Big Idea 2:

Biological systems utilize free energy and molecular building blocks to grow, to reproduce and to maintain dynamic homeostasis.

Enduring Understanding 2.E:

Many biological processes involved in growth, reproduction and dynamic homeostasis include temporal regulation and coordination.

Learning Objectives:

Essential Knowledge 2.E.2: Timing and coordination of physiological events are regulated by multiple mechanisms.

– (2.35) The student is able to design a plan for collecting data to support the scientific claim that the timing and coordination of physiological events involve regulation.
– (2.36) The student is able to justify scientific claims with evidence to show how timing and coordination of physiological events involve regulation.
– (2.37) The student is able to connect concepts that describe mechanisms that regulate the timing and coordination of physiological events.

Essential Knowledge 2.E.3: Timing and coordination of behavior are regulated by various mechanisms and are important in natural selection.

– (2.38) The student is able to analyze data to support the claim that responses to information and communication of information affect natural selection.
– (2.39) The student is able to justify scientific claims, using evidence, to describe how timing and coordination of behavioral events in organisms are regulated by several mechanisms.
– (2.40) The student is able to connect concepts in and across domains to predict how environmental factors affect responses to information and change behavior.

Required Readings:

Ch. 39 (pp. 831; 825-826; 839-840; 833-834);
Ch. 11 (pp. 207);
Ch. 51;
Ch. 54 (pp. 1198-1203);
Ch. 41 (pp. 649-650);
Ch. 36 (pp. 766-767);
Ch. 41 (pp. 892);

Practicing Biology Homework Questions:

Questions #47-49

Essential Knowledge 2.E.2: Timing and coordination of physiological events are regulated by multiple mechanisms.

Multiple mechanisms regulate the timing and coordination of molecular, physiological and behavioral events that are necessary for an organism’s development and survival. For example, programmed cell death (apoptosis) plays a role in normal development and differentiation (i.e., morphogenesis). Physiological events in organisms can involve interactions between environmental stimuli and internal molecular signals; phototropism and photoperiodism in plants and circadian rhythms and seasonal responses in animals are examples.

STUDY TIP

When reviewing this section of notes, students are encouraged to focus on how a particular physiological or behavioral event is regulated, triggered, responded to, and related to the overall fitness of a group of individuals.
In plants, physiological events involve interactions between **EXTERNAL** environmental stimuli and **INTERNAL** molecular signals. **Illustrative examples** include: seed germination, phototropism, photoperiodism, and flower development.

**Seed Germination in Plants:** [http://www.indiana.edu/~oso/animations/barley.html](http://www.indiana.edu/~oso/animations/barley.html)

Signal transmission within and between cells mediates gene expression in both plants and animals. Many seeds break dormancy and germinate **only when** the light in the environment is near optimal. Temperature is also a factor in seed germination as chemical and metabolic processes are sped up at higher temperatures.

- In addition to light availability and temperature, germination in plant seeds depends on **imbibition**, the uptake of water due to low water potential of a dry seed.
- Imbibing water causes the embryo to release gibberellins, a hormone that triggers the seed to expand and rupture its coat and also triggers metabolic changes in the embryo that enable it to resume growth after dormancy.
- **NOTE:** gibberellins are a hormone – when released they signal a transduction pathway that leads to cellular response.
- Following hydration, enzymes begin digesting the storage materials of the endosperm or cotyledons, and the nutrients are transferred to the growing regions of the embryo.
- **HOW IS THIS EVENT REGULATED? WHY IS REGULATION IMPORTANT TO THE OVERALL SURVIVAL OF THIS GROUP OF ORGANISMS?**

**Phototropism in Plants:** [http://bcs.whfreeman.com/thelifewire/content/chp38/3802001.html](http://bcs.whfreeman.com/thelifewire/content/chp38/3802001.html)

The growth of a shoot toward light or away from it is called **phototropism**. Auxin is responsible for phototropism due to an unequal distribution of the hormone along the stem of the plant. Plant stems bend toward light as a result of increased cell elongation on the side of the stem away from the light source. **HOW IS THIS EVENT REGULATED? WHY IS REGULATION IMPORTANT TO THE OVERALL SURVIVAL OF THIS GROUP OF ORGANISMS?**

**Photoperiodism in Plants:** [http://bcs.whfreeman.com/thelifewire/content/chp39/3902002.html](http://bcs.whfreeman.com/thelifewire/content/chp39/3902002.html)

In plants, a photoperiod allows the organism to detect the relative length of day and night, which is directly related to when the plant will produce its flower. **HOW IS THIS EVENT REGULATED? WHY IS REGULATION IMPORTANT TO THE OVERALL SURVIVAL OF THIS GROUP OF ORGANISMS?**

Response to information and communication of information are vital to natural selection in plants.

- In **phototropism**, changes in the light source lead to differential growth, resulting in maximum exposure of leaves to light for photosynthesis.
- In **photoperiodism**, changes in the length of night regulate flowering and preparation for winter.
Apoptosis & Flower Development in Plants
Programmed cell death (apoptosis) plays a role in the normal development and differentiation of an organism. Flowers have a species-specific life span with an irreversible program of senescence (biological aging). The life span of the entire flower is regulated for ecological and energetic reasons, but the death of individual tissues and cells within the flower is coordinated at many levels to ensure correct timing.

- In many species, chemicals released during pollination trigger apoptosis in floral components (overproduction of ethylene) – why would this make sense?
- Flowers are a substantial sink on a plant’s resources – and programmed cell death following pollination is a necessary, energy conserving, life sustaining process.
- **HOW IS THIS EVENT REGULATED? WHY IS REGULATION IMPORTANT TO THE OVERALL SURVIVAL OF THIS GROUP OF ORGANISMS?**

In animals, internal and external signals regulate a variety of physiological responses that synchronize with environmental cycles and cues. **Illustrative examples** include: circadian rhythms, diurnal/nocturnal and sleep/wake cycles, and seasonal responses such as hibernation, estivation and migration.

Circadian Rhythms in Animals
Circadian rhythms, or the physiological cycle of about 24 hours that is present in all eukaryotes, persists even in the absence of external cues. In all animals, certain cyclic alterations in metabolism reflect a circadian rhythm:

- In humans, the body temperature typically undergoes a cyclic rise and fall of more than 0.6°C in every 24 hour period. A biological clock maintains this rhythm even when variations in human activity, room temperature, and light levels are minimized.
- External stimuli can reset the biological clock, but the effect is not immediate. That is why flying across several time zones results in jet lag, a mismatch between the circadian rhythm and local environment that persists until the clock fully resets.
- **HOW IS THIS EVENT REGULATED? WHY IS REGULATION IMPORTANT TO THE OVERALL SURVIVAL OF THIS GROUP OF ORGANISMS?**

Nocturnal & Diurnal Activity in Animals
Nocturnal activity is an animal behavior characterized by activity during the night and sleeping during the day. Diurnal animals, such as squirrels and songbirds, are active during the daytime. Many times, these cycles are of adaptive value to the organism:

- **Resource competition** - Being active at night is a form of niche differentiation, where a species’ niche is partitioned not by the amount of resources but by the amount of time (i.e. temporal division of the ecological niche). Hawks and owls can hunt the same field or meadow for the same rodents without conflict because hawks are diurnal and owls are nocturnal. This means they are not in-competition for each other’s prey.
- **Predation** - Nocturnality is a form of crypsis, an adaptation to avoid or enhance predation. One of the reasons that lions prefer to hunt at night is that many of their prey species (zebra, atelope, impala, etc.) have poor night vision. Many species of small rodents are active at night because most of the dozen or so birds of prey that hunt them are diurnal.
- **Water conservation** - Another reason for nocturnality is avoiding the heat of the day. This is especially true in arid biomes like deserts, where nocturnal behavior prevents creatures from losing precious water during the hot, dry daytime. This is an adaptation that enhances osmoregulation.
- **HOW IS THIS EVENT REGULATED? WHY IS REGULATION IMPORTANT TO THE OVERALL SURVIVAL OF THIS GROUP OF ORGANISMS?**
Sleep/Wake Cycles in Animals

Despite their many adaptations for homeostasis, animals may encounter conditions that severely challenge their abilities to balance their heat, energy, and materials budgets. **Torpor** is a physiological state of decreased activity and metabolism, an adaptation that enables animals to save energy while avoiding difficult and dangerous conditions. Examples: some bats feed at night and exhibit daily torpor. Hummingbirds feed during the day and go into torpor on cold nights. Many animals exhibit seasonal torpor as a response to unfavorable conditions during certain times of the year.

- **Hibernation**: a physiological state in which metabolism decreases, the heart and respiratory system slow down, and body temperature is maintained at a lower level than normal during winter months. When mammals enter hibernation, their body temperature declines as its body's thermostat is turned down. In hibernating animals, the molecular components of the biological clock stop oscillating. This means that, for all practical purposes, the circadian stop ceases to operate during hibernation.
- **Estivation**: a physiological state in which metabolism decreases, the heart and respiratory system slow down, and body temperature is maintained at a lower level than normal during summer months.

**HOW IS THIS EVENT REGULATED? WHY IS REGULATION IMPORTANT TO THE OVERALL SURVIVAL OF THIS GROUP OF ORGANISMS?**

Oriented Movement/Migration in Animals

Migration is a regular, long-distance change in location observed in a wide variety of birds, fishes, and other animals. Many migrating animals track their position relative to the sun, and adjust to changes in the time of day using their circadian clock. Migration is of adaptive value because it allows certain animals to travel long distances in an effort to reach improved environmental conditions during certain unfavorable seasons. **HOW IS THIS EVENT REGULATED? WHY IS REGULATION IMPORTANT TO THE OVERALL SURVIVAL OF THIS GROUP OF ORGANISMS?**

Quorum Sensing in Bacteria

In bacteria, internal and external signals regulate a variety of physiological responses that synchronize with environmental cycles and cues. **Quorum sensing** is a system of stimulus and response correlated to population density — it enables bacteria to coordinate their behavior for the overall survival of the population.

- Bacteria use quorum sensing to coordinate certain behaviors such as biofilm formation, virulence, and antibiotic resistance, based on the local density of the bacterial population. This is a type of regulatory process in bacteria that ensures there is a sufficient cell density before a specific gene product is made.
- As environmental conditions often change rapidly, bacteria need to respond quickly in order to survive.
- These responses include adaptation to availability of nutrients, defense against other microorganisms which may compete for the same nutrients and the avoidance of toxic compounds potentially dangerous for the bacteria.
- It is very important for pathogenic bacteria during infection of a host (e.g. humans, other animals or plants) to co-ordinate their virulence in order to escape the immune response of the host in order to be able to establish a successful infection.

**HOW IS THIS EVENT REGULATED? WHY IS REGULATION IMPORTANT TO THE OVERALL SURVIVAL OF THIS GROUP OF ORGANISMS?**
Essential Knowledge 2.E.3: Timing and coordination of behavior are regulated by various mechanisms and are important in natural selection.

Just as physiological events are regulated by multiple mechanisms, timing and coordination of behavior are also regulated by several means; individuals can act on information and communicate it to others, and responses to information are vital to natural selection. Examples include behaviors in animals triggered by environmental cues (hibernation, migration and estivation), courtship rituals and other visual displays, and photoperiodism in plants due to changes in critical night length. Communication and cooperative behavior within or between populations contributes to the survival of individuals and the overall population. For example, changes in resource availability can lead to fruiting body formation in certain bacteria and niche partitioning among animals in a population.

Animal Behaviors

Discrete sensory inputs can stimulate both simple and complex behaviors. Ethology is the scientific study of how animals behave. This field suggests that understanding any behavior requires answering four basic questions:

- What stimulus elicits the behavior, and what physiological mechanisms mediate the response?
- How does the animal’s experience during growth and development influence the response?
- How does the behavior aid in survival and reproduction?
- What is the behavior’s evolutionary history?

These questions highlight the complementary nature of proximate and ultimate perspectives:

- **Proximate causation**, or “how” explanations, focus on
  - Environmental stimuli that trigger a behavior
  - Genetic, physiological, and anatomical mechanisms underlying a behavior
- **Ultimate causation**, or “why” explanations, focus on
  - Evolutionary significance of a behavior

A **behavior** is an action carried out by muscles or glands under control of the nervous system in response to a stimulus. Behavior in animals are triggered by environmental cues and are necessary to:

- Obtain food
- Find a partner for sexual reproduction
- Maintain homeostasis
- Response to information and communication of information is vital to natural selection.

<table>
<thead>
<tr>
<th>Innate Behaviors</th>
<th>Learned Behaviors</th>
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<tbody>
<tr>
<td><strong>Behavior that is developmentally fixed</strong>, where nearly all individuals in a population exhibit virtually the same behavior, despite internal and external differences during development throughout life.</td>
<td><strong>Behavior that is variable from one individual in a population to the next, depending on experience.</strong> These types of behaviors are learned and modified based on specific experiences.</td>
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<tr>
<td>Illustrative examples include:</td>
<td>Illustrative examples include:</td>
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<tr>
<td>Fixed Action Patterns</td>
<td>Habituation</td>
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<tr>
<td>Taxis &amp; Kinesis</td>
<td>Imprinting</td>
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<tr>
<td>Pheromone Signaling</td>
<td>Spatial Learning</td>
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<tr>
<td>Migration</td>
<td>Associative Learning</td>
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<tr>
<td>Behavioral Rhythms</td>
<td>Cognition / Problem Solving</td>
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**Fixed Action Patterns in Animals (Innate)**

A type of behavior directly linked to a simple stimulus is a **fixed action pattern**. This is a sequence of UNLEARNED acts that is essentially unchangeable and, once initiated, usually carried to completion. The trigger for a fixed action pattern is an external cue known as a **sign stimulus**.

**Figure 51.3: Sign Stimuli in a Classic Fixed Action Pattern**

In male stickleback fish, the sign stimulus for attack behavior is the red underside of an intruder. When presented with unrealistic models, as long as some red is present, the attack behavior occurs. **How is this event regulated? Why is regulation important to the overall survival of this group of organisms?**
Oriented Movement: Kinesis & Taxis (Innate)
Environmental cues not only trigger some simple behaviors but also provide stimuli that animals use to change or orient both simple and complex movements in a particular direction.

- **Kinesis**: a change in activity or turning rate in response to a stimulus.
- **Taxis**: an oriented movement toward (positive) or away from (negative) some stimulus.

**HOW IS THIS EVENT REGULATED? WHY IS REGULATION IMPORTANT TO THE OVERALL SURVIVAL OF THIS GROUP OF ORGANISMS?**

Pheromone Signaling (Innate)
Many animals that communicate through odors emit chemical substances called **pheromones**. Pheromones are especially common in mammals and insects and often relate to reproductive behavior. Pheromones are effective at very low concentrations – and can be used over short or long distances.

**Figure 51.9:** Minnows responding to the presence of an alarm substance – pheromones can be used in non-reproductive behavior also.

When a minnow or catfish is injured, an alarm substance in the fish’s skin disperses in the water, inducing a fright response among fish in the area

- (a) Minnows widely dispersed in aquarium
- (b) Minnows aggregate near bottom of tank and reduce their movement.

**HOW IS THIS EVENT REGULATED? WHY IS REGULATION IMPORTANT TO THE OVERALL SURVIVAL OF THIS GROUP OF ORGANISMS?**

Learning Establishes Specific Links Between Experience and Behavior
**Innate behavior** is developmentally fixed and under strong genetic influence. **Learning** is the modification of behavior based on specific experiences. Learning occurs through interactions with the environment and other organisms.

- Individuals can act on information and communicate it to others – these behaviors are highly regulated and important in natural selection.
- Innate behaviors are behaviors that are inherited, but learning occurs through interactions of information with the environment and other organisms.

**Habituation (Learned)**
**Habituation** is a simple form of learning that involves loss of responsiveness to stimuli that convey little or no information:

- For example, birds will stop responding to alarm calls from their species if these are not followed by an actual attack.
- Habituation allows an animal’s nervous system to focus on stimuli that signal the presence of food, a mate, or real danger, rather than waste energy on stimuli that are irrelevant to the animal’s survival and reproduction. In this way – habituation may increase an individual’s fitness.

**HOW IS THIS EVENT REGULATED? WHY IS REGULATION IMPORTANT TO THE OVERALL SURVIVAL OF THIS GROUP OF ORGANISMS?**
Imprinting (Learned)
Imprinting is a behavior that includes learning and innate components and is generally irreversible. It is distinguished from other learning by a sensitive period. A sensitive period is a limited developmental phase that is the only time when certain behaviors can be learned.

Figure 51.10 Imprinting
An example of imprinting is young geese following their mother. Konrad Lorenz showed that when baby geese spent the first few hours of their life with him, they imprinted on him as their parent. Conservation biologists have taken advantage of imprinting in programs to save the whooping crane from extinction. Young whooping cranes can imprint on humans in “crane suits” who then lead crane migrations using ultralight aircraft.

HOW IS THIS EVENT REGULATED? WHY IS REGULATION IMPORTANT TO THE OVERALL SURVIVAL OF THIS GROUP OF ORGANISMS?

Response & Natural Selection in Animals
Behaviors in animals are triggered by environmental cues and are vital to reproduction, natural selection and survival. Illustrative Examples include:
• Hibernation (REVIEW ESSENTIAL KNOWLEDGE 2.C.2 NOTES)
• Estivation (REVIEW ESSENTIAL KNOWLEDGE 2.C.2 NOTES)
• Migration (REVIEW ESSENTIAL KNOWLEDGE 2.C.2 NOTES)
• Courtship

Courtship Behaviors
Courtship in fruit flies (Drosophila melanogaster) constitutes a stimulus-response chain, in which the response to each stimulus is itself the stimulus for the next behavior. The courtship ritual includes:
• Visual communication
• Chemical communication
• Tactile communication
• Auditory communication

HOW IS THIS EVENT REGULATED? WHY IS REGULATION IMPORTANT TO THE OVERALL SURVIVAL OF THIS GROUP OF ORGANISMS?

Cooperative Behavior
Cooperative behavior within or between populations contributes to the survival of the populations. Illustrative Examples include:
• Niche & Resource Partitioning
• Mutualistic Relationships
• Pollination

→ Ecological Niches: The total of a species’ use of biotic and abiotic resources is called the species’ ecological niche. An ecological niche can also be thought of as an organism’s ecological role. Ecologically similar species can coexist in a community only if there are one or more significant differences in their niches. Strong competition can lead to competitive exclusion, local elimination of a competing species.
Two species cannot coexist in a community if their niches are too similar. If two species with the same niche coexist, then one will be excluded (competitive exclusion principle). If each species chooses to occupy a slightly different niche than preferred – then they may coexist.

- The competitive exclusion principle states that two species competing for the same limiting resources cannot coexist in the same place.

**Figure 54.2 Resource partitioning among Dominican Republic Lizards**

Cooperative behavior within or between populations contributes to the survival of the populations.

**Resource partitioning** is differentiation of ecological niches, enabling similar species to coexist in a community.

Seven species of *Anolis* lizards live in close proximity, and all feed on insects and other small arthropods.

However, competition for food is reduced because each lizard species has a different preferred perch, thus occupying a distinct niche.

**Symbiosis:** is a relationship where two or more species live in direct and intimate contact with one another. **Mutualism** is an interspecific interaction that benefits both species. A mutualism can be: (1) obligate, where one species cannot survive without the other; or (2) facultative, where both species can survive alone. Examples of mutualism: Lichens; mycorrhizae; bacteria in digestive tract of animals.

- **Lichens:** are composite organisms consisting of a fungus and a photosynthetic partner (usually green algae) growing together in a symbiotic relationship. The morphology, physiology and biochemistry of lichens are very different from those of the isolated fungus and alga in culture. The algae photosynthesize during the cooperation, and the fungi surround the cell wall of the algae, protecting it from dessication.

- **Mycorrhizae:** is a symbiotic association between a fungus and the roots of a vascular plant. This mutualistic association provides the fungus with relatively constant and direct access to carbohydrates. In return, the plant gains the benefits of the mycelium's higher absorptive capacity for water and mineral nutrients due to the comparatively large surface area of mycelium: root ratio, thus improving the plant's mineral absorption capabilities.

- **Digestive Bacteria:** **Gut flora** consists of a complex of microorganism species that live in the digestive tracts of animals and is the largest reservoir of human flora. Gut flora's primary benefit to the host is the gleaning of energy from the fermentation of undigested carbohydrates and the subsequent absorption of short chain fatty acids. Many herbivorous animals have fermentation chambers where symbiotic microorganisms digest cellulose. The most elaborate adaptations for an herbivorous diet have evolved in the animals called ruminants.
Both Genetic Makeup and Environment Contribute to the Development of Behaviors

Animal behavior is governed by complex interactions between genetic and environmental factors. Cross-fostering studies help behavioral ecologists to identify the contribution of environment to an animal’s behavior. A cross-fostering study places the young from one species in the care of adults from another species.

- Studies of California mice and white-footed mice have uncovered an influence of social environment on aggressive and parental behaviors.
- Cross-fostered mice developed some behaviors that were consistent with their foster parents.
- **HOW IS THIS EVENT REGULATED? WHY IS REGULATION IMPORTANT TO THE OVERALL SURVIVAL OF THIS GROUP OF ORGANISMS?**

Regulatory Genes and Behavior

A master regulatory gene can control many behaviors. For example, a single gene controls many behaviors of the male fruit fly courtship ritual. Multiple independent genes can contribute to a single behavior. For example, in green lacewings, the courtship song is unique to each species; multiple independent genes govern different components of the courtship song. **Selection for individual survival and reproductive success can explain most behaviors.**

- Genetic components of behavior evolve through natural selection.
- Behavior can affect fitness by influencing both foraging and mate choice.
- Natural selection refines behaviors that enhance the efficiency of feeding and mate selection.

**Figure 51.18 Evolution of Foraging Behavior by Laboratory Populations of Drosophila Melanogaster**

Foraging, or food-obtaining behavior, includes recognizing, searching for, capturing, and eating food items

- In *Drosophila melanogaster*, variation in a gene dictates foraging behavior in the larvae
- Larvae with one allele travel farther while foraging than larvae with the other allele
- Larvae in high-density populations benefit from foraging farther for food, while larvae in low-density populations benefit from short-distance foraging
- Natural selection favors different foraging behavior depending on the density of the population
- **HOW IS THIS EVENT REGULATED? WHY IS REGULATION IMPORTANT TO THE OVERALL SURVIVAL OF THIS GROUP OF ORGANISMS?**

The optimal foraging model views foraging behavior as a compromise between benefits of nutrition and costs of obtaining food. The costs of obtaining food include energy expenditure and the risk of being eaten while foraging. Natural selection should favor foraging behavior that minimizes the costs and maximizes the benefits.

**Figure 51.19 Energy Costs and Benefits in Foraging Behavior**

Optimal foraging behavior is demonstrated by the Northwestern crow. A crow will drop a whelk (a mollusk) from a height to break its shell and feed on the soft parts. The crow faces a trade-off between the height from which it drops the whelk and the number of times it must drop the whelk. Researchers determined experimentally that the total flight height (which reflects total energy expenditure) was minimized at a drop height of 5 m. The average flight height for crows is 5.2 m.

**HOW IS THIS EVENT REGULATED? WHY IS REGULATION IMPORTANT TO THE OVERALL SURVIVAL OF THIS GROUP OF ORGANISMS?**
Balancing Risk and Reward
Risk of predation affects foraging behavior. For example, mule deer are more likely to feed in open forested areas where they are less likely to be killed by mountain lions.

**HOW IS THIS EVENT REGULATED? WHY IS REGULATION IMPORTANT TO THE OVERALL SURVIVAL OF THIS GROUP OF ORGANISMS?**

Inclusive Fitness can Account for the Evolution of Altruistic Social Behavior
Natural selection favors behavior that maximizes an individual’s survival and reproduction...and these behaviors are often selfish. On occasion, some animals behave in ways that reduce their individual fitness but increase the fitness of others. This kind of behavior is called **altruism**, or selflessness.

**Figure 51.27 Naked Mole Rats Exhibits Altruistic Behavior**
In naked mole rat populations, non-reproductive individuals may sacrifice their lives protecting their reproductive queen and kings from predators.

**HOW IS THIS EVENT REGULATED? WHY IS REGULATION IMPORTANT TO THE OVERALL SURVIVAL OF THIS GROUP OF ORGANISMS?**

Review: Exchange of Information
Individuals can act on information and communicate it to others. Organisms exchange information with each other in response to internal changes and external cues, which can change behavior. **Illustrative Examples** include:

- Predator warnings
- Protection of young
- Avoidance Responses

On seeing a python, vervet monkeys give a distinct “snake” alarm call, and all members of the group stand upright and look down. The alarm call for seeing leopards and eagles is different than that of a python, and therefore elicits a different response from the monkeys.

**HOW IS THIS EVENT REGULATED? WHY IS REGULATION IMPORTANT TO THE OVERALL SURVIVAL OF THIS GROUP OF ORGANISMS?**

Communication within a population occurs through various mechanisms. Living systems have a variety of signal behaviors or cues that produce changes in the behavior of other organisms and can result in differential reproductive success. **Illustrative Examples** include: territorial marking in mammals:

- Cheetahs use chemical communication to warn other cheetahs of their territorial boundaries.
- Maintaining a territory increases the likelihood that a cheetah will capture enough food to reproduce.

**HOW IS THIS EVENT REGULATED? WHY IS REGULATION IMPORTANT TO THE OVERALL SURVIVAL OF THIS GROUP OF ORGANISMS?**

Review: Behaviors Favored by Natural Selection
Responses to information and communication of information are vital to natural selection and evolution. Natural selection favors innate and learned behaviors that increase survival and reproductive fitness. **Illustrative Examples** include:

- Parent/offspring interactions
- Migration patterns
- Courtship behaviors
- Foraging behavior
- Avoidance behavior

An avoidance response is a behavior based on the concept that animals will avoid performing behaviors that result in an aversive outcome. It is a learned reaction to undesirable sensations or feedback that leads to avoiding the behavior that is followed by this unpleasant or fear-inducing stimulus. A white-footed mouse will avoid eating caterpillars with specific colors after a bad experience with a distasteful monarch butterfly caterpillar. A predator may learn to avoid a specific type of prey associated with a painful experience. **HOW IS THIS EVENT REGULATED? WHY IS REGULATION IMPORTANT TO THE OVERALL SURVIVAL OF THIS GROUP OF ORGANISMS?**