoodon*
                - Northern Bottlenose Whale, *Hyperoodon ampullatus*

        - Southern Bottlenose Whale, *Hyperoodon planifrons*
    - Genus *Indopacetus*
        - Indo-Pacific Beaked Whale (Longman's Beaked Whale), *Indopacetus pacificus*
    - Genus *Mesoplodon*, Mesoplodont Whale
        - Sowerby's Beaked Whale, *Mesoplodon bidens*
        - Andrews' Beaked Whale, *Mesoplodon bowdoini*
        - Hubbs' Beaked Whale, *Mesoplodon carlhubbsi*
        - Blainville's Beaked Whale, *Mesoplodon densirostris*
        - Gervais' Beaked Whale, *Mesoplodon europaeus*
        - Ginkgo-toothed Beaked Whale, *Mesoplodon ginkgodens*
        - Gray's Beaked Whale, *Mesoplodon grayi*
        - Hector's Beaked Whale, *Mesoplodon hectori*
        - Layard's Beaked Whale, *Mesoplodon layardii*
        - True's Beaked Whale, *Mesoplodon mirus*
        - Perrin's Beaked Whale, *Mesoplodon perrini*. This species was recognised in 2002 and as such is listed by MSW3 but not Rice.
        - Pygmy Beaked Whale, *Mesoplodon peruvianus*
        - Stejneger's Beaked Whale, *Mesoplodon stejnegeri*
        - Spade Toothed Whale, *Mesoplodon traversii*
- Genus *Tasmacetus*
    - Tasman Beaked Whale (Shepherd's Beaked Whale), *Tasmacetus shepherdi*
- Genus *Ziphius*
    - Cuvier's Beaked Whale, *Ziphius cavirostris*

Chapter- 12

Freshwater Snail

Bithynia tentaculata, a small freshwater gastropod in the family Bithyniidae

Pomacea insularum, an apple snail

Planorbella trivolvis, and air-breathing ramshorn snail

A **freshwater snail** is one kind of freshwater mollusc, the other kind being freshwater clams and mussels, i.e. freshwater bivalves. Specifically a freshwater snail is a gastropod that lives in a non-marine or freshwater habitat. The majority of freshwater gastropods have a shell, with very few exceptions. Some groups of snails that live in freshwater respire using gills, other groups need to come up to the surface of the water in order to take in air to breathe.

The total number of Recent species of freshwater gastropods is about 4,000 (3,795-3,972).

Taxonomy

2005 taxonomy

The following cladogram is an overview of the main clades of gastropods based on the taxonomy of Bouchet & Rocroi (2005), with families that contain freshwater species marked in **boldface**: (Some of these highlighted families consist entirely of freshwater species, but some of them also contain, or even mainly consist of, marine species.)

Neritimorpha

Note: The numbers of species quoted in this overview refer to extant species only, in other words, extinct fossil species are not counted here.

- Neritiliidae, 5 freshwater species
- Neritidae, largely confined to the tropics, also the rivers of Europe, family includes the marine "nerites". There are about 110 freshwater species.

Family Neritidae, shells of *Theodoxus fluviatilis*.

Family Neritidae, *Neritina natalensis*

Caenogastropoda

These are freshwater snails with a gill and an operculum. In freshwater habitats there are ten major families, as well as other families of lesser importance:

Architaenioglossa

- Ampullariidae, an exclusively freshwater family that is largely tropical and includes the large "apple snails" kept in aquaria. 105-170 species.
- Viviparidae, medium to large snails, live-bearing, commonly referred to as "mystery snails". World wide except South America, and everywhere confined to fresh waters. 125-150 species.

Family Ampullariidae, *Pomacea bridgesii*.

Family Viviparidae, *Viviparus viviparus*.

Sorbeoconcha

- Melanopsidae, family native to rivers draining to the Mediterranean, also Middle East, and some South Pacific islands. About 25-50 species.
- Pachychilidae - 165-225 species. native to South and Central America. Formerly included with the Pleuroceridae by many authors.
- Paludomidae - about 100 species in south Asia, diverse in African Lakes, and Sri Lanka. Formerly classified with the Pleuroceridae by some authors.
- Pleuroceridae, abundant and diverse in eastern North America, largely high-spired snails of small to large size. About 200 species
- Semisulcospiridae, - primarily eastern Asia, Japan, also the *Juga* snails of northwestern North America. Formerly included with the Pleuroceridae.
- Thiaridae, high-spired parthenogenic snails of the tropics, includes those referred to as "trumpet snails" in aquaria. 135 species.

Family Pleuroceridae, *Io fluvialis*.

Family Semisulcospiridae, *Semisulcospira kurodai*.

Family Thiaridae, *Melanoides tuberculatus*.

Littorinimorpha

- Littorinidae - 2 species in the genus *Cremnoconchus* are freshwater living in waterfalls. Other species are marine.
- Amnicolidae - about 200 species.
- Assimineidae - about 20 freshwater species, other are marine
- Bithyniidae, small snails, native to Eastern Hemisphere. About 130 species.
- Cochliopidae - 246 species.
- Helicostoidae, the only species *Helicostoa sinensis* lives in China.
- Hydrobiidae, small to very small snails found world wide. About 1250 freshwater species other are marine.
- Lithoglyphidae - about 100 species.
- Moitessieriidae - 55 species.
- Pomatiopsidae, small amphibious snails scattered worldwide, most diverse in eastern and Southeast Asia. About 170 species.
- Stenothyridae - about 60 freshwater species, others are marine.

Clea helena, family Buccinidae.

Neogastropoda

- Buccinidae - 8-10 freshwater species in the genus *Clea*,native to Southeast Asia. Other Buccinidae are marine.
- Marginellidae - 2 freshwater species in the genus *Rivomarginella*, native to Southeast Asia. Other Marginellidae are marine.

Heterobranchia

Family Valvatidae, shells of *Valvata sibirica*, scale is in mm

Lower Heterobranchia

- Glacidorbidae - 20 species.

- Valvatidae, small low-spired snails referred to as "valve snails". 71 species.

Acochlidium fijiiensis is one of very few freshwater gastropods without a shell.
Acochlidiacea

- Acochlidiidae (including synonym Strubelliidae) - 5 shell-less species: *Acochlidium amboinense*, *Acochlidium bayerfehlmanni*, *Acochlidium fijiiensis*, *Palliohedyle sutteri* and *Strubellia paradoxa*
- Tantulidae - there is only one species which is shell-less *Tantulum elegans*.

Pulmonata, Basommatophora

Basommatophorans are pulmonate or air-breathing aquatic snails, characterized by having their eyes located at the base of their tentacles, rather than at the tips, as in the true land snails Stylommatophora. The majority of basommatophorans have shells that are thin, translucent, and relatively colorless, and all five freshwater basommatophoran families lack an operculum.

- Chilinidae, small to medium-sized snails confined to temperate and cold South America. About 15 species.
- Latiidae, small limpet-like snails confined to New Zealand. One or three species.
- Acroloxidae - about 40 species.
- Lymnaeidae, found worldwide, but are most numerous in temperate and northern regions. These are the dextral (right-handed) pond snails. About 100 species.
- Planorbidae, "rams horn" snails, with a worldwide distribution. About 250 species.
- Physidae, left-handed (sinistral) "pouch snails", native to Europe, Asia, North America. About 80 species.

Family Lymnaeidae, *Lymnaea stagnalis*.

Family Physidae, *Physella acuta*.

Family Planorbidae, *Planorbarius corneus*.

As human food

A dish of cooked freshwater nerites from the Rajang River, Sarawak, Malaysia

A dish of cooked freshwater snails, ampullariids and viviparids from Poipet, Cambodia

Several different snail species are eaten in Asian cuisine, including freshwater species.

Archaeological investigations in Guatemala have revealed that the diet of the Maya of the Classic Period (AD 250-900) included freshwater snails.

Aquarium snails

In the developed world, people encounter freshwater snails most commonly in aquaria along with tropical fish. Species available vary in different parts of the world. In the United States, commonly available species include ramshorn snails such as *Planorbella duryi*, apple snails such as *Pomacea bridgesii* and the high-spired thiarid malaysian trumpet snail *Melanoides tuberculata*.

Parasitology

Freshwater snails are widely known to be hosts in the lifecycles of a variety of human and animal parasites, particularly trematodes or "flukes". Some of these relations for prosobranch snails include *Oncomelania* in the family Pomatiopsidae as hosts of *Schistosoma*, and *Bithynia*, *Parafossarulus* and *Amnicola* as hosts of *Opisthorchis*. *Thiara* and *Semisulcospira* may host *Paragonimus*, and *Goniobasis* (older term including

Elimia, *Juga* and other small high-spired pleurocerid snails) may host *Nanophyetus salmincola*. Basommatophoran snails are even more widely infected, with many *Biomphalaria* (Planorbidae) serving as hosts for *Schistosoma mansoni*, *Fasciolopsis* and other parasitic groups. The tiny *Bulinus* snails are hosts for *Schistosoma haematobium*. Lymnaeid snails (Lymnaeidae) serve as hosts for *Fasciola* and the cerceriae causing swimmer's itch.

it is worth pointing out that snail-vectored parasites of humans can also be considered to be human-borne parasites of snails; humans are much more likely to carry and spread exotic diseases over long distances than snails are.