AMPHIBIAN LIFE CYCLES

ANURA (Greek) / SALIENTIA (Latin): Frogs

Nearly worldwide except few above Arctic Circle and none in Antarctica; 45 families, 5450+ species.

URODELA / CAUDATA: Salamanders

Mostly north temperate; Plethodontidae to the Amazon Basin; 9 families, 560+ species (378 of which belong to the Plethodontidae)

GYMNOPHIONA / APODA: Caecilians

Worldwide in tropics except Madagascar and Oceania; 6 families, ca. 170 species

SEASONALITY

Primary Cues: Induce production and release of reproductive hormones and responsiveness of target organs

Temperature

Moisture

Day Length

Some amphibians, especially in temperate zones, have definite reproductive seasons (late winter/early spring, summer, fall), especially in temperate areas

Some amphibians, especially in aseasonal tropical environments, breed year-round, although breeding may be more intense in periods of greater or lesser precipitation or, possibly, longer day length

Most species bred once a year, but some bred only every other year

MATE ATTRACTION and RECOGNITION

ANURA

Females attracted to species-specific call of males

Primary recognition by females associated with call of male; primary recognition by males associated with female behavior

URODELA

Recognition based on olfactory cues and courtship rituals

GYMNOPHIONA

Unknown
FERTILIZATION

EXTERNAL
1. Most frogs: Amplexus - inguinal (waist; ancestral), axillary (behind foreleg, cephalic, others (e.g., no amplexus)
2. A few salamanders (Cryptobranchidae, Hynobiidae)

INTERNAL
1. A few frogs: Hylidae - (e.g., Bufo calamita in Africa; Phyllomedusa bicolor in South America)
2. Most salamanders - Spadephores
3. Caecilians - phalodeum (modified cloaca)

A "TYPICAL" LIFE CYCLE - occurs in Anura, Urodela, Gymnophiona

ADULT MALE

ADULT FEMALE

EGGS may be laid on land or in water

Hatch

AQUATIC LARVAE

(Feeding)

Metamorphosis

JUVENILES

Growth

Notophthalmus viridescens (Salamandridae) LIFE CYCLE
High - Elevation Populations

ADULT MALE

ADULT FEMALE

EGGS laid in water

Hatch

AQUATIC LARVAE

(Feeding)

Metamorphosis I

TERRESTRIAL EFT

(Non-Reproductive)

Metamorphosis II

Growth
**“Typical” Life Cycle with Non-Feeding Terrestrial Larvae**

occurs in some Anura

- **ADULT MALE**
- **ADULT FEMALE**
- **EGGS laid on land**
- **Hatch**
- **TERRESTRIAL LARVAE**
  - Non-Feeding
  - Metamorphosis
- **JUVENILES**
  - Growth

**Direct Development Life Cycle**

- **ADULT MALE**
- **ADULT FEMALE**
- **EGGS laid on land**
- **Hatch**
- **TERRESTRIAL JUVENILES**
  - Growth

**Live-Bearing Life Cycle (Oovoviviparity/Viviparity)**

occurs in Anura, Urodela, Gymnophiona

- **ADULT MALE**
- **ADULT FEMALE**
- **Birth in water or on land**
- **JUVENILES**
  - Growth
PARTHENOGENESIS

Parthenogenesis is a form of unisexual (not asexual) reproduction. All individuals in a population or a species are female, and all are reproductive as adults.

Females produce eggs which develop mitotically without fertilization.

Parthenogenesis may be obligate (permanent) or facultative (individuals belonging to a population or an entire species may reproduce parthenogenetically but, in response to environmental cues, may begin to produce both male and female offspring which reproduce sexually).

Known to occur in many invertebrates, as well as some fishes, lizards and snakes. Suspected in salamanders (Ambystoma jeffersonianum complex [Ambystomatidae]) and frogs (XXX esculenta complex [Ranidae]). Has been artificially induced in mammals (rabbits) and birds (turkeys).

KLEPTOGENETIC LIFE CYCLE - occurs in Urodela e.g., Ambystoma jeffersonianum Complex (Part) (Ambystomatidae) and in the Pelophylax esculenta group (Ranidae) of frogs in Europe

HYDRIDOGENETIC LIFE CYCLE - occurs in Anura and Urodela e.g., Pelophylax [Rana] esculenta Complex (Ranidae) Ambystoma jeffersonianum Complex
HETEROCHRONY

“Shape arises from differential growth within a structure” (Vitt and Caldwell 2008, p. 37).

Heterochrony is a change in the timing and/or rate of growth of a trait relative to that in the ancestral taxon.

Several patterns of heterochrony are recognized (Reilly et al. 1997) and two are emphasized here:

1. Paedomorphosis
2. Paedogenesis

Both occur in taxa in which sexual maturity is achieved while larval characteristics are retained.

PAEDOMORPHOSIS

This is an interspecific process and reflects change over evolutionary time. Comparison is made between the paedomorphic taxon and its immediate non-paedomorphic ancestor. It is irreversible in the short term (i.e., full metamorphosis does not occur).

Examples include salamanders in the families Siren and Proteidae, and Ambystoma mexicanum (the Axolotl; Ambystomatidae). It also occurs in several genera of salamanders in the family Plethodontidae.

Caecilians and salamanders in the families Amphiumidae and Cryptobranchidae, as well as some species in the family Salamandridae, exhibit some paedomorphic traits although their morphology is not so fully larval as the taxa cited above.

PAEDOGENESIS

This is an intraspecific process and reflects change over ecological time.

Individuals within populations of a species retain larval characteristics while achieving sexual maturity, and may or may not metamorphose into a “fully adult” stage, depending on environmental conditions.

Examples include some, but not all, populations of Ambystoma talpoideum, populations of Ambystoma tigrinum in the Great Plains and at higher elevations in the Rocky Mountains, and Ambystoma gracile in northwestern United States and southwestern Canada.
I PAEDOMORPHIC and PAEDOGENETIC LIFE CYCLE - occurs in some Urodela

![Diagram of life cycle]

* "LARVA" MALE (Sexually Mature)*
* "LARVA" FEMALE (Sexually Mature)*

EGGS → Hatch → AQUATIC LARVAE (Feeding) → Growth and Development

* In some populations of some species, "adulthood" may be controversial.

PARENTAL CARE

Parental care occurs in Anura, Urodela, and Gymnoophiona and there are a wide variety of types. Among these are:

A. Construction of nests (e.g., Physalaemus (Lanaranterid), Hyla boans (Hylidae), many salamanders, some caecilians)
B. Guarding of eggs, or eggs and larvae, by the male or female parent (e.g., some hylid frogs, Physalaemus altiviridis (Lanaranteridae), many salamanders, some caecilians)
C. Carrying of the eggs on or in the body of the parent (e.g., Physalaemus (Lanaranteridae), many salamanders, some caecilians)
D. Carrying of the tadpoles on or in the body of a parent (e.g., Pipa Pipa (Pipidae), many salamanders, some caecilians)
E. Carrying of the eggs, tadpoles and, in a few species, newly metamorphosed young on the body of a parent (e.g., Hemiphractus (Hemiphractidae), many salamanders, some caecilians)

REFERENCES


<table>
<thead>
<tr>
<th>Slide</th>
<th>Image</th>
<th>Taxon</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>a</td>
<td>Atelopus varius (Bufonidae)</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>Plethodon jordani (Plethodontidae)</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Dermophis mexicanus (&quot;Caeciliidae&quot;)</td>
</tr>
<tr>
<td>3</td>
<td>a</td>
<td>Anaxyrus americanus (Bufonidae)</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>Anaxyrus bufo (Bufonidae)</td>
</tr>
<tr>
<td>4</td>
<td>a</td>
<td>Ascaphus montanus (Leiopelmatidae)</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>Pyxicephalus adspersa (Pyxicephalidae)</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Cryptobranchus alleganiensis (Cryptobranchidae)</td>
</tr>
<tr>
<td>6</td>
<td>a</td>
<td>Notophthalmus viridescens (Salamandridae) - Adult</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>Notophthalmus viridescens (Salamandridae) - Eft</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>Plethodontohyla inguinalis (Microhylidae)</td>
</tr>
</tbody>
</table>

KEY TO SPECIES APPEARING ON SLIDES
Continued

<table>
<thead>
<tr>
<th>Slide</th>
<th>Image</th>
<th>Taxon</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>a</td>
<td>Hemidactylium scutatum (Plethodontidae)</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>Plethodon yonahlossee (Plethodontidae)</td>
</tr>
<tr>
<td></td>
<td>c</td>
<td>Elsetherodactylus coqui (Brachycephalidae)</td>
</tr>
<tr>
<td>9</td>
<td>a</td>
<td>Typhlonectes natans (Typhlonectidae)</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>Elsetherodactylus jasperi (Brachycephalidae)</td>
</tr>
<tr>
<td></td>
<td>c</td>
<td>Salamandra salamandra (Salamandridae)</td>
</tr>
<tr>
<td>11</td>
<td>a</td>
<td>Ambystoma jeffersonianum (Ambystomatidae)</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>Ambystoma laterale (Ambystomatidae)</td>
</tr>
<tr>
<td>12</td>
<td>a</td>
<td>Pelophylax esculentus (Ranidae)</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>Pelophylax lesseae (Ranidae)</td>
</tr>
<tr>
<td></td>
<td>c</td>
<td>Pelophylax ridibunda (Ranidae)</td>
</tr>
<tr>
<td>16</td>
<td>a</td>
<td>Siren intermedia (Sirenidae)</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>Necturus maculosus (Proteidae)</td>
</tr>
</tbody>
</table>

KEY TO SPECIES APPEARING ON SLIDES
Continued

<table>
<thead>
<tr>
<th>Slide</th>
<th>Image</th>
<th>Taxon</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>a</td>
<td>Chiromantis xeramplina (Rhacophoridae)</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>Chiromantis xeramplina (Rhacophoridae) – Egg Mass</td>
</tr>
<tr>
<td></td>
<td>c</td>
<td>Ambystoma maculatum (Ambystomatidae)</td>
</tr>
<tr>
<td></td>
<td>d</td>
<td>Alytes cisternasi (Alytidae)</td>
</tr>
<tr>
<td></td>
<td>e</td>
<td>Gastrotheca piperata (Amphignathodontidae)</td>
</tr>
<tr>
<td></td>
<td>f</td>
<td>Pipa pipa (Pipidae)</td>
</tr>
<tr>
<td></td>
<td>g</td>
<td>Dendrobates pumilus (Dendrobatidae)</td>
</tr>
<tr>
<td></td>
<td>h</td>
<td>Rhinoderma darwinii (Cycloramphidae)</td>
</tr>
</tbody>
</table>

\(^{1}\) a and b – top left and right, respectively, etc.