Title	A study of the formation of folding that extend to a 3D morphology in insects
Author(s)	足立, 晴彦
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論　文　内　容　の　要　旨

氏　名　（足立　晴彦　　　　　）	
論文題名	A study of the formation of folding that extend to a 3D morphology in insects (昆虫における展開後に三次元形態になる折り畳み形成に関する研究)

論文内容の要旨

Morphogenesis mechanisms are an important issue in the field of developmental biology. In the study of morphogenesis, much research has focused on embryogenesis, which is the process of drastic morphological change from a single cell. On the other hand, morphogenesis after embryonic development is not well understood. Metamorphosis is a characteristic example of drastic morphological changes that occur after embryogenesis. It is important issue to analyze the morphogenesis of metamorphosis in that the size scale is different from embryogenesis. In this study, I focused on the insect especially beetle horn and treehopper, morphogenesis through molting in the post-embryonic development.

Beetle horns are not present in the larvae, but suddenly appear when the beetle molts into a pupa. In a previous study, it was reported that beetle horns exist in a folded state in the head of the final instar larvae just before molting, and that simply physically expanding them would result in the final horn shape. On the other hand, there was no understanding of how the folding formation was controlled. Therefore, in this study, I first analyzed the formation of the horn primordia in the beetle. Analysis of the horn primordia of dachsous (ds) RNAi, which were known to get thicker and shorter horns, revealed that the macro shape of the horn primordia (especially the stalk portion of the mushroom morphology) changed significantly, while the micro furrows remained almost unchanged. Analysis of cell division showed that the anisotropy of cell division was abolished in ds RNAi. This suggests that macroscopic morphology and microscopic wrinkles are independently regulated, and that anisotropy of cell division is involved in macro shape. From the analysis of beetle of different body sizes, it was found that the depth of microscopic wrinkles and surface pattern (direction) did not change with size. Then, I searched for RNAi individuals in which these parameters were changed. As a result, I found that the Notch gene and cyclinE gene play important roles in each. In addition, I found that in the control primordia, the frequency of cell division was higher in the areas where concentric folding patterns were expected to form than in other areas. In addition, in Notch RNAi, the pattern of cell division was not disrupted, but the overall frequency of division was reduced, as seen in controls. Furthermore, in cyclinE RNAi, the frequency of cell division was reduced compared to controls only in areas where concentric folding patterns were expected to form. These results indicate that the pattern (direction) and depth of folding of the horn primordia of the beetle are formed by independent mechanisms. It was also suggested that the regulation mechanism could be the control of the overall cell division frequency and the pattern of division frequency.

Next, in order to confirm the hierarchical developmental process observed in beetle horns, which also occurs in the morphogenesis of hemimetabolous insects, helmet structure of the treehoppers, which suddenly appears during molting into an adult, was focused on. Histological analysis using a combination of μCT, SEM, and paraffin sections revealed a continuous process of macro shape and micro furrow formation, suggesting the existence of a universality of morphogenesis process through folding and unfolding.

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論文審査の結果の要旨及び担当者

氏　名　（　足立　晴彦　）			
論文審査担当者		（職）	氏　名
	主 査	教授	近藤　滋
	副 査	教授	佐々木　洋
	副 査	教授	上田　昌宏
	副 査	教授	木村　真一

論文審査の結果の要旨

硬いクチクラで覆われている節足生物は、脱皮により成長を行う。その中で、特定の節足動物の器官は脱皮の前後で大きく形が変わることがある。例えば、カブトムシの角は、幼虫時には存在せず、蛹になると突然現れる。脱皮に先立ち、①古い外骨格の内側に新しい外骨格を「折り畳んだ」状態で作っておき、②これを脱皮時に物理的に展開するという２段階の発生機構が、この現象を可能にしている。一方で、この折り畳みをいかにして形成しているのかはほとんど明らかになっていなかった。足立氏の研究は、カブトムシの角に加えて、近縁種で多様な形を持つツノゼミのヘルメットを対象に、RNAi による遺伝子機能阻害や組織学的解析を用いて、その折りたたみ形成機構を解析し、構造を階層的に分けることで、その共通性と違いについて議論した。本研究内容は、昆虫の形態形成原理に関する、極めてユニークで重要な貢献をしており、学位授与に値すると判断した。