FOCUS QUESTIONS

- What are some examples of amphibians and what roles do amphibians play in their ecosystems?
- What makes the skin of amphibians so unique among terrestrial vertebrates?
- What is captive breeding and what role does it play in the conservation of endangered species?
- How does an individual develop adaptive immunity to a disease?
- What role does genetic diversity play in the ability of a population to survive in a rapidly changing environment?

OVERVIEW

"To be able to apply the tools we have developed to conserve these species, it's a very important contribution for amphibian conservation. My vision for amphibians is to see them thrive again." Dr. Gina Della Togna, Reproductive Physiologist and Research Associate, Smithsonian's Tropical Research Institute

In ***The Frog Ark*** we learn about the chytridiomycosis pandemic and its devastating effects on hundreds of amphibian species worldwide, especially frogs. We meet reproductive physiologist, Dr. Gina Della Togna, who helps run a captive breeding program for imperiled tropical frog species called The Ark. As climate change, habitat destruction, and disease continue to ravage amphibian populations throughout the world, scientific efforts like those taking place at The Ark provide hope for populations of species like the Panamanian Golden Frog (*Atelopus zeteki*) that are currently threatened with extinction.

KEY CONCEPTS

- Threatened and Endangered Species: The International Union for the Conservation of Nature (IUCN) lists more than 44,000 species threatened with extinction. Habitat loss and destruction and agriculture are the major threats for more than 85% of these species. The IUCN also lists disease as a major factor contributing to the endangerment of species and the overall loss of biodiversity.
- Biodiversity: The global trade of amphibians coupled with human development have removed the natural barriers to the spread of wildlife diseases that threaten Earth's biodiversity. Scientists have now recorded the decline of over 500 amphibian species since 1970, including nearly 100 presumed extinctions.
- Genetic diversity: The captive populations of frogs being reared in The Ark are small and are at risk of genetic drift which can cause the random loss of genetic diversity. The Ark scientists search for frogs still living in the wild that may have alleles that provide resistance to the chytrid disease and breed them with the captive frogs to increase their genetic diversity.
- Food webs: Frogs play a vital role in food webs as both predators and prey, with tadpoles consuming algae and aquatic insects, and adult frogs eating invertebrates, including the insect pests of agricultural systems. Frogs also serve as prey for various animals like snakes, birds, and fish. The loss of global frog populations, including those in tropical habitats, disrupts food web functioning.
- Indicator species: The presence or absence of certain species can indicate the condition of a specific environmental variable, serving as a proxy to assess the health of an ecosystem. Tropical frogs are considered indicator species because their highly permeable skin and eggs make them extremely sensitive to environmental changes, acting as early warning signs for ecosystem health issues like pollution, habitat destruction, and climate change.
- Conservation biology: The practice of conservation biology recognizes the intrinsic value of the Earth's natural diversity of organisms. Conservation biology works to understand how the natural world operates, how humans affect nature, and how we can use collective scientific and cultural knowledge to conserve Earth's biological diversity.
- Captive breeding: Breeding animals in a controlled environment, like zoos or conservation facilities, can protect species from extinction, enhance their health, and potentially lead to reintroduction to the wild.

The captive breeding program we learn about in ***The Frog Ark*** creates an indoor artificial rainforest where the air is kept cool and moist and the frogs are exposed to just the right amount of UV light for healthy bone development.

BACKGROUND

Chytridiomycosis, or chytrid for short, is a skin disease of amphibians caused by the fungal pathogen *Batrachochytrium dendrobatidis* (*Bd*). Chytrid has led to the decline and extinction of hundreds of amphibian species worldwide, particularly in tropical montane regions. The chytrid pandemic was first recognized in the late 20th century, with mass die-offs observed in Queensland (Australia) and Panama (Central America). Research linked these declines to *Bd*, which causes a skin condition called epidermal hyperplasia and hyperkeratosis (excessive skin growth and thickening). The skin of amphibians is unique among terrestrial vertebrates because it allows for the exchange of carbon dioxide and oxygen and is critical in maintaining osmotic balance. When amphibians are infected with *Bd* and are suffering from chytrid, the inability to regulate water movement through their permeable skin can quickly lead to heart failure.

The spread of *Bd* has been attributed to globalization, the pet trade, and climate change, all of which may have facilitated its transmission across continents. The chytrid disease has caused catastrophic losses in biodiversity, particularly in high-elevation tropical regions, where species have little resistance to infection and where climate change is forcing cloud forest species like frogs to higher elevations while also allowing *Bd* to move into those habitats. Scientists have now recorded the decline of over 500 amphibian species since 1970, including nearly 100 presumed extinctions. Fortunately, there are efforts to mitigate the impact of chytrid, including captive breeding programs.

In ***The Frog Ark*** film we learn about a captive breeding program for imperiled tropical frog species, some of which are extinct in the wild. Reproductive physiologist, Dr. Gina Della Togna of the Smithsonian's Tropical Research Institute, and her colleagues have been working for several years to rear frogs, many of which are extinct in the wild. The scientists use a series of shipping containers to create indoor artificial rainforests where the air is kept cool and moist and the frogs are exposed to just the right amount of UV light for healthy bone development. In the artificial environments and the labs that adjoin them the scientists are running experiments to develop methods for conserving the frogs. In one experiment the researchers carefully expose the frogs to the chytrid pathogen to help individual frogs slowly develop resistance to the disease using the adaptability of their own immune systems. At the same time, the scientists are searching for individuals in the wild that may already be preadapted to manage the disease and breeding them with individuals of the same species that are part of the captive breeding program. This approach helps reduce the likelihood of a loss of genetic diversity through genetic drift while also introducing new, better adapted alleles to the captive populations. As climate change, habitat destruction, and disease continue to ravage amphibian populations throughout the world, scientific efforts like those taking place at The Ark provide hope for populations of species that are threatened with extinction. Species like the Panamanian Golden Frog (*Atelopus zeteki*) that currently only exists in captivity, may once again have a self-sustaining population in the wild.

BIODIVERSITY THREATS

The major threats to the Earth's biodiversity can be grouped into seven categories that spell the easily recalled acronym H.I.P.P.O.: **H**abitat destruction and fragmentation, **I**ntroduced species, **P**ollution, **P**opulation growth, and **O**verharvesting. Many species are threatened by a combination of these factors, but habitat loss is the greatest threat to biodiversity. In ***The Frog Ark*** we learn that introduced species can also include diseases and that new diseases can ravage populations of species that have never developed specific resistance to those diseases. Climate change and habitat loss can also exacerbate the effects of a disease on populations.

DISCUSSION QUESTIONS

- [Before showing the film] Have students brainstorm what they know about endangered and threatened species and how captive breeding programs have helped conserve wild populations of many species. Ideas for students to think about could include the California Condor (*Gymnogyps californianus*), the Black-footed Ferret (*Mustela nigripes*), the Golden Lion Tamarin (*Leontopithecus rosalia*), and the Red Wolf (*Canis rufus*).
- [Before showing the film] Explain to students that the extinction of species is a natural evolutionary process. Have students discuss the reasons for conserving species of animals and plants that are currently threatened with extinction.
- In the film we learn that the fungal pathogen *Batrachochytrium dendrobatidis* (*Bd*) causes a skin disease in amphibians called chytridiomycosis (chytrid). Have students research common fungal skin infections in humans and discuss why human fungal skin infections are likely not deadly while chytrid in amphibians can be.
- Ask students to explain the meaning of the word *pandemic* and explain why the chytrid disease qualifies as a pandemic for amphibians.
- Ask students to identify which of the H.I.P.P.O. threats best describes the chytrid disease and which of the threats has made the disease even more deadly for amphibians, especially tropical montane frog species.
- ***The Frog Ark*** film does not explicitly discuss genetic drift and artificial gene flow but both processes play a role in the frog captive breeding program. Have students discuss why the researchers need to have at least 300 individuals in each of their captive populations (small populations like the captive frogs are at risk of losing genetic diversity through genetic drift). Have students also discuss how bringing wild frogs into the captive population is an example of artificial gene flow and how the strategy of assisted reproductive technology might help increase genetic diversity and help the captive population adapt to the chytrid disease.

Curriculum Connections

NGSS

HS-LS2 Ecosystems: Interactions, Energy, and Dynamics

- LS2.A: Interdependent Relationships in Ecosystems
- LS2.C: Ecosystem Dynamics, Functioning, and Resilience
- LS4.D: Biodiversity and Humans

HS-LS3 Heredity: Inheritance and Variation of Traits

- LS3.A: Inheritance of Traits
- LS3.B: Variation of Traits

HS-LS4 Biological Evolution: Unity and Diversity

- LS4.B: Natural Selection
- LS4.C: Adaptation

ETS1.B: Developing Possible Solutions

AP Biology (2021)

Enduring Understandings

- Evolution (EVO)
    - EVO-1: Evolution is characterized by a change in the genetic makeup of a population over time and is supported by multiple lines of evidence.
    - EVO-3: Life continues to evolve within a changing environment.
- Energetics (ENE)

    - ENE-3: Timing and coordination of biological mechanisms involved in growth, reproduction, and homeostasis depend on organisms responding to environmental cues.
    - ENE-4: Communities and ecosystems change on the basis of interactions among populations and disruptions to the environment.
- Information Storage and Transmission (IST)
    - IST-1: Heritable information provides for continuity of life.
    - IST-2: Differences in the expression of genes account for some of the phenotypic differences between organisms.
- Systems Interactions (SYI)
    - SYI-1: Living systems are organized in a hierarchy of structural levels that interact.
    - SYI-3: Naturally occurring diversity among and between components within biological systems affects interactions with the environment.

IB Biology (First Exam May 2025)
A. Unity and Diversity: Common ancestry has given living organisms many shared features while evolution has resulted in the rich biodiversity of life on Earth.

- A1.1 Water
- A3.1 Diversity of organisms
- A4.2 Conservation of biodiversity

B. Form and Function: Adaptations are forms that correspond to function. These adaptations persist from generation to generation because they increase the chances of survival.

- B3.1 Gas exchange
- B4.1 Adaptation to environment
- B4.2 Ecological niches

C. Interaction and Interdependence: Systems are based on interactions, interdependence and integration of components. Systems result in emergence of new properties at each level of biological organization.

- C3.2 Defence against disease
- C4.1 Populations and communities

D. Continuity and Change: Living things have mechanisms for maintaining equilibrium and for bringing about transformation. Environmental change is a driver of evolution by natural selection.

- D3.1 Reproduction
- D3.2 Inheritance
- D3.3 Homeostasis
- D4.1 Natural selection
- D4.2 Stability and change
- D4.3 Climate change

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CREDIT

Written by Paul K. Strode, Ph.D., Fairview High School, Boulder, Colorado