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Polyembryony: An Evolutionary Debate

S. K. Raut

Ecology and Ethology Laboratory
Department of Zoology, University of Calcutta
Corresponding author: srimantakraut@gmail.com

Abstract

The tendency of recruitment of offspring at a maximum level is customary among biological species. To ensure the same various strategies have been developed by various group of organisms. Of these, binary fission, multiple fission, fragmentation, budding, vegetative propagation, sporogenesis are means of asexual mode of recruitment. Though parthenogenesis is very much involved with the female gamete where the offspring is produced by female without participation of male gamete could be considered as a passage towards sexual reproduction. According to some authorities, parthenogenesis is one kind of asexual reproduction while many authorities opined that parthenogenesis is a derivative of normal sexual reproduction. However, to get the quality offspring some biological species have evolved the process of recruitment of a good number of offspring following sexual reproduction on way of producing many embryos either individually in respect to union of male gamete with the female ones or from an embryo through cloning devices. Perhaps, to overcome hurdles, on way of evolution, polyembryony is emerged to produce individual with many upcoming characters in biology. But the fact is very much involved with the sexual reproduction even after the production of embryo from a zygote. This sort of recruiting mechanism in organisms is not only an aspect of evolutionary debate but also a question of analysis whether this type of recruitment behavior is influenced by the asexual recruitment devices.

Keywords: Recruitment of offspring, polyembryony, origin, diversification, evolutionary impact

Introduction

Embryo (em-bree-oh). In Greak em=into, bruein=swell or grow. Usually, embryo means the early stage in the development of plants, animals and humans. Embryo is formed due to multiplication of zygote cell which is the resultant effect of fertilization of egg or female gamete by the sperm or male gamete in sexual reproduction. Antonie van Leeuwenhoek first described polyembryony in 1719 when the seed in *Citrus* was observed in having two germinating embryos (Batygino and Vinogradera, 2007). Fertilization in flowering plants was discovered by Strasburger in 1884. He also gave the idea of double fertilization in which one of the male gamete fuses with ovum to form zygote and another male gamete fuses with two polar nuclei to form triploid primary endosperm nucleus. Thereafter, various workers have paid due attention to study the events of fertilization in plants (Faure, 1999; Dresselhaus *et al.* 2016). Hertwing (1876) discovered first the nature of fertilization-the fusion of the eggs and spermatozoon's nuclei to produce a zygote, in sea urchin. Thereafter, studies on the events of fertilization enabled us to recognize the four processes (i) sperm preparation, (ii) sperm recognition and binding, (iii) sperm-egg fusion and (iv) fusion of sperm and egg pronuclei and activation of the zygote (Wassaman1999; Georgadki *et al.* 2016; Ebisa *et al.* 2017)

As a rule, one male gamete fertilizes one female gamete and as a result one embryo is developed to produce one offspring. But there are ample evidences of production of many embryos from one ovule. The phenomenon is known as polyembryony. Interestingly, having only one egg in an ovule how and why more than one embryo is produced is a matter of discussion for a long time by the developmental biologists. In the present article an attempt has been made to interpret the available information with a view to determine the possible origin, evolutionary pathway of polyembryony.

Genesis of Polyembryony

It is the inherent property of organisms to maintain their race all along. In fact, it's a challenge to species to recruit the organisms as many as possible, in respect to negotiation capacity to overcome environmental hardship. Thus, many monerans, protists and fungi have developed the art of enhancement of their recruitment rate by applying various reproductive strategies viz. binary fission, multiple fission, sporulation etc. where each fragment of the parent's body succeeds to produce one organism. In *Plasmodium*, in the midgut lumen of *Anopheles* mosquito, gametes fuse to form zygote that develop into motile ookinetie. Ookinete traverses the midgut-epithelium and transforms into oocyst. Multiple rounds of endomitotic replications inside an oocyst result in production of thousands of sporozoites, a process known as sporogony. The oocyst ruptures in due course of time and the sporozoites migrate to the salivary gland for transmission to humans via a mosquito bite (Habtewold *et al.* 2021). Likewise, in many multinucleated organisms plasmotomy is well evident. In

Opalina, the multinucleated cell divides and forms multiple nuclei without the process of mitosis. Thus, from a multinucleated parent body two similar daughter cells, because of binary fission, are produced. This process is continued unabatedly. Therefore, plasmotomy is something which is uncountable. But it is a type of asexual reproduction. Thus, there are ample examples in protozoa where the parent organism divides into daughter organisms without the process of cell division.

It is well evident that, to increase their progeny rather numbers the monerans, protists and fungi have evolved different types of reproduction strategies. But it is, at the same time notable that the rate of recruitment through asexual reproduction means is always higher in respect to individuals produced by them through sexual reproduction. Such a behavioral trend in asexual reproduction in organisms belonging to lower taxa tempted them to increase the rate of recruitment of individuals through sexual means. Though in most cases both asexual and sexual reproductions are in progress and the occurrence of new variety of individuals do not get overlooked by the concerned species it is most likely that these organisms would try to develop the strategy so as to ensure the appearance of more and more individuals through sexual reproduction. This is more so, as the sexually produced organisms are more effective to overcome the environmental hazards because of inherent effective properties developed due to the exchange of genetic materials. For argument, if large number of asexually produced individuals are exposed to same kind of adverse environmental conditions, then, one cannot expect survival of a single individual because of non-variations in their withstanding ability. On the contrary, whatever be the number of sexually produced individuals of a species one cannot rule out the possibility of survival of some individuals who have developed more plasticity because of genetic make up, somehow different to others. As a consequence, a lineage is evolved either from a single source or from different sources side by side to enhance the production of quality offspring through sexual reproduction to strengthen the survival rate of their race. It is, actually, the 'will force' (Raut 2017) of the groups of certain taxa that enabled them to shape the strategy of polyembryony where many individuals but with different genetic makeup would be pronounced.

Evidences of Polyembryony

Leeuwanhoek in 1719, observed the emergence of two plantlets from the same citrus seed and thus recognized polyembryony. The term polyembryony, thus used by the botanists first. Plant embryologists applied the said term in all cases in which multiple embryos are formed in the embryo sac, no matter from which source the embryos are originated. It is opined by the botanists that, in plants multiple embryos (polyembryony) may arise from two eggs inside an ovule or from any one of the following sources: nucellus integument, synergids, antipodal cells, endosperm cells and suspensor. In contrast, animal embryologist is confined to apply the said term to cases in which several embryos are developed from one egg.

Polyembryony in Plants

Polyembryony is so frequent in gymnosperms that it may be considered a distinguishing feature of the group. In the majority of gymnosperms with polyembryony, a female gametophyte develops two or more archegonia. As each archegonium carries an egg, the presence of multiple archegonia results in two or more eggs being fertilized, resulting in the creation of two or more possible embryos (Harshitha, 2022). Polyembryony may be of (1) Induced polyembryony (i.e., induced artificially) and (2) Spontaneous polyembryony (i.e., naturally occurring polyembryony). But, according to Webber (1940) polyembryony may be of (1) Cleavagepolyembryony (when a young embryo or zygote divides into two or more units) – where each unit eventually develops into independent embryo. It is common in gymnosperms but rare in angiosperms. *Pinus* may be cited as a good example where zygote splits twice, resulting in four nuclei (2) Simple polyembryony occurs when more than one egg or a large number of archegonia (a haploid structure that generates female gametes) are fertilized. *Pinus* is a good example for this type of polyembryony. (3) Rosette polyembryony, where additional embryos emerge from the rosette cells in some gymnosperms (e.g., a few species of *Pinus*) and the kind of polyembryony is known as rosette polyembryony.

In Cycadales simple polyembryony is seen in rare cases. Rao (1964) first detect the polyembryony in *Cycas circinalis.* It is stated that two adjacent archegonia from the same ovule can sometimes develop into two embryos and in rare cases, two seedlings. Simple polyembryony, cleavage polyembryony have been noted in Coniferales also. In Taxales the female gametophyte has many archegonia and many of their eggs might be fertilized; resulting in simple polyembryony. Surprisingly, only one embryo matures at the end of the process. Also, suspensor cell cleavage is observed in *Taxus* (Sterling, 1948). Here, the suspensors are separated from one another and may each contain one or more embryonal units. Occasionally, the clusters of meristematic cells locating at the base of suspensor cells, produce the rosette embryos. Cope (1998) discussed at length on the aspect of polyembryony in Taxaceae.

In Gnetales polyembryony occurs in various ways : (a) each of the primary suspensor tube has the potential to produce an embryo at its tip and, thus produce a large number of embryos; (b) the embryonal mass at the secondary suspensor's tip may grow and give birth to more embryos; (c) the cells of the secondary suspensor can sometimes become meristematic, resulting in large number of embryos, and (d) instead of one group of cells, two or more groups of cells may be generated in the main suspensor tube, resulting in a large number of embryos at the top.

Angiosperms present the unique phenomenon of double fertilization. But the occurrence of polyembryony has been noted (a) because of budding or cleavage of zygote where a single fertilized egg produces a number of embryos; (b) due to fertilization of synergids where a number of embryos are formed as a result of fertilization of eggs along with synergids; (c) polyembryony may be due to the fertilization of eggs along with antipodal cells, and (d) formation of embryos from the structure outside the embryo-sac (adventive polyembryony) like nucellus and integuments.

Polyembryony in Animals

In animals polyembryony has been recorded in Cnidarians, Cestodes, Trematodes, Oligochaetes, Bryozoans, certain colonial invertebrates, insects, echinoderms as well as in mammals (Nancy 1997, Craig *et al.* 1997, Loughry *et al.* 1998, Strand 2009, Tenkins *et al.* 2017, Subramaniam, 2018). Most animals exhibit an accidental type of polyembryony, or twinning, in which a single egg obligatory form is very rare. Twinning itself must be regarded as the simplest type of polyembryony. In bryozoans, insects and some other invertebrates polyembryony is the resultant effect of embryonic cloning where the splitting of one sexually produced embryo into many offspring which are genetically identical to each other but distinct from their parent(s) (Subramaniam 2018). In cyclostome bryozoa cloning occurs by fission of blastula stage-embryo, with each blastomere becoming an individual offspring. Of the insects, the female wasp, *Copidosoma,* oviposits one or two eggs inside the moth egg, which develops subsequently into a caterpillar larva. Inside the moth larva, the wasp's egg develops into a single compact mass of cells, called morula, which fragments into a large number of diminutive units that develop into two types of larvae. One type develops into a normal fertile adult, while the other type, called soldier larva, has a thin worm-like body, and becomes sterile.

Of the vertebrates, armadillos are the most well studied vertebrate which are always polyembryonic (6 species) (Loughry *et al.* 1998). Four identical young are produced at a time. There are two conditions that are expected to promote the evolution of polyembryony: the mother does not know the environmental conditions of her offspring as in the case of parasitoids or a constraint on reproduction (Craig *et al.*, 1997). It is thought that nine banded armadillos evolved to be polyembryonic because of the latter (Loughry *et al.* 1998). Recently, Wu and Ye (2022) reported the possible polyembryony in the world's largest salamander, *Andrias davidianus*

Polyembryony in Humans

A Malian woman broke records by giving birth to nine babies (five daughters and four sons) in a single pregnancy (timesofindia.com, up-dated: Apr 3, 2022, 20:28 1st). However, production of two babies in more common than a greater number of babies in humans. It is stated that, following splitting of one fertilized egg (ovum) two embryos took the shape and finally two babies with exactly the same genetic information are produced. On the other hand, in case of dizygotic, twins, two eggs (ova) are fertilized by two sperms and produce two genetically unique children.

Twinning rate is gradually increasing in human population. A detailed account on the said aspect have been discussed at length by Monden *et al.* (2021). Also, it is reported that, in humans medically assisted reproduction (MAR) has been one of the main drivers of increasing twin rates in several countries (Imaizumi 1997; Bondel and Kaminshi 2002; Hoekstra *et al.* 2008; Martin *et al.* 2012; Pison *et al.* 2015; Gomez *et al.* 2019). But still, it is not clear how MAR is stimulating to increase the rate of twin production (Monden *et al.* 2021).

Inference

Polyembryony is a strategy in some groups of organisms to enhance the rate of recruitment of offspring as a product of sexual reproduction. As a rule, sexually emerged individuals are, because of different genotypic make-up, more effective to overcome the adverse environmental condition to ensure their survival. Since, in sexual reproduction the rate of production of individuals is always higher in respect to the output of sexual reproduction, the strategy developed by the organisms to maximize the number of offspring is triggered by the evolutionary forces only to ensure more adaptability in respect to changing environmental conditions than asexually produced individuals. Accordingly, the device either by utilizing certain germinal cells or the somatic cells occurring adjacent to germinal cells adopted by certain species to develop the egg or the embryo evolved following fertilization to produce similar kinds of numerous embryos, of course, different in nature, in respect to their parents.

The sort of recruitment behaviour undoubtedly one step forward in respect to plasticity of a sexually reproduced individuals so far survival and propagation are concerned. It is still a debate how polyembryony is shaped in course of evolution of various types of population recruitment strategies among species and also, how such mechanism is genetically operated.

Conclusion

Though various attempts have been made to throw light on the evolutionary significance of polyembryony no attempt has ever been made to determine the origin of polyembryony. Available reports are confined to certain gymnosperm and angiosperm species as well as in certain species of cnidarians, platyhelminthes, trematodes, cestodes, oligochaetes, insects, echinoderms, bryozoans, armadillo mammals as well as in humans. Obviously, these reports are sporadic and exists no consistency in the published reports to say few words on the trend of polyembryony through phylogenetic lineage.

Thus, it requires sequential studies among different taxa in hierarchical order. However, it is assumed that, the polyembryony event was triggered through the development of sporozoites in the mosquito host of *Plasmodium*, the causative agent of malaria disease.

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