Introduction

When you search online for the term migration, a multitude of definitions appear regarding the movement of everything, from large charismatic mega fauna – whales and elephants – to the repositioning of atoms within a molecule and from the monumental treks of ancient human populations across continents to the recent heart-wrenching tales of people seeking political asylum. The underlying thread of all these definitions is the movement from one location to another. Migration, as intended here, is the movement of organisms between distinct geographical locations. Such regular migrations, in general, involve outward and return journeys, one for breeding and the other for non-breeding, each offering seasonal resources that increase the overall fitness of an individual. The migration life history stages (i.e., outward and return) have evolved multiple times across phyla, creating diverse forms and striking parallels, all providing a rich platform for investigating multiple pathways for this adaptation and the endocrine mechanisms underlying it.

Historical Perspective of Migration

Knowledge of the major movements of organisms has been appreciated since ancient times. Seasonal appearance of prey is a vital cue for predators to time breeding. In fact, there are biblical references to the predictable return of the delectable European Quail (*Coturnix coturnix*) to the Middle East in autumn. The Paleolithic cave paintings of the Ardèche region of France depicting herds of mammals suggest a keen awareness of predictable animal movements representing a seasonal food source for primitive peoples. However, not all migratory movements are predictable or constructive. The sporadic appearance of plague species such as the migratory locusts (*Schistocerca gregaria*, *Chortoicetes terminifera*), African armyworms (*Spodoptera exempta*), Brown Plant hoppers (*Nilaparvata lugens*), aphids (*Toxoptera graminum*), and the avian Red-billed Quelea (*Quelea quelea*) can denude fields of planted crops at a devastating speed and present serious problems to agriculture and the livelihood of people.

Seasonal movements did not evade such keen observers of nature as Aristotle and Linnaeus. Their writings noted that swallows, namely, *Hirundo rustica*, would appear in early spring, flying low over open water, hunting insects. At the end of the summer, they vanished mysteriously. Little did the observers realize that at departure, the birds were embarking on a long-distance migration that would take them from breeding grounds in Europe to wintering sites in South Africa, some 7000 km away. Rather, it was thought by some that the birds had dived into the water and were hibernating in the mud at the bottom of the ponds and lakes where they were last seen hunting at the close of summer. To accomplish this, the birds would have to transform to an alternative state allowing them to withstand the cold and anoxic conditions. These ideas held sway over some naturalists, but the writings of Reverend Gilbert White in his treatise, the *Natural History of Selbourne* in the eighteenth century, describe how he actually observed birds leaving for the south and never saw any diving into the water. In spring, they would return flying from the south. Such astute observations by White and others herald the beginning of the study of seasonal movements – migration.

Migration: A Response to Living in a Changing Environment

Organisms that live in locations with distinct seasonal changes alter their behavior, physiology, and morphology to minimize mortality and maximize fitness under diverse sets of conditions. To be successful, organisms must be able to perceive and respond to changes in the environment. These changes fall into three basic categories. First, predictable or seasonal changes include the phenological fluctuations of resources, including food, water, and shelter. Second, the unpredictable changes in weather, predator numbers, and ecological features may occur at any time of the year. Third, the impact of social interactions, that is, competition (dominant-subordinate relationships), can affect access to valuable resources, that is, food and shelter, for certain members of a group. All the three environmental conditions can influence individuals by forcing them to move to breed or to survive. In the discussion that follows, each of these three conditions serves as selective agents molding the diversity of migratory patterns across taxa.

Considering Migration as Life History Stages of the Life Cycle

The annual cycle of species that live for more than 1 year is made up of a repeating sequence of unique stages of
specific activities, each representing adaptations for the environmental conditions that exist at a location at a specific time of the year. Such species are referred to as iteroparous signifying the annual cycle reiterates or cycles. For example, the life history stages for a migratory bird can include wintering, prealternate molt, spring migration, breeding and prebasic molt, and autumn migration stages (Figure 1). Each of the stages may be considered an alteration in the expression of morphological, physiological, and behavioral traits representing phenotypic flexibility throughout the annual cycle. Upon closer inspection, each stage is composed of three phases – development, mature expression, and termination – that involve the differentiation of cells, tissues, and organs resulting in specific behaviors and physiology. Factors that regulate the onset, progression, and termination of each stage are largely unknown but environmental conditions and endogenous rhythms play a major role. For organisms that live for 1 year or less, including many invertebrates, particularly insects, passage through the stages occurs only once in a lifetime. Thus, the variations observed in their morphology and physiology may be attributed to genetic differences or phenotypic plasticity.

The following are some examples of various forms of migration across invertebrates and vertebrates that illustrate both phenotypic plasticity as well as flexibility within a phenotype. Hormonal bases, where known, of these migratory patterns are also discussed.

### Phenotypic Plasticity

#### Intergenerational Migration: Monarch Butterflies

Multivoltine species such as the Monarch butterfly (*Danaus plexippus*) produce several generations annually and together complete a migratory route that is an inter-generational roundtrip. This complex system accommodates the acquisition of a preferred food source and an overwintering site that provides constant temperature for diapause. One population migrates as far north as the Great Lakes region and the northeastern corridor of the United States during spring and summer months and then returns to overwinter in the highly localized Oyamel fir forests (*Abies religiosa*) of the transvolcanic mountains of Central Mexico (Figures 2–4). Phenotypic plasticity of longevity is apparent in this species with the adult population that migrates from the northern extent of the range south in autumn and overwinters in reproductive

**Figure 2** Round trip intergenerational route of the eastern population of Monarch butterflies. Multiple generations of summer breeding adults move north and east to breed throughout the summer range (pink-filled area). In autumn, the most northern populations commence a southward migration to the overwintering site (green-filled circle) in the Oyamel fir forests of the transverse neovolcanic belt of Mexico. Here, adults congregate en masse in reproductive diapause in the fir trees. The forest conditions and large number of individuals contribute to maintaining optimal temperatures for diapause. In March, the adults emerge from this state of reproduction and migrate to the Gulf coast, identified as the spring range (gray-filled area), where they breed and oviposit on the southern milkweed plants (*Ascelpias*) and then succumb. Larvae hatch, feed on the milkweed, and later metamorphose into the summer, breeding adults to migrate into the breeding range. Successive generations move north throughout the summer months relying on the phenology of the northern milkweed. In autumn, the last breeding population migrates south and west to the Oyamel forests. Outward spring routes are indicated by hatched arrows and return autumn routes by solid black arrows. Portions of Rocky Mountain Range are indicated by small triangles. Modified from Brower LP (1996) Monarch butterfly orientation: Missing pieces of a magnificent puzzle. *Journal of Experimental Biology* 199: 93–103.
stage is regulated by juvenile hormone (JH), an acyclic sesquiterpene, produced by the neuroendocrine gland, the corpora allata. During the ontogenetic stages, JH regulates the development of immature characteristics. However, in the adult stage, the elevated hormone levels influence gonadal development and breeding behavior. For the Monarch Butterfly, JH-directed breeding is followed in quick succession with death. Synthesis of the active forms of juvenile hormone (JH I, II) is suppressed under reduced photoperiod and low environmental temperatures experienced by the adult Monarchs during autumn and winter months. In spring, increased photoperiod and elevated temperatures release the inhibition of JH I, II and promote migration, breeding, and eventual death. Studies of gene expression of Monarchs have noted that a suite of 40 genes with differential expressions appear to influence the behavior and physiology of these two states. The results link key behavioral traits with gene expression profiles in the brain that differentiate migratory from summer butterflies and thus show that seasonal changes in genomic function help define the migratory state. It is thought that the Monarch’s locate the fir forests by relying on environmental cues that are dependent upon a genetic vector system integrated into an endogenous program.

One-Way Migrations: Desert Locusts

In contrast to other species, the migratory routes of most insects are not round-trip but one-way migrations. The adults do not necessarily return to locations where they were hatched. Though speculative, one explanation for this phenomenon is that migratory insects are ‘hedging their bets’ by depositing offspring in a wide variety of locations, which may prove productive for the next generation. Another possibility is that if food availability is unpredictable, then a strategy of nomadism relying on cues in the environment that may indicate spatial opportunism could be a decisive factor. A prime example of this is the desert locust, S. gregaria, a migratory species that shows extreme phenotypic plasticity. The ontogenetic life cycle is represented by a hemi-metabolous metamorphosis typical of the more advanced insects. This process consists of the egg, the multiple nymphal stages, and the adult. The nymphs (instars) or immatures resemble the adult in form and eating habits but differ in size and genitalia, and lack wings (Figure 5). Phenotypic plasticity is apparent among the adults and induced by the environmental variable – population density. When density is low, the solitary phenotype is prominent. Adults of this phenotype breed but are rarely observed in groups and are intolerant of close contact. If the density increases, the morphology, physiology, and behavior of individuals switch in short order (2 h) to the gregarious phenotype. In this form, individuals no longer show mutual repulsion. Rather they form massive swarms of up to $10^{13}$ individuals.
that migrate en masse and land in agricultural areas where they deplete crops with devastating speed. Upon landing, adults may breed multiple times and at various locations throughout the broad geographical range of this species (Figure 6). Following this, the adults succumb.

Recent studies have identified a hormonal factor associated with the trigger for phenotypic transition from the solitary to gregarious phenotype. The levels of the neuropeptide, serotonin (5-hydroxytryptamine, 5-HT), increased in the thoracic ganglia in solitary adults following exposure to crowded conditions and acquisition of gregarious behavior. A highly conserved indolamine, 5-HT has been associated with neuronal plasticity in vertebrates, but the effect on the large-scale changes of population dynamics and on the onset of mass migrations, is recent.

**Round Trip Routes**

**Ontogenetic migrations**

**Semelparous fish**

Migratory movements are not restricted to the adult life history stage but may occur during ontogeny. Such migrations, however, transpire only once and do not cycle on an annual basis. A common example of this includes semelparous species that breed once and die and include diadromous fish that migrate between fresh and seawater. The most prominent organisms in this group are anadromous species – two Agnathan genera of lamprey (*Petromyzon* and *Lampetra*), teleost fish such as Pacific Salmonids (*Oncorhynchus* sp.) and Eels (*Anguilla* sp.), and a catadromous teleost. Although there is variation among these species, the general life cycle of the Pacific salmon provides an illustrative example involving the following: at hatching, alevins emerge from the gravel of fresh water streams with yolk sacs attached and develop into fry, followed by the parr stage that can be identified by vertical line markings and the exhibition of rheotaxis (Figure 7). In preparation for seawater entry, the parr metamorphose into the smolts (called smoltification) with dramatic changes in physiology and behavior to accommodate saline conditions. Increases in thyroid hormones are thought to initiate the metamorphosis with prolactin and cortisol aiding in osmoregulatory changes. At this point, smolts enter seawater (sea run form) and travel into the Pacific Gyre where they spend differential amounts of time depending upon the species to complete growth. At the climax of this stage, sexual maturation is initiated, the hypothalamic pituitary gonad axis is activated and spawning migration begins as fish prepare for entry into

![Figure 5](image5.png) Ontogenetic life history stages of the migratory desert locust (*Schistocerca gregaria*). The fertilized egg hatches into four successive instars each of increasing size and development. All are wingless and terrestrial. The fifth instar has vestigial wings. The final instar molts into one of two fully winged adult phenotypes depending upon the environmental conditions. In low densities, the solitary form appears and is rarely observed. Yet, under crowded conditions, the gregarious form is apparent, forming huge swarms and migrates to locations where food is available, but which can be demolished in short order. Photograph by Tom Fayle.

![Figure 6](image6.png) Map depicting portions of Africa, Southern Europe, Middle East, Southern Asia. Shaded areas indicate the geographical distribution of *Schistocerca gregaria*.

![Figure 7](image7.png) Life cycle of Pacific salmon (*Oncorhynchus* sp.) drawn by Kathleen Neely, NOAA, Seattle, WA.
fresh water navigating back into natal streams and rivers to spawn. Navigation to the natal waters has been attributed to imprinting of the chemical composition of the natal streams experienced by smolts during first migration to open water and guided by the memory of the olfactory cues accumulated earlier in life. Again, prolactin and cortisol are thought to regulate osmoregulatory changes as fish enter fresh water. Navigation back to natal streams is considered to be influenced by cortisol, which may prime or activate regions in the teleost brain, namely, hippocampus and other olfactory regions to recall memory and help to guide during the return trip. Increasing levels of sex steroids as gonads mature control changes in the morphology and behavior, leading to territoriality and reproductive behavior. Castration tends to prolong life, but only for a few months, suggesting that death postspawning is, indeed, programmed. The connection between reproductive hormones and programmed cell death in semelparous vertebrates is reminiscent of the life histories of the insect systems described earlier and presents a fruitful avenue for further comparative investigations.

Evolutionary explanations for Salmonid semelparity revolve around a combination of factors that include distance and arduousness of the return trip, which leave adults spent after the production of a multitude of gametes. Also, streams in which the young hatch are largely nutrient-poor, and the decaying carcasses of moribund adults can deliver dissolved elements, including N₂ and P, which serve to enrich the nursery conditions for the young fish.

**African black Oystercatcher: a ploy to avoid adults?**

In birds, another example of an ontogenetic migration is found among juvenile African Black Oystercatchers (*Hematopus moquini*). In this species, adults are sedentary and remain year round on the breeding grounds on the southern coasts of Namibia and South Africa. Following the postfledgling molt, young birds migrate away from the breeding grounds to specific locations along the coast called nurseries. After a period of years, the birds return to the natal territories to breed, assume a sedentary lifestyle, and never again migrate. Nothing is known of the endocrine mechanisms involved in the juvenile movement. Although speculative, the explanation for the ontogenetic migration may be that availability of specific foods, reduced competition, or low predation pressure at the nursery sites could play roles for the appearance and maintenance of this migratory pattern.

**White Stork: delayed migration and breeding**

White storks (*Ciconia ciconia*) present an intriguing condition of delayed maturity in that the birds do not normally breed until they reach 3 or 4 years of age. This is a migratory species with populations that breed extensively from the northwestern tip of Africa north through Spain and extending eastward into Europe and beyond. Following breeding, birds return in autumn via western and eastern routes to overwinter in the south of the Sahara in eastern and southern Africa. At the end of breeding, young birds migrate with adults in autumn to the overwintering sites. However, in spring a few young birds return with the adults to breed. Most second-year birds remain south of the Sahara. Third and most fourth-year birds migrate north in spring for increasing distances but most neither complete the full trip nor breed successfully until their fifth and sixth years. This ontogenetic pattern of failure to complete the spring migratory route and delayed breeding suggests a tight linkage between both functions. The cycles of molt, body mass, fat, and reproductive hormones appeared similar between the juvenile and adult birds indicating that these regulatory mechanisms are not involved. Possibly, the capacity, to complete the spring migratory route and to breed require full maturation of the behavioral and physiological systems. Storks are diurnal migrants and rely on rising thermals to support soaring during migration which reduces the requirement of powered flight and energetic costs. Thermals are created during daylight hours as heat rises off the surface of the land or slopes in vertical columns of warm air rising through the atmosphere. Thus, storks avoid crossing open bodies of water, including the Mediterranean, effectively lengthening the flight distance for the outward and return journeys. Diurnal flight also leaves little time for feeding, replenishing fuel stores, and rest on a daily basis at stopover sites. Adult birds may be more competent in acquiring and storing fuel for flight at take off or locating novel food resources during the brief period of stopover. Juveniles could lack the ‘know-how’ to maintain themselves during spring migration. The delayed pattern of migration and breeding, therefore, may represent the time required to gain the experience necessary to successfully complete spring migration and arrive on the breeding grounds in condition to breed. This example suggests that both environmental conditions and migration strategies play a role in molding ontogenetic migration.

**Seasonal Roundtrip Migrations**

**Spiny lobster**

The Caribbean spiny lobster (*Panulirus argus*) is found in the tropical and subtropical waters of the Atlantic and Caribbean Oceans extending into the Gulf of Mexico. It is nocturnally active, spending daylight hours in crevices and holes within the coral reefs. At night, animals move away from these protective sites to feed on a wide variety of marine invertebrates as well as scavenger for detritus along the ocean floor. In early autumn, juvenile and young adults are found feeding over a wide area in the Caribbean
at depths of 3–10 m, a region of minimal cover with few rock and coral outcrops, patches of sea grass, and large colonies of sponges. However, by the end of autumn, these locations are plagued with seasonal disturbances associated with the southeastern hurricane season. Water temperature in the shallow areas drops as the ocean swells and wave action stirs up the sandy bottom, the turbidity increases, hampering feeding by lobsters. Autumn storms are thought to instigate mass movements of lobsters to deeper water where there is little effect of storms, and water temperatures are elevated above those of the shallows.

During migration, individual lobsters line up in a single file called *queuing*, with each resting its long antennae over the carapace of the individual in front to increase laminar flow and reduce drag (Figure 8). During the outward migration, the queue moves generally in a southerly direction and covers 30–50 km to reach reefs at depths from 10 to 30 m. The movement is recorded to occur during the night as well as by day, and animals have been shown to navigate by an internal magnetic compass using the earth's geomagnetic field. On the return migration, the spring movements appear to be less synchronized as animals reappear in the shallow areas in smaller numbers. At this time, breeding and molt ensue during the spring and summer months (Figure 9). Unlike other migratory systems, the mass migrations of spiny lobsters are not associated with reproduction directly but are rather thought to indicate an avoidance of cold water that impairs development, spawning, and survival of adults, particularly during molt. The endocrinology of this system is not well understood and deserves further attention.

**Migratory song birds**

The life cycles for many iteroparous migratory songbirds are variable and complex, and by far the most well studied. Some birds migrate between the breeding and overwintering sites solely. Others may migrate to special locations after breeding to molt, and when completed, will continue on to an overwintering location. Migratory patterns also vary within a species. For example, some members of populations, usually adults, will show no migratory activity and remain on the breeding territories year round. While other members, usually juveniles, migrate from the breeding grounds in autumn and overwinter in a location, but return the following spring to breed. In this case, the migratory pattern of the population is described as partial migratory.

A differential migratory pattern refers to the different wintering sites utilized by the members of a population. Here, males may overwinter at locations in closer proximity to the wintering grounds, whereas females (juvenile and adults) may migrate further away. In both partial and differential migratory patterns, competition over limited resources is usually the selective force influencing the mode of migration. These diverse patterns of migration represent distinct selective pressures on individuals within a population and illustrate the diversity of adaptations to seasonal variations and availability of resources.

For all taxa, the migratory life history stages are probably best known from the studies of passerine birds that have been the focus of scientific investigations for well over 100 years. The descriptions that follow are based on the migratory bird literature with a particular emphasis drawn from a long-distance migrant, the White-crowned Sparrow (*Zonotrichia leucophrys gambelii*) (Figure 10). Both the vernal and autumn migratory life history stages are composed of three phases (Figure 11). The first is the developmental phase in which all the cellular and molecular aspects of migration are set in place. The trigger for initiation of the spring developmental phase for many species is the vernal increase in day length, but for others, endogenous rhythms are most prominent, particularly for species that overwinter on or near the equator where changes in photoperiod are negligible. The trigger for the autumn phase, however, is poorly understood but is thought to be related to photorefractoriness that occurs at the termination of the breeding stage. The developmental phase for migration involves morphological changes that include muscle and liver hypertrophy,
and the physiological changes in the expression of enzymes that direct the synthesis and deposition of fuel for flight, namely, lipid and protein as well as the catabolism necessary for utilizing the stored fuels once flight begins. Also, the oxygen-carrying capacity of the blood improves with an increase in red blood cells as measured by hematocrit. This process entails the synthesis of the protein growth factor erythropoietin by the liver and kidney that is thought to be regulated by gonadal androgen and thyroid hormones. Behavioral changes include hyperphagia or an increase in appetite, and changes in social behavior, all of which culminate in the mature capability phase when migration actually begins.

During this phase, all the aspects that were developed in the preceding phase are now expressed, namely, cycles of fueling and flight. Fueling occurs both at the outset and throughout the migratory period at specific locations called stopovers. For birds and other species that do not feed while migrating, stopovers are a critical factor for refueling and rest. If prohibited, owing to the restriction of stopover sites because of ecological disturbance and reduction in resource availability, the success of migration is greatly jeopardized. Fueling is achieved by hyperphagia, lipogenesis, fat deposition, increased length of the gut and size of the digestive organs as well as flight muscle hypertrophy. The vernal increase in day length acts in conjunction with testosterone to organize the hypothalamic feeding centers in the brain to regulate feeding. NYP, central prolactin, and possibly, CCK, appear to play important roles, but the specific mechanisms in relation to migration are not well understood. The hormonal mechanisms regulating the digestive organ size and flight muscle are not well known.

At the end of this refueling substage, feeding ceases and birds rest prior to departure. In captivity, this state is described as the quiescent phase, which serves as a transition between the anabolic and catabolic stages, and may be required for an orderly transition. The plasma glucocorticoid, corticosterone, increases prior to departure, which is thought to be involved in the transition and/or preparation for flight. Factors that influence the timing of actual take-off may involve atmospheric conditions, lunar

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**Figure 9** Life history stages of spiny lobster (*Panulirus argus*). Throughout late spring and summer months, juveniles and adults are found in the shallow waters (light blue-filled boxes) off the southeastern coast of the USA. In early autumn, individuals migrate in large numbers in lines or queues to deeper waters (dark blue-filled box) to avoid storm conditions in the shallow waters. By early spring, individuals return to the shallows to hatch young, molt, and breed.

**Figure 10** White-crowned sparrow (*Zonotrichia leucophrys gambelii*). Photo by John C Wingfield.

**Figure 11** The three phases of the adult migration life history stage drawn from the literature of migratory passerine birds.
phase, or social inducement from flock members, but much remains unknown. After flight ensues, the levels of corticosterone rise further in conjunction with other mediators of lipid and protein utilization, all of which serve to meet the energetic demands of flight. Concomitantly, the digestive organs that were built up during the fueling phase are reduced in size and this is as a weight-saving strategy. At stopovers, the cycle begins again, with the anabolic functions taking over to replace lost fuel. How quickly and effectively birds regain their lost mass, fat, and muscle enroute is not known, but such information is critical to understanding the true costs of migration.

In addition to the physiological parameters, the behaviors expressed during migration change radically. Some species are nocturnal migrants in that they migrate during the night. Others are diurnal or day migrants and fly during the daylight hours. The distinction here is that the movement is oriented and the distances covered are much increased over daily activities observed in the previous or subsequent life history stages. To orientate and navigate to a specific location, migrants rely on a variety of exogenous cues. Many species utilize the earth’s magnetic field, and solar and celestial cues; some even rely on olfaction. How birds know the route is an interesting point. Some species fly with adults and learn the routing. In other cases, young birds must rely on ‘genetic knowledge’ at least for their first autumn flight. Studies have shown that the route and ability to correctly perceive cues for orientation are ‘learned’ over time and resemble at some level the systems apparent in semelparous fish during spawning migration. Upon reaching the destination (overwinter or breeding sites), all the behavioral and physiological attributes of the migratory life stage are terminated allowing progression to the next stage, be it breeding or overwintering.

Irruptive and Nomadic Migrants

The Red-crossbill (Loxia curvirostria) is a classic example of an irruptive and nomadic migrant (Figure 12). This species relies on coniferous cone seeds that nourish both the adults and the young. Cone crops mature at regular intervals but in irregular quantities; thus, the amount of seed and how long it is available are unpredictable in space and time. Studies have demonstrated that fat deposition and migratory movements display a seasonal component that is linked to photoperiod and endogenous cycles. For example, in spring, birds show regular seasonal fattening and migratory movements. This is a time when seeds likely develop and are possibly easy to find with nomadic movements. Birds locating a sufficient supply will stop and commence breeding.

By midsummer, breeding is interrupted as birds complete their prebasic molt. In most years, locating mature seeds in the autumn is highly unpredictable. In response to this seasonal uncertainty, birds show a second peak of fattening as an insurance policy in case food is not located. Should local cone crops be sufficient, birds may remain in the area and breed again. If, however, the seed crop at this site is poor, birds will respond with irruptive movements and commence searching for more productive coniferous stands. Should a rich cone crop be found, a second round of breeding can occur, but this time, during the winter months. The irruptive movements have been associated with elevations of plasma corticosterone. Experimental studies of captive birds have revealed that reducing or eliminating food results in increased locomotor activity as well as plasma corticosterone. It is suggested that this endocrine link plays a role in the initiation of the irruptive movements.

Conclusion

Considering migration as a life history stage within the context of the annual cycle provides a heuristic model for determining mechanisms. Compartmentalizing each life history stage allows of an investigation of the environmental factors that affect the onset, expression, and termination of each phase. Migration is an organism’s solution to solving the problem of variable environments. This solution may be an expression of multiple phenotypes or phenotypic flexibility within the year, each matching the conditional requirements of ecology present at a given location. Or it may come in the version of multiple phenotypes at a particular time to match the conditions at that point as seen in insects (phenotypic plasticity). Thinking broadly, such ideas harken back to the earlier misconceptions of migration presented at the outset of this article. Certainly, migration is not a transformation of form from an aerial aerobic passerine to one capable of withstanding the conditions of winter by assuming a subaquatic (benthic) and anaerobic form. But the concept of alteration of form is, nevertheless, compelling.
Migrants prepare, express and terminate characteristic traits that allow for movement from local to distant habitats for breeding or survival. In doing so, the phenotype that is expressed, whether it is plasticity or flexibility, then matches the demands of the current local conditions. Thus, studies of migration that consider the concepts of alteration, coupled with movement, are key and propel future studies and advancements in the topic of migration.

See also: Bat Migration; Bats: Orientation, Navigation and Homing; Bird Migration; Collective Intelligence; Fish Migration; Food Intake: Behavioral Endocrinology; Insect Migration; Irruptive Migration; Magnetic Orientation in Migratory Songbirds.

Further Reading


Relevant Websites

http://www.movebank.org/community – Community for Remote Animal Monitoring