様式４

平成２７年度　学術振興基金助成による成果報告書

平成２７年６月２３日

学　長　　殿

所属部局・職名　共生システム理工学類教授

申　請　者　名　塘　　忠顕

助成事業の区分 (該当するものに○印)	研究協力に関する事業 （学術出版・叢書・○学会等） 学術振興に関する事業 （学生・事務職員・その他の特別事業）
事　　業　　名	日本節足動物発生学会第51回大会及び本学会が本大会前に開催する公開講演会
事業実施期間	平成２７年６月１２日　～　平成２７年６月１３日
成果の概要	日本節足動物発生学会第51回大会は平成27年6月12-13日，福島県耶麻郡北塩原村の休暇村裏磐梯天文台ホールにて開催された。参加者は福島大学の他，筑波大学，愛媛大学，名古屋大学，自治医科大学，生物資源研究所，海洋研究開発機構，JT生命誌研究館，横須賀市自然・人文博物館などに所属する34名の研究者・大学院生などで，講演題数は本大会前に開催した公開講演会における特別講演２題，本大会の一般講演11題，学会奨励賞受賞者による受賞講演１題の計14題であった（福島大学からは教員３名，大学院生等８名が参加し，教員１名，大学院生２名が研究発表を行った。）。 初日（12日）の13:00からの公開講演会は，２名の外国人研究者を演者に迎えて実施した。世界的に著名な昆虫形態学者であるProf. R.G.Beutel（ドイツ・イェーナ大学）は「The Evolution of Megadiversity in Hexapoda (Arthropoda) 」とのタイトルで，新進気鋭の昆虫形態学者であるDr. A. Blanke（ドイツ・ボン大学）は「Mouthpart Evolution in Early Hexapoda」とのタイトルで，それぞれの分野における最新の知見を盛り込んだ非常にエキサイティングな講演をされた。 学会大会は学会奨励賞を受賞した筑波大学菅平高原実験センター所属のPD真下雄太氏による受賞者講演「Comparative Embryology of Zoraptera」，そして，昆虫の胚発生，形態の機能解析，遺伝子発現解析，節足動物の系統進化，新しい研究手法の導入など多様な分野にわたる一般講演が実施された。11題の一般講演のうち9題のプレゼンテーションが英語で実施され，いずれもアクティヴなディスカッションが繰り広げられた。 最後に学会の総会が開催され，２日目（13日）の14:00にすべてのプログラムが終了した。

日本節足動物発生学会第51回大会プログラム（福島・裏磐梯　2015年6月12-13日）
Program of the 51st Annual Meeting of the Arthropodan Embryological Society of Japan
Urabandai, Fukushima, Japan, June 12-13, 2015

6月12日（金）　June 12 (Friday)

12:00　受付開始　Reception

13:00　公開講演会　Special featuring lecture (Extension Lecture)

座長：町田龍一郎　Chairperson, MACHIDA Ryuichiro

13:00-13:10　開会　小林幸正会長　Opening Address by Yukimasa KOBAYASHI (President of AESJ)

13:10-14:30　**Rolf Georg BEUTEL**　/Institut für Spezielle Zoologie und Evolutionsbiologie,Friedrich-Schiller-Universität Jena
The Evolution of Megadiversity in Hexapoda (Arthropoda)

14:30-15:10　**Alexander BLANKE**[1,2]　/[1]Sugadaira Montane Research Center, University of Tsukuba, [2]Zoologisches Forschungsmuseum Alexander König, Rheinische Friedlich-Wilhelms-Universiät Bonn
Mouthpart Evolution in Early Hexapoda

15:30　一般講演1（座長：内舩芳江）　General session 1 (Chairperson, UCHIFUNE Yoshie)

01　15:30　○**MASHIMO Yuta, MACHIDA Ryuichiro**　/Sugadaira Montane Research Center, University of Tsukuba
A challenge to the subcoxal theories of pleural and sternal origins in insects

02　15:50　○**HARADA Atsuhiro, FUKUI Makiko**　/Graduate School of Science and Engineering, Ehime University
Egg structure and egg tooth in Orthoptera (Insecta・Polyneoptera)

03　16:10　○**NIITSU Shuhei**[1,2]**, KAMITO Takehiko**[2]　/[1]Graduate School of Science and Engineering, Tokyo Metropolitan University, [2]Graduate School of Arts and Science, International Christian University
Early cellular and histological changes induced by ecdysteroid in the pupal wing epithelium of the wingless-female winter moth

16:30-16:40　休憩　Coffee break

16:40-16:50　安藤　裕賞　表彰式　Ando Hiroshi Award Ceremony

16:50-17:30　安藤　裕賞　受賞講演　Ando Hiroshi Award Speech

04　16:50　**MASHIMO Yuta**　/Sugadaira Montane Research Center, University of Tsukuba
Ando Hiroshi Award Speech

18:00-20:00　シンポジウム（夕食付き）　Symposium with Dinner

20:00-　ワークショップ　Workshop

6月13日（土）　June 13 (Saturday)

07:30-08:30　朝食　Breakfast

08:30-　一般講演2（座長：福井眞生子）　General session 2 (Chairperson, FUKUI Makiko)

05　08:30　○**FUJITA Mari**[1]**, NOMURA Shuhei**[2]**, MACHIDA Ryuichiro**[1]　/[1]Sugadaira Montane Research Center, University of Tsukuba, [2]National Museum of Nature and Science
Simple, artifact-free SEM observations of embryos: "Nano-suit method"

06 08:50 ○**KOBAYASHI Yukimasa**[1], **SUZUKI Nobuo**[2], **SHIMIZU Satoru**[3] /[1]Sayama-shi, [2]Japan Women's College of Physical Education, [3]Ueda-shi

Labial egg burster of *Sialis japonica* and its possible phylogenetic significance: A comment on the article by Ando *et al.* (1985) (Megaloptera; Sialidae)

07 09:10 ○**MTOW Shodo, MACHIDA Ryuichiro** /Sugadaira Montane Research Center, University of Tsukuba

Comparative Embryology of Plecoptera (Insecta)

08 09:30 ○**KOJIMA Kazuki, MACHIDA Ryuichiro** /Sugadaira Montane Research Center, University of Tsukuba

Embryology of a "living fossil" beetle, *Tenomerga mucida* (Chevrolat, 1829) (Archostemata, Cupedidae)

09:50-10:00 休憩 Coffee break

10:00- 一般講演３（座長：内舩俊樹） General session 3 (Chairperson, UCHIFUNE Toshiki)

09 10:00 ○**KIMEZAWA Yurie**[1], **KANEKO Shingo**[2], **TSUTSUMI Tadaaki**[2] /[1]Graduate School of Symbiotic Systems Science and Technology, Fukushima University, [2]Faculty of Symbiotic Systems Science, Fukushima University

Molecular phylogeny of *Thrips* genus-group (Thysanoptera: Thripidae) based on nuclear 18SrDNA sequences

10 10:20 ○**GOTOH Hiroki**[1], **OKANISHI Masanori**[2], **YAGINUMA Toshinobu**[1], **NIIMI Teruyuki**[1] /[1]Nagoya University, Bioagricultural Sciences, [2]Kyoto University, Field Science Education and Research Center

Molecular phylogeny of genus *Cyclommatus* (Coleoptera, Lucanidae)

11 10:40 ○**OHIRA Hajime**[1], **KANEKO Shingo**[2], **TSUTSUMI Tadaaki**[2] /[1]Graduate School of Symbiotic Systems Science and Technology, Fukushima University, [2]Faculty of Symbiotic Systems Science, Fukushima University

Molecular phylogeny of genus *Mundochthonius* (Pseudoscorpiones: Chthoniidae) reveals the existence of multiple cryptic taxa and their complex distribution pattern

12 11:00 **SATO Koichi**[1], **OHIRA Hajime**[2], **TSUTSUMI Tadaaki**[1], ○**KANEKO Shingo**[1] /[1]Faculty of Symbiotic Systems Science, Fukushima University, [2]Graduate School of Symbiotic Systems Science and Technology, Fukushima University

Intraspecific molecular phylogeny of putative parthenogenetic pseudoscorpion, *Microbisium pygmaeum* (Iocheirata, Neobisiidae)

11:20-11:30 休憩 Coffee break

11:30- 一般講演４（座長：山本大介） General session 4 (Chairperson, YAMAMOTO Daisuke)

13 11:30 **TOMITA Shuichiro** /National Institute of Agrobiological Sciences

Regulatory role of homeotic genes in lepidopteran proleg development

14 11:50 **HATAKEYAMA Masatsugu** /National Institute of Agrobiological Sciences

Roles of homeobox genes in the proleg development in the sawfly, *Athalia rosae ruficornis*

12:10- 閉会 塘 忠顕大会実行委員 Closing address by Tadaaki TSUTSUMI (Convener)

12:10-12:20　写真撮影　Taking Photos of participants

12:20-13:00　昼食　Lunch

13:00-　総会 General meeting of AESJ

日本節足動物発生学会第51回大会は福島大学学術振興基金の助成を受けて開催しています

Arthropodan Embryological Society of Japan

Special Featuring Lecture (Extension Lecture)

June 12, 2015
13:00 - 15:10 in Tenmondai Hall, National Park Resort URABANDAI

PROGRAM

13:00 **Opening Address**
Yukimasa KOBAYASHI (President of AESJ)

13:10 **The Evolution of Megadiversity in Hexapoda (Arthropoda)**
Rolf Georg BEUTEL (Institut für Spezielle Zoologie und Evolutionsbiologie, Friedrich-Schiller-Universität Jena)

14:30 **Mouthpart Evolution in Early Hexapoda**
Alexander BLANKE (Sugadaira Montane Research Center, University of Tsukuba, Zoologisches Forschungsmuseum Alexander König, Rheinische Friedlich-Wilhelms-Universiät Bonn)

Chairperson:
Ryuichiro MACHIDA (Sugadaira Montane Research Center, University of Tsukuba)

本講演会は福島大学学術振興基金の助成を受けて開催しています

The Evolution of Megadiversity in Hexapoda (Arthropoda)

Rolf Georg BEUTEL

Institut für Spezielle Zoologie und Evolutionsbiologie, Friedrich-Schiller-Universität Jena, GERMANY

With ca. 1.000.000 described species Hexapoda comprise more than half all known organisms. The topic of this presentation is the evolution of this unique diversity. **"Evolutionary szenarios" without sound phylogenetic basis are problematic**. Fortunately now a robust phylogeny for Hexapoda is abvailable from the international **1KITE** project.

Traditionally Hexapoda are placed in Tracheata with Myriapoda, suggesting that a common Silurian ancestor acquired terrestrial habits and specific adaptations (e.g. tracheal system). The well suppported new Pancrustacea concept implies that hexapods and myriapods invaded land independently. Under similar selective pressure they independently evolved a tracheal system and other features. **Evolutionary scenarios are only as good as the underlying phylogenetic hypothesis. The picture can change radically when long accepted systematic concepts turn out as wrong.**

A conspicuous autapomorphy of Hexapoda is a tagmosis with 3-segmented thorax and 11-segmented abdomen. It is uncertain whether this has contributed to the evolutionary success. **If characters have independently evolved in non-related succesful groups, it is likely that they have played a role in the diversification.** As the tagomisis of Hexapoda is unique this does not help in this case. The division of labor within the body could be an advantage, with the thorax specialized on locomotion and digestive and genital organs concentrated in the abdomen. This has aparently not have caused a burst of diversification as the diversity of basal groups is low. However, the compact thorax was a necessary precondition for the evolution of flight.

Collembola are clearly the most diverse apterygote group. The jumping capacity (flight mechanism), the ecological versatility and the high reproduction rate have contributed to the diversification. An important evolutionary novelty of Insecta (=Ectognatha) is the ovipositor, linked with the capacity to deposit eggs in narrow crevices or plant tissue. The subdivided tarsus is a precondition for the development of tarsal attachment devices, which enable insects to walk efficiently on plant surfaces. The dicondylic manibular articulation is an important innovation of Zygentoma + Pterygota (Dicondylia). Due to reduced degrees of freedom at the mandibular base more powerful biting movements are possible and a much broader spectrum of food can be processed.

The most important innovation in insect evolution was the development of wings. Pterygota comprise ca. 99% of all species. Advantage are the increased ability to escape predators and a greatly increased dispersal capacity. The latter also applies to the successful non-related spiders (Aranea) which fly as juveniles using silk rafts. In the Carboniferous - linked with the evolution of flight - the first great wave of diversification takes place. Another important novelty is internal sperm transfer. The increased reproductive economy has also contributed to the evolutionary success. The extreme diversity of the genitalia is mainly caused by sexual selection (female cryptic choice). An example of an **evolutionary arms race** is that females vary their genitalia to aggravate fertilization and that male genitalia vary to overcome the obstacles.

A key innovation of Neoptera (Pterygota excl. Ephemeroptera and Odonata) is the ability to fold back the wings, resulting in the ability to hide in narrow spaces, which means better protection and reduced water. Another apomophy is the arolium, the first of several types of attachment devices. Plants modify their surfaces to prevent insects from walking and feeding on them and insects modify their attachment devices to overcome these obstacles. This is another example for an **evolutionary arms race**.

Neoptera are divided into 3 large groups, Polyneoptera, Acercaria and Holometabola. The strongly debated monophyly of Polyneoptera is now confirmed, especially by embryonic features. The only very diverse group is Orthoptera, characterized by jumping legs, acoustic communication, and primarily phytophagous habits. Insect-plant interrelationships have played a major role in the diversification of different groups. Two secondarily wingless groups, Grylloblattodea and Mantophasmatodea, comprise only ca. 50 species. An advantage in the former is the reduced risk to be drifted away by wind. The very low diversity is related with the drastically reduced dispersal ability.

A key characteristic of Acercaria (Psocodea, Thysanoptera, Hemiptera) is the piercing-sucking apparatus, but this is not a groundplan feature. Ca. 90% of the species (ca. 100.000) belong to Hemiptera. Phytophagous habits have trigered this megadiversification and highly diverse attachment devices enable them to move very efficiently on plant surfaces. The non-phytophagous Psocodea comprise only ca. 7.000 spp. Cicada (ca. 42.000 spp.) show evolutionary parallels to the successful Orthoptera, a very good jumping capacity and acoustic communication. Consequently both character complexes have contributed to the diversification in both groups.

Holometabola is extremely diverse with ca. 800.000 spp. The holometabolous development is an important novelty but has not triggerd a major diversification in the early evolution of the group, as the diversity of several orders is low. The immobilized and unprotected pupa is a risk-factor in the life cycle (**evolutionary costs**). The ability of larvae and adults to use different resources is an advantage (decreased intraspecific competition).

Another key feature is the absence of external wing buds. It enables the larvae to penetrate under bark or to burrow in plant tissue, very narrow spaces not accessible for most predators. These factors do not sufficiently explain the extreme species richness. The diversification of the four extremely species rich oders ("Big4") was closely linked with the „angiosperm revolution" (Cretaceous). New food sources became available. Reciprocally insects have immensely contributed to the dispersal and evolutionary success of angiosperms as pollinators. The positive evolutionary interaction resulted in ca. 200.000 spp. of angiosperms and the fantastic number of ca. 800.000 spp. in Holometabola. **This is probably the most important example of successful co-evolution**.

Mouthpart Evolution in Early Hexapoda

Alexander BLANKE

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Insects evolved many mechanisms of food uptake. For example, dragonflies and crickets use biting actions of their mandibles to chop food particles, true bugs evolved piercing-sucking mouthparts to suck on plants, flies evolved sponging mouthparts, and moth and butterflies evolved the typical proboscis to siphon mostly nectar of flowers. Corresponding morphological changes are radical and morphologically very different to each other. However, the common morphological trend in many higher insects is that mouthparääts interact or, as a special case of interaction, even fuse together so that new mouthpart types are formed (e.g. the proboscis). It is unclear how this major trend in insect evolution – structural mouthpart interaction (SMI) of consecutive mouthparts – could evolve apparently multiple times independently e.g. in true bugs, bees and butterflies. Mouthpart diversification enabled the exploration of new food sources and accordingly was probably triggered by the evolution of vascular plants (~415Ma) and trees (~380Ma), the radiation of seed plants (~340-280Ma) and the radiation of flowering plants (~120-70Ma). Current hypotheses assume the rolling-biting mouthpart type without any form of SMI, but composed of mandibles attached with joint(s) to the head, as the potential ground pattern for insects (Archaeognathan mandible type). However, these theories neglect the mouthpart configuration and probable phylogenetic relationships of the earliest insects, Protura, Collembola and Diplura.

These minute, primary wingless, soil and leaf litter inhabitants are important decomposers of rotten organic material or feed on the sap of fungi hyphen, plant roots and other soft bodied soil arthropods. They possess mouthparts (mandibles and maxillae) which are almost entirely hidden within the head capsule (entognathous) and perform piercing motions through a narrow mouth opening to penetrate plant cell walls or soft animal tissue and suck out the liquids. Small food particles are also subsequently milled between the mandibles in many Collembola. Some species of Diplura prey on other soil organisms with their knive-like mandibles after hauling them towards the mouth cavity with the maxillae.

Due to their entognathy and their small size, mouthpart morphology and movement during food uptake has been a long standing enigma in Collembola and Diplura. Through the complementary use of three synchrotron microCT (SR-μCT) imaging setups, we investigated the mouthpart anatomy of Collembola and Diplura at high magnifications while entirely preserving the spatial arrangement of the mouthparts to each other. Their mouthpart morphology shows two unusual ways of SMI, based on homologous structures of mandibles and maxillae in conjunction with the hypopharynx and the head capsule. This leads to the conclusion that the foundation for the mouthpart interaction and fusion types in higher insects has already been present in the bauplan at the stemline of the earliest insects.

The evolution of two-jointed mandibles is considered to be another major step in the evolution of insect mouthparts. Two-jointed – or dicondylic – mandibles are believed to be a groundplan characteristic for winged insects and silverfish. Jumping bristletails are thought to possess mandibles with one joint and are the sistergroup of winged insects+silverfish. However, our knowledge of the cephalic morphology of bristletails is limited to data from a few species and thus fragmentary. Bristletails show a previously unknown coupling structure between the maxillary palps and the mandibles and an additional anterior articulation of the mandibles in the region of the anterior tentorial pits. The articulation can be homologised with the anterior articulation in silverfish and winged insects. Together with a description of the functional morphology of the mandible system of bristletails and a discussion of the homology of mandibular articulations and related characters, we provide conclusive evidence that bristletails are, in fact, dicondylic insects.