Introduction

How does one go about designing an enclosure for amphibians? Considering the variability of species in the class amphibia, it is not as simple as providing them a wet area and a dry area. One must understand the special needs of an amphibian, and biologically what is required from the environment. The natural behavior of the animal in the wild is also of concern. Meeting biological and behavioral needs must be the primary goal of any enclosure/exhibit design. Certain topics are important to all amphibians including enclosure materials, lighting, heating/cooling, humidity/water source, ventilation, substrate, and plants. From a health standpoint, the environment and the diet, when appropriately maintained, should be the two subjects given the most consideration to prevent medical problems.

Amphibian Classification

The word amphibian comes from the Greek word *amphibios*, which means double life. This applies to the animals in the class amphibia, as they require water and/or land environments for survival at one or more stages of their life cycle. Once the adult stage has been attained, the animal may be amphibious, terrestrial, or aquatic. The age of the animals, and whether breeding will be attempted, must factor into the design of the exhibit.

The class amphibia is divided into three major orders:

Gymnophiona (or Apoda)(caecilians).

The order Gymnophiona consists of elongated, limbless amphibians. They are found in equatorial regions of Southeast Asia, Central Africa, and South America. Caecilians inhabit environments near streams in loose, moist soil. Most are burrowers that rarely immerge from the soil, which makes them less appropriate for zoo exhibit displays. Some are aquatic. Caecilians are opportunistic feeders, consuming earthworms, termites, and orthopterans. All caecilians reproduce via internal fertilization; and eggs are layed near streams or are buried.

Urodela (or Caudata)(salamanders, newts)

The order Urodela consists of the tailed amphibians that inhabit North America, northern South America, Asia, Europe, and northern Africa. In general, these amphibians are nocternal and live in temperate climates in cool, shady areas. Urodelans cannot tolerate hot, dry conditions, and will become inactive in cold temperatures. They are generally carnivorous feeders that catch their prey from the cover of a hiding area. Their diet consists of fish, smaller salamanders, insects, and worms. Most reproduce via internal fertilization, and egg laying locations vary.

Anura (or Salientia)(frogs, toads)

The Anurans are tailless amphibians distributed on all continents except Antarctica, surviving in most environments except polar regions and extremely dry deserts. Approximately 80% of frogs and toads are found in tropical and subtropical regions. Anurans tend to be mainly terrestrial, although exceptions do occur. African clawed frogs and Surinam toads, both of the Pipidae family, are entirely aquatic. Anurans are carnivorous as adults, and depending on the species, will consume a variety of insects, invertebrates, and fish, and may be cannibalistic. Fertilization is mostly external, and breeding may be triggered by changes in daylight, temperature, and rainfall.

Amphibian Biology/Physiology

Characteristics of amphibian biology must be considered in order to provide suitable living environments. Of significant importance is amphibian skin. This structure is highly dynamic and serves many vital functions including gas exchange, absorption and excretion of electrolytes, hydrostatic maintenance, temperature regulation, and sensory functions. Amphibians have no physiological ability to control evaporation of body water on land. Therefore, water and humidity become significant factors when developing amphibian environments. The absorption of solutes through the skin becomes an important medical concern when the solutes are toxins like ammonia or urea, which will build up in poorly maintained environments.

Physiologically, amphibians are ectotherms, relying on the environmental temperature to maintain body temperature. Each species has a Preferred Optimal Temperature Zone (POTZ). In general, temperature gradients should be offered to the animal so it can maintain an optimum body temperature. Researching individual species needs, prior to environment design, is required. Tropical species require temperatures of 70–85 F (21–29 C); temperate species 65–72 F (18–22 C). Seasonal drops in temperature may be required by some species. The POTZ of amphibians tends to be cooler than those appreciated by most reptiles. If an animal spends all of its time in one temperature zone, there may be a problem with the gradient offered. The gradient should be adjusted to allow the amphibian to use the gradient more efficiently for temperature maintenance.

Environment Design

From a zoo collection perspective, environmental design will vary greatly. An enclosure may be a relatively sterile container providing the bare essentials of an animal's needs. Or the enclosure may be an elaborate, naturalistic vivarium, which is pleasing to view and more enriching for the animal. The minimal environment is easy to maintain, while the vivarium will be complex and more intense to manage. Either way, husbandry requirements will be similar to both.

Enclosure Materials

Enclosures may be constructed from a variety of materials including glass, plastic, wood and metal. Cages may be ordered prefabricated or constructed on site. Consideration must be given to the ease of cleaning and the ability of the materials to withstand a humid or aquatic environment. In situations where the animal will be on display, transparent materials need to be used. Therefore, glass and plastic materials constructed with silicon sealant are commonly used for exhibit construction. These materials allow for construction of any shape or size, incorporation of dividers and shelves, and compartments for pumps and filters if needed. If enclosures are designed to incorporate a removable lid, items of consideration include ventilation, secure closure to prevent animal escape and escape of the food items like insects or mice, and the ability to place heat and light sources above the lid. The appropriate sized wire mesh lid can address these concerns.

Substrates

The materials within the enclosures will vary, again dependent on the minimal versus elaborate environment, and whether the animal is arboreal, terrestrial, or fossorial. Amphibians kept off exhibit in plastic boxes may only require moist paper toweling. Vivariums may be constructed using combinations of sand, gravel, pebbles, potting soil, peat moss, wood or bark chips, leaf litter, artificial turf, or foam rubber as a space occupier. The selection of these materials will depend on the natural environment of the individual species of amphibian. Due to the need for humidity in the environment, substrates should stay moist for a period, and then dry out; at which time, it may be moistened again. Chronic soggy substrate or unwanted pools should be prevented.

Lighting

Amphibians in general prefer subdued lighting. But appropriate levels of light must be provided to separate light/dark cycles, and to provide for live plants if present. Feeding routines and reproductive cycles may be governed by light cycles. Having the lighting on an automated timer allows for consistent cycling. The amount of light versus dark time will need to be adjusted for annual changes to induce breeding of many species. Fluorescent bulbs that provide full spectrum light are preferable in most situations. Metabolic and behavioral improvement have been noted when appropriate wavelengths of light are present in the environment. Calcium and Vitamin D metabolism is well known to improve when appropriate levels of UVB radiation are provided.

Heating/Cooling

Temperature maintenance of aquatic environments tends to be relatively easy to achieve. Water heaters or chillers can be placed into the enclosure, or incorporated into the water filtration system. Terrestrial environments may be heated in one or more ways. Under-tank heating devices are commonly used, usually only heating a portion of the enclosure to allow

for a temperature gradient. Incandescent bulbs will provide heat to a focal area, but can only be used during the 'day' part of the light cycle. Ceramic heating elements may be used for focal heat. These can be used throughout the light/dark cycle, as they do not emit light during use. Infrared bulbs may also be used for non-light heat. The latter two sources may be inappropriate due to the potential for extreme heat production, and the increased chance of dehydration of the amphibian. Forced air heating may be found in very large exhibits. Any heating device should be incorporated into a thermostatic device system to allow regulation of the environmental temperature. Day and night temperature variance may be required with certain amphibian species. Seasonal alteration of temperature may also be required, especially in those species that estivate or hibernate prior to the next breeding season.

Humidity

Because amphibians have no physiologic control over evaporative water loss, humidity is an essential aspect of the environment. Hygrometers should be present in the enclosure to monitor the relative humidity. The degree of humidity is a direct relationship between temperature and the amount of ventilation. For example, at a constant temperature, humidity can be controlled by changing the amount of ventilation. Humidity can be provided by a number of means. Heated pools, running water, waterfalls, rainmakers, misters, and foggers are all mechanisms for providing humidity to an exhibit. The rainmakers, misters, and foggers can be equipped with timers to simulate periodic precipitation. Evaporation will occur, so these devises should be checked periodically to be sure that the needed water is available to run them.

Ventilation

Ventilation to the enclosure will help control temperature and humidity, as well as ensure fresh airflow. Access for ventilation should be incorporated into the upper and lower areas of the enclosure, if possible. Ventilation ports should be adjustable and covered with a material, fine screen mesh for example, to prevent escape of the animals. As the enclosure is heated, the warmer air will rise, drawing fresh air in from the lower vents. Aquatic enclosures should include water aerating devices.

Vegetation

Planting a vivarium has a two-fold benefit. The plants, if well chosen and cared for, enhance the appearance if the enclosure, and complement the amphibian inhabitants. Vegetation provides hiding places and climbing opportunities. Plants will also maintain the humidity in the enclosure. Additionally, vegetation may also be an indicator of the health of the environment. Plants to be selected must be able to survive the environment in which they will be placed, and must be non-toxic. Vegetation may be planted directly into the soils of the vivarium, or may be maintained in buried pots. Potted plants are best if the amphibians burrow. Below is a list of plants suitable for vivariums. Each plant must be cross-referenced with the expected amphibian inhabitants to be sure they are compatible. In the event one does not have a 'green thumb,' artificial vegetation may be utilized.

Abelia	Bridal Veil	Hibiscus	Petunia
African Violet	Bougainvillea	Iceplant	Spineless Cacti
Areca Palm	Bromeliads	Impatiens	Swedish Ivy
Asparagus Fern	Camellia	Jasmine	Sweet Asylum
Aster	Coleus	Lavender	Wandering Jew
Baby Tears	Dracaena	Marigold	
Bird's Nest Fern	Grass	Palms	

Cool, moist conditions	Small ferns (*Asplenium*), Ivies, Club Mosses (*Salaginella*)
Cool, wet conditions	Sedges (*Carex*), Creeping Jenny (*Lysimachia nummularia*), Aroid (*Acoris gramineus*), Bladderworts (*Utricularia*), Butterworts (*Pinguicula*)
Warm, dry conditions	Houseleeks (*Sempervivum*), Stonecrops (*Sedum*)
Warm, moist conditions	Peace Lily (*Spathiflium*), Hare's Foot, Flamingo Flower (*Anthurium*), Philodendron, Orchids (*Odontoglossum, Oncidium, Masdevallia, Pleurothallus, Coelogyne*), Bromeliads
Warm, wet conditions	Java moss (*Vesicularia dubyana*), Tree Fern Root, Mosses

Diet

Appropriate nutrition is essential to health. Numerous insects and other invertebrates make up the fare of amphibian menus (see below). Individual amphibian species should be assessed for the appropriate foodstuff. Insects should be 'gut loaded' and vitamin supplemented prior to being fed out. Commercial insect feed, chick mash, and vegetables may be fed as gut load to the insects to improve their nutritional value. Commercial vitamin supplement powders may be used to coat the insects prior to feeding to amphibians. Feeding small amounts frequently may be better than large amounts infrequently. Remove uneaten food, as uneaten insects may prey upon the amphibians designated to eat them. Be aware that some amphibians are cannibalistic, therefore they may need to be housed individually, especially if various ages and sizes of amphibians are housed together.

Aphids	Cockroaches	Goldfish	Millipedes	Tubiflex worms
Beetles	Crickets	Grubs	Pillbugs	Waxworms
Butterworms	Earthworms	Houseflies	Spiders	
Centipedes	Fruit Flies	Mealworms	Spring Tails	Cannibalism