Cryptobiosis and Diapause in Insects

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ABSTRACT

This study explores the physiological and ecological mechanisms of Cryptobiosis and diapause, two distinct strategies insects use to survive extreme environmental stress. While both involve a suppression of metabolic activity, they differ significantly in their triggers, complexity, and biological "depth." Cryptobiosis is an extreme state of am metabolic dormancy where all observable signs of life such as growth, reproduction, and repair cease. It is an opportunistic response to immediate, lethal physical threats. Another Diapause is a genetically programmed state of developmental arrest. Unlike a simple reaction to cold (quiescence), diapause is proactive; insects enter this state before the onset of harsh conditions, usually triggered by "token stimuli" like changing day lengths (photoperiod).

INTRODUCTION

Cryptobiosis

It is a phenomenon when insect become quiescent due to adverse climatic conditions and sows no visible sign of metabolic activity is called Cryptobiosis. In the cryptobiotic state, all the metabolic processes and chemical reactions responsible for maintenance and growth almost cease, and oxygen consumption is reduced to a negligible amount. The viability of organisms in a state of Cryptobiosis decreases with the passage of time, however. This decrease is due to adventitious oxidations and reductions, and is caused by chemical reactions that have nothing to do with metabolism. It can, of course, be greatly accelerated by raising the temperature. For instance, when dehydrated cryptobiotic eggs of the Brine shrimp ***Artemia salina*** [It is small aquatic crustaceans known for surviving extreme salinity in salt lakes and coastal pools. They are widely used in aquaculture as highprotein larval food and are popular as "Sea-Monkeys" due to their durable, resting eggs (cysts) that hatch in salt water within 24–36 hours] are exposed to high temperatures, there is little reduction in the percentage hatching (when subsequently placed in a solution of salt) if the length of exposure has been below a critical period of time. Continued exposure beyond the critical period, however, results in a steep decline in the numbers hatching.

Another Sleeping chironomid (***Polypedilum vanderplanki***) by complete dehydration the insect can survive for many years. **H.E. Hinton's** work with the Chironomid midge (*Polypedilum vanderplanki*) whose larvae inhabit shallow rock pools in Nigeria and Uganda. At the beginning of the rainy season these pools may fill and dry several times. When they dry out, the larvae dry out too surviving in a state of Cryptobiosis. At a relative humidity of 60% their moisture content is 8%, and it falls to 3% at 0% relative humidity. When the pools fill the larvae rapidly absorb water through their integument until their normal moisture content of 85-90% has been restored and within an hour they may be feeding again. In the dry state, the larvae of Polypedilum can withstand exposure to 106°C for 3 hours and 200°C for 5 minutes. They can also tolerate immersion in liquid air (-190°C) or liquid helium (-270°C) and subsequently produce normal adults. A dry larva can be cut in half or into smaller pieces and kept for years. If the pieces are then placed in water they recover for a short time as they take up water then die as a result of their injuries.

These observations illustrate the sharp distinction between biological age and calendar age in Polypedilum. The biological age of a larva may be, say, 2 weeks while its calendar age would be 3 years and 2 weeks if it had been in Cryptobiosis for 3 years. Cryptobiosis is an efficient adaptation for coping with the exigencies of a severe and fluctuating environment.

States of Cryptobiosis:

1. **Anhydrobiosis:** Survival during near-total dehydration (common in larvae of the Sleeping chironomid midge, *Polypedilum vanderplanki*).
2. **Cryobiosis:** Survival during freezing temperatures.
3. **Osmobiosis:** Survival in response to high solute concentrations

Diapause

Diapause is a genetically programmed, hormonally controlled state of suspended development and arrested growth in insects, allowing them to survive adverse environmental conditions like winter or drought. It involves significantly reduced metabolism and occurs in specific life stages (egg, larva, pupa, or adult). It is considered to be a physiological state of the dormancy with very specific initiating and inhibiting conditions. It is long adaptive form of dormancy. It is an important adaptation in many insect species enabling them to sustain in regions which would otherwise be unfavorable for permanent habitation, and to maintain high numbers in an environment which might otherwise support only a low population (Andrewartha, 1952). The term “diapause” was applied by Wheeler to egg stage of grasshopper, *Conocephalus ensiferum* at which its development was ceased. Later the scope of diapause widened into various stages of insects as “periods of arrest in ontogenetic (origin and development of organisms) development” by Henneguy 1903.

The possession of a resting phase of diapause enables many insects, mites and probably some other arthropods to survive the winter in a dormant state which is characterized by enhanced resistance to cold and drought. Diapause is under hormonal control, and is usually induced by decreasing temperature and or photoperiod. It has been the subject of much research. In general, the photoperiodic reaction is independent of the intensity and total energy of the light, provided that this exceeds a minimum threshold value. It is no coincidence that this threshold exceeds the intensity of moonlight. The selective advantage of diapause in the life cycle of an arthropod is twofold. It not only provides a mechanism for survival when food is scarce and the climate unfavorable, but it synchronizes the development of the individuals in a population so that they emerge as adults and reproduce at the appropriate season. Photoperiod and temperature are the main environmental factors that influence the rate and development of diapause, and serve to maintain it. This implies the possession of

1. Receptors that detect the presence of daylight.
2. A 'biological clock' to measure the length of the photoperiod.
3. An effectors system to control the metabolic changes necessary for the induction of diapause.

The state of diapause is largely a dynamic one and, as the season progresses, decreases in intensity and the animal's responses to the factors that maintain it decrease. Long photoperiods and/or exposure to low temperature may terminate diapause experimentally but, under natural conditions, they usually regulate the rate of its development rather than terminate it actively. Within anyone species, however, there is often considerable variation in the duration of diapause. After diapause has been induced, it is maintained by low temperature and short- or decreasing-day length. As autumn proceeds, the response to photoperiod diminishes, and the low temperature threshold rises.

Type of Diapause in insect: It is two types

1. Facultative Diapause (Hibernation and Aestivation)
2. Obligate Diapause

1. Facultative diapause: It is most common diapause occurs in all insects. It is induced by environmental conditions. Termination of diapause occurs by Token stimuli (it means the insect's "biological clock" is waiting for a specific signal to wake up). It is two type

A. Hibernation: Any insect/living organism check growth and development due to low temperature it's called hibernation.

OR

The period of suspended activity in individuals occurring due to seasonal low temperature is known as hibernation. It is also known as winter diapause.

B. Aestivation: Any insect/living organism check growth and development due to high temperature it's called Aestivation.

OR

The period of suspended activity in individuals occurring due to seasonal high temperature is known as estimation. It is also known as summer diapause.

2. Obligate Diapause: It is the rare diapause. It is occurs specific life stage in every generation regardless of environmental conditions. Termination of diapause occurs spontaneously without any external stimuli or agent.

Classification of Diapause on the basis of stage in insect

Diapause type	Insect Name
Egg Diapause	Mulberry silk moth (***Bombyx mori***)
	Gypsy moth (***Lamantria dispar***)
	Locust (***Locusta migratoria, Chortoicetes terminifera*** and ***Locustana pardalina***)
	Grasshopper (***Camnula pellucida, Melanoplus bivittatus, Melanoplus differentialis, Hieroglyphus banian*** and ***Omocestus viridulus***)
	Forest Tent Caterpillar (***Malacosoma disstria***)
	Aedes Mosquitoes (***Aedes aegypti*** and ***Aedes albopictus***)
	Floodwater Mosquitoes (***Aedes vexans***)
Nymphal Diapause	Cicada (***Magicicada***)
	Dragonflies and Damselflies (Odonata)
	Field Cricket (***Gryllus pennsylvanicus***)
	Boxelder Bugs (***Boisea trivittata***)
	Small Winter Stonefly (***Allocapnia pygmaea***)
Larval Diapause	Pink Bollworm (***Pectinophora gossypiella***)
	Tussock moth (***Euproctis chrysorrhoea***)
	Apple stem borer (***Apriona cinerea***)
	Rice Yellow stem borer/YSB (***Scirpophaga incertulas***)
	European Corn Borer (***Ostrinia nubilalis***)
	Codling Moth (***Cydia pomonella***)
	Pitcher Plant Mosquito (***Wyeomyia smithii***)
Prepual Diapause	Indian Meal moth (***Plodia interpunctella***)
	Wheat Stem Sawfly (***Cephus cinctus***)
	Green Bottle Fly (***Lucilia sericata***)
Pupal Diapause	Cabbage Butterfly (***Pieris brassicae***)
	Red hairy caterpillar (***Amsacta albistriga***)
	Pea leaf minor (***Chromatomyia horticola***)
	Sorghum shoot fly (***Atherigona soccata***)
	Tobacco Hornworm (***Manduca sexta***)
	Bihar hairy caterpillar (***Spilosoma oblique***)
	Swallowtail butterfly (***Papilio polyxenes*** and ***Papilio demoleus***)
Adult Diapause	Red pumpkin beetle (***Aulacophora foveicollis***)
	Cotton boll weevil (***Anthonomus grandis***)
	Mango hopper (***Amritodus atkinsoni***)
	Rice hispa (***Dicladispa armigera***)
	Monarch butterfly (***Danaus plexippus***)
	White grub (***Holotrichea consanguinea***)
	Epilachna beetle (***Epilachna vigintioctopunctata***)
	Mango nut weevil (***Sternochetus mangiferae***)
	Cotton stem weevil (***Pempherulus affinis***)
	Colorado Potato Beetle (***Leptinotarsa decemlineata***)
	Bombay Locust (***Nomadacris succincta***)
	Red Locust (***Nomadacris septemfasciata***)

In 1934 V.B. Wigglesworth suggested that insects enter diapause on account of a temporary lack of certain hormones. This hypothesis has since been verified experimentally for a wide variety of species. It appears that the effectors system controlling the onset of diapause involves glands in the brain. When these are exposed to short photoperiods, the release of hormones is inhibited; when the brain is exposed to longer day length, their release is promoted.

Hypothesis in Diapause: Two hypotheses as to how insects' measure times have been proposed.

1: According to the first, the length of the day or night is measured by an interval timer- an hour glass-type of mechanism. Such a mechanism could be started by dawn and stopped by dusk, or initiated by nightfall and halted at dawn.

2: The second hypothesis that of **E.B. Biinning**, is that measurement of the length of the day or night is accomplished by the endogenous daily rhythm or 'biological clock'.

Each cycle consists of a photophilic and a scotophilic phase. The endogenous rhythm is set by dawn. If the daily light period is long, the period of illumination extends into the scotophilic part of the cycle, and the organism exhibits a long-day response. If the photoperiod is short, however, the organism exhibits short-day responses. Quite possibly both systems operate in different organisms:

clear hourglass effects have been demonstrated in mites and aphids, for example, but this does not preclude the existence of a circadian clock operating simultaneously.

Although both temperature and photoperiod are key environmental triggers in the regulation of diapause, the process is usually mediated by the neuro endocrine system and in pupae and adult insects, involves withholding the secretion of a stimulatory hormone. In adult insects, the failure to release juvenile hormone inhibits the development of the eggs and in males, of the accessory glands. Unlike pupal and adult diapause that of eggs and larvae is induced by the presence of an inhibitory hormone. In some Lepidoptera, larval diapause is limited to the maintenance of high levels of juvenile hormone in the blood. Egg diapause has been examined primarily in the silk worm Bambyx mari. It has long been known that injection of an extract of the sub oesophageal ganglion of adult females, reared as larvae on a short-day photoperiod, will induce diapause in the eggs of non-treated adults. Subsequent research on this maternal diapause hormone has shown it to be a peptide, but its mode of action is not yet fully understood.

CONCLUSION

Cryptobiosis is a **biological emergency brake** that allows specialized insects to survive conditions that would otherwise be incompatible with life. Understanding these states is critical for advancements in cryobiology, pest management, and our understanding of life's limits. While Diapause is a sophisticated **ecological timer** used for seasonal navigation.

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