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4 Morphology of the Viscerocranium and Evolution of Vertebrates -Evidence of Experimental Neoteny Using Ascidia-

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Viscerocranium of mammals is thought originated from branchial gut of archetype- ascidia of primeval vertebrate. In this paper experimental evolutionary study is reported. Larval metamorphosis of ascidia was successfully induced in experiment in artificial sea water with gadolinium ion. The mechanism of larval metamorphosis was considered biomechanically. Use and Disuse Theory of Lamarck was evidenced. Biomechanics was originated by W. Roux about 100 years ago, who convinced that for development and differentiation of organism not only gravity but mechanical stress was essential.

Key Words: Larval metamorphosis, Ascidia, Use and disuse theory, Biomechanics, Hemopoiesis, Artificial bone marrow, Physical stimuli, Experimental evolutionary study

1. Introduction

Reviewing the evolutionary history, the process of the primitive ascidia losing the opportunity to attach itself to a rock in its larval form thereafter, advancing to be a vertebrate in maturity[1, 2]. When this all-mouth organism ascidia is on its evolutionary way to becoming a vertebrate, eventually differentiating into the four sections of the face which represent organism, neck, chest and abdomen.

Origin of the face is in the life organism itself of the primitive ascidia which was constructed with almost all mouth having the gill cleft; gradually becoming differentiated, in the process of evolution, into the four sections[3].

2. Experiments

To clarify a cause of larval metamorphosis of ascidia, following working hypothesis was set.

1)Larval metamorphosis occurs if sticking of larva is disturbed.

2)Larval metamorphosis occur if concentration of mineral ion in sea water is changed.

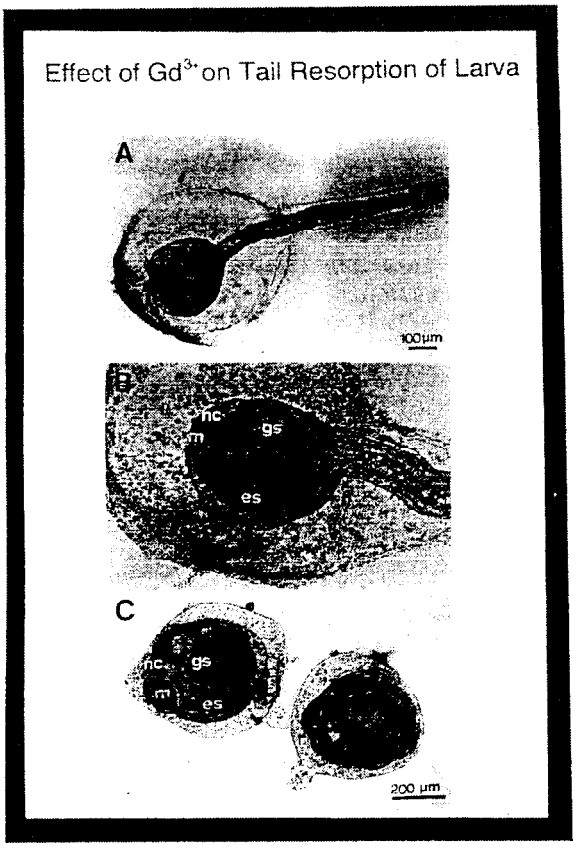
Following experiments were carried out in the Misaki Marine Biological Station, the University of Tokyo.

1) Ova of ascidia (Maboya and Katayureiboya) were incubated in natural water 13°C and 18°C, respectively which was whirled with stirrer to inhibit sticking of ascidia.
2) Ova of ascidia (Maboya) were hatched in natural sea water, after that incubated in Fandhoff's artificial sea water (PH8.2) 13°C in following condition,
   (1) Artificial sea water with 10^{-5}/mM calcium ions.
   (2) Artificial sea water with 10^{-5}/mM gadolinium ions instead of calcium ions.
   (3) Natural sea water for control.

3. Results

1) Ova of ascidia were incubated and transformed normally by stimuli of whirled sea water.

2) In artificial sea water:
   (1) With 10^{-5}/mM calcium ions among 500 of hatched ascidia metamorphosis occurred in 30 with half shrunk tail.
   (2) With 10^{-5}/mM gadolinium ions among 500 0f hatched ascidia, metamorphosis with tail occurred in 30 (Fig.).
   (3) In natural sea water, all of ova hatched and transformed normally.



4. Discussion

The viscerocranium, as the name itself suggests, was phylogenically derived from the visceral muscle (smooth muscle) which existed in the respiratory visceral system of branchial intestine and its auxiliary skeletal system.

Haeckel integrated comparative anatomy (Cuvier, 1795) with embryology through his study of the ontogenesis of vertebrates, and set forth his famous Recapitulation Theory (Biogenetic Law) together with the new terms "phylogeny" and "ontogeny" based on observational studies. The new term "Recapitulation" proposed by Haeckel means in vertebrates, the main portion (head) of development is seen as if it repeats phylogenesis in a short time after fertilization." Recapitulation theory was unable to explain neoteny, which was discovered later, and for this reason this theory has been almost entirely ignored in this century. Roux, who succeeded Haeckel, discerned the essentially important effects of mechanics such as gravity behind both ontogenesis and phylogenesis, and proposed a new scient-ific area of "biomechanics". Through the introduction of biomechanics and molecular genetics, the relationship between ontogenesis and phylogenesis has been clarified and, at the same time, neoteny can now be explained as a genetic phenomenon. In the phylogenesis of vertebrates, the importance of the viscerocranium seems evident. The organ characteristics and essential functions of the viscerocranium can be understood by clarifying how the basic system of archetypes in vertebrates has been modified, and what factors have driven the evolution [3]. Today, the evolution of vertebrates is considered to be dependent upon the characteristics of the collagen apatite complex (Halstead); and surveying the evolution of the oro-maxillofacial organ from the above mentioned viewpoint, a close relationship between the organ and biomechanics can be clearly discerned [3]. The mysteries of the evolution of vertebrates lie in the biomechanical properties of apatite which is the characteristic material in vertebrates and, therefore, there is a possibility of demystifying evolution by investigations integrating phylogenesis,

paleontology, morphology, molecular genetics, immunology, and biomechanics [3]. The starting point of vertebrates was when pterobranchia, having a cutaneous respiratory system, took the gill cleft into the intestine [1]. Since this was the first step to the vertebrates, it can be seen as the primeval vertebrate revolution [2]. And then the first overt vertebrate revolution is said to be the acquisition of teeth and jaws by the acanthodii in the Silurian period. The second vertebrate revolution is the dramatic terrestialization from water that occurred in the Devonian period. By biomechanical response, a drastic conversion occurred not only from branchial to pulmonary respiration, but also in ossification of the cartilaginous endoskeleton [3]. Phylogenical change in morphology can be explained biomechanical response of topographical skeletal organs to physicochemical stimuli, which affect to organisms internally or externally just as Use and Disuse Theory of Lamark [4]. In this way organisms even with changeless genetic character transform their morphology according to physicochemical stimuli applied as environmental factors.

Nishihara, one of authors has successfully induced hemopoiesis conjugated with osteoid formation by means of experimental evolutionary research method, i.e., implantation of artificial bone marrow chambers of sintered hydroxyapatite in muscles of cyclostomata, chondrichthyes, amphibian, and mammals [5]. He has also evidenced mechanism of bone remodeling in functional adaptation, i.e., Wolff's Law using artificial bone marrow chamber with bone morphogenetic protein and electric stimuli[5,6]. Both hemopoiesis in bone marrow in archetype vertebrate and bone remodeling system by biomechanical loading are induced by the gene expression of undifferentiated mesenchymal cells by physicochemical stimuli, i.e., streaming potential with calcium and phosphate ions [6]. Larval metamorphosis, i.e., neoteny of ascidia can be understood as the gene expression of mesenchymal cells in skeleton by physicochemical stimuli e.g., gadolinium just as bone marrow hemopoiesis by biomechanical stimuli.

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