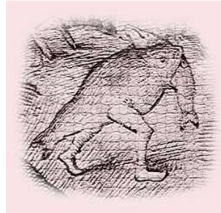
Лаборатория проблем эволюционной морфологии

Основные задачи лаборатории

Разработка проблемы целостности организма в онто- и филогенезе; исследование закономерностей морфологической эволюции и её механизмов; разработка критериев и принципов филогенетики; разработка методов оценки морфологического, морфогенетического, генетического и экологического разнообразия низших позвоночных на популяционном и видовом уровнях.

Экспедиции 2018-2020



Эфиопия
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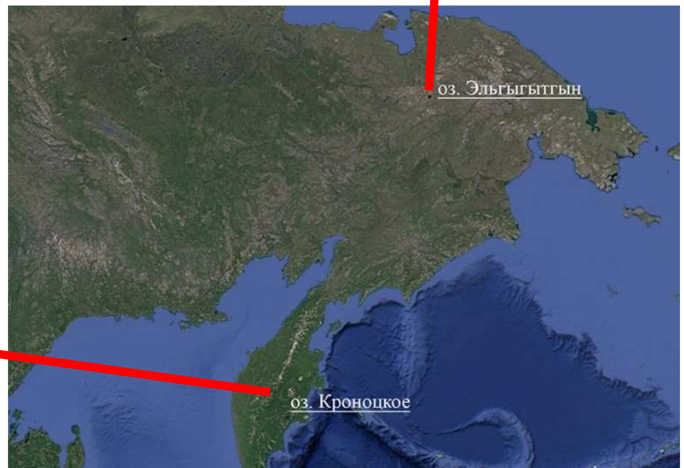
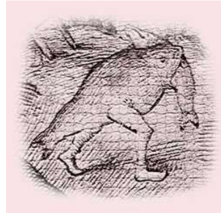


Важнейшие результаты



ВОПРОСЫ ИХТИОЛОГИИ, 2019, том 59, № 5, с. 1–11

УДК 597.593.7.574.24

ОСОБЕННОСТИ РАННЕГО ОНТОГЕНЕЗА АНАБАСА *ANABAS TESTUDINEUS* (ANABANTIDAE), СВЯЗАННЫЕ С ДИНАМИКОЙ ПЛАВУЧЕСТИ

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После доработки 04.01.2019 г.
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Представлены результаты исследования раннего развития анабаса *Anabas testudineus* в связи с динамикой его плавучести. Описаны основные особенности онтогенеза на протяжении первых 140 ч развития. Нетипичная для пресноводных рыб положительная плавучесть икры и ранних личинок анабаса, благодаря которой они развиваются под самой поверхностью воды, обеспечивается крупной жировой каплей, содержащейся в желтке. Приведены данные по ориентации тела личинок в пространстве, их вертикальному распределению в толще воды, началу экзогенного питания и локомоции, а также по двигательной реакции личинок на испуг в разном возрасте. Наиболее значимые изменения поведения личинок анабаса связаны с изменением формы желточного мешка, который с ~80-го ч развития начинает выполнять функции провизорного гидростатического органа.

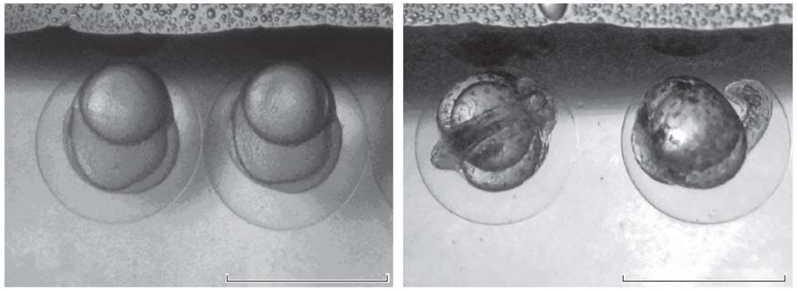


Рис. 1. Эмбриональное развитие анабаса *Anabas testudineus* под поверхностной плёнкой воды, вид сбоку: а – гаструла, 8 ч 51 мин с момента нереста; б – подвижный эмбрион с отделившимся хвостовым отделом, 20 ч 51 мин. Масштаб здесь и на рис. 2: 1 мм.

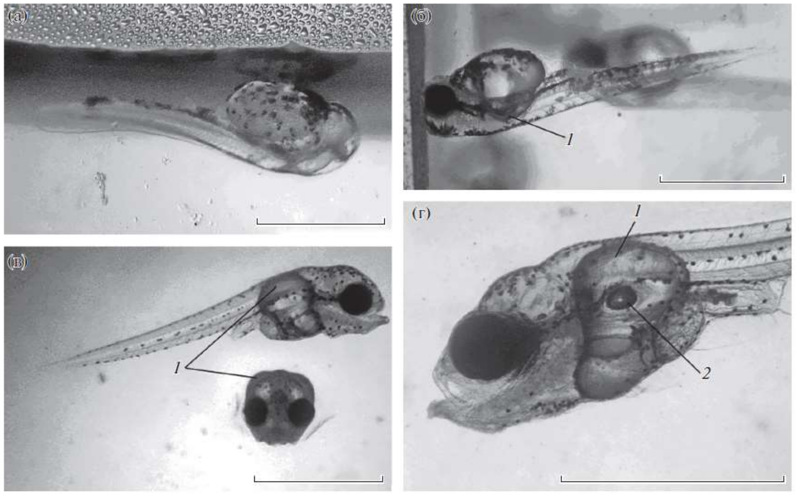
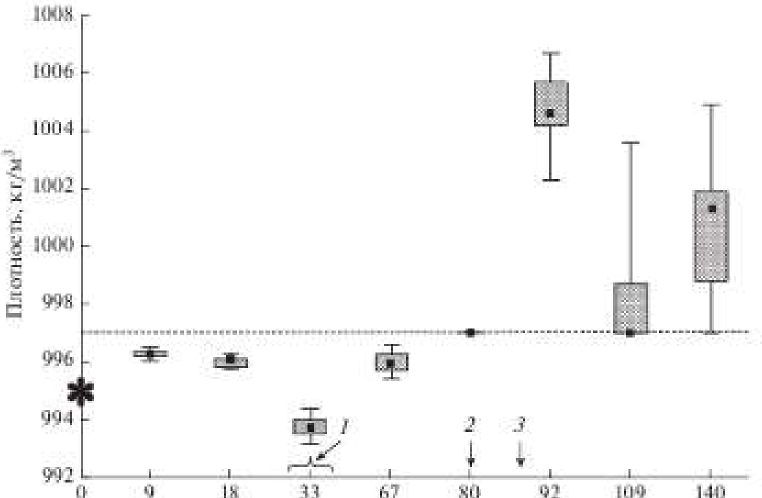
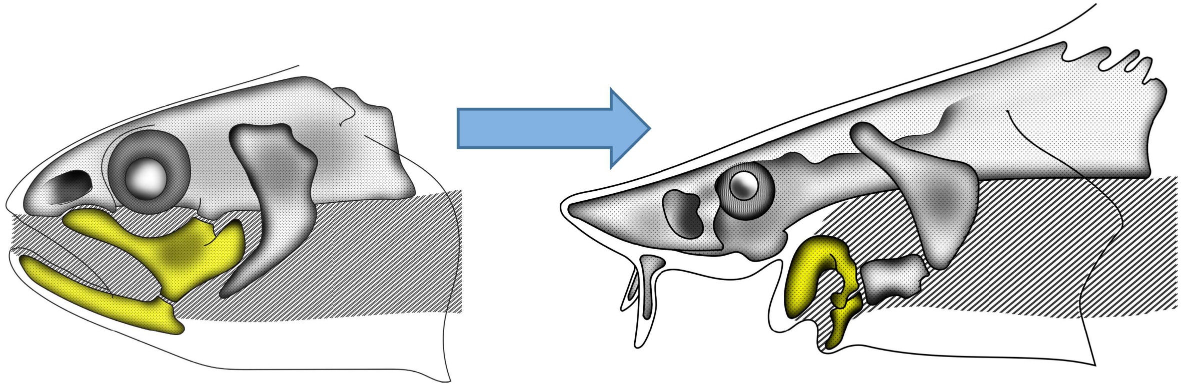
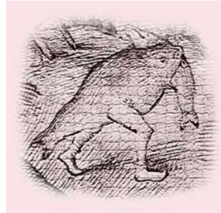


Рис. 2. Личинки анабаса *Anabas testudineus* возрасте: а – 31 ч 48 мин с момента нереста, б – 62 ч 44 мин, в – 79 ч 51 мин, г – 107 ч 55 мин; *1* – дорсальный вырост желточного мешка, *2* – плавательный пузырь, заполненный газом.



Важнейшие результаты





ЖУРНАЛ ОБЩЕЙ БИОЛОГИИ, 2019, том 80, № 5, с. 334–347

УДК 597.423

РОЛЬ ПЕДОМОРФОЗА В СТАНОВЛЕНИИ СТРУКТУРНОГО ТИПА ЧЕРЕПА ОСЕТРООБРАЗНЫХ (ACIPENSERIFORMES, ACTINOPTERYGII)

© 2019 г. А. А. Цессарский*

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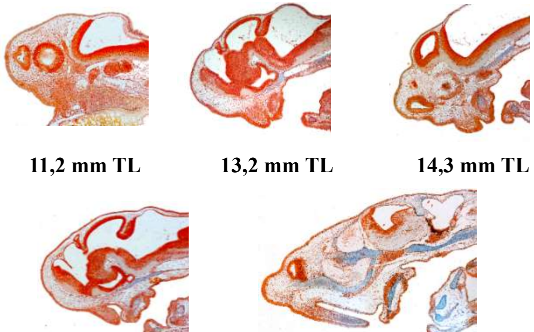
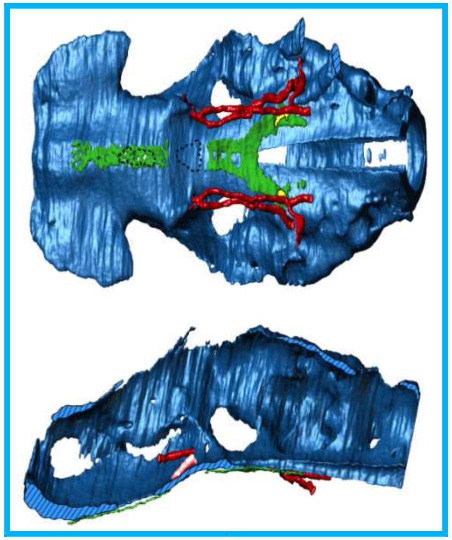
После доработки 27.01.2019 г.
Принята к публикации 06.06.2019 г.

Осетрообразные (Acipenseriformes, Actinopterygii) рассматриваются в качестве сестринского таксона по отношению к Neopterygii и наряду с *Polypterus* (Polypteriformes) занимают наиболее базальное положение на кладограмме рецентных лучеперых. Такое положение в системе определяет ключевое значение осетрообразных для понимания эволюционной истории не только лучеперых, но и костных рыб в целом. Вместе с тем уникальная морфология и отсутствие сколько-нибудь надежных гомологий – в первую очередь для этмоидной области черепа и челюстной дуги – не позволяют в полной мере использовать этих рыб для тестирования филогенетических гипотез и реконструкции эволюции Osteichthyes. В настоящей статье представлены результаты сравнительно-анатомического анализа челюстной дуги и этмоидной области головы осетрообразных, установлены гомологии всех основных морфологических элементов этих отделов головы и предложен эволюционный сценарий преобразования челюстной дуги и этмоидного отдела черепа при переходе от палеонискоидных предков к структурному типу головы современных осетров и полиодонтид. Показано, что в основе этих преобразований лежали процессы педоморфоза, который обусловил недоразвитие нижней челюсти и привел к высвобождению передних концов ветвей верхней челюсти и всего этмоидного отдела от функциональных ограничений, связанных с работой челюстного аппарата.





ДОКЛАДЫ АКАДЕМИИ НАУК, 2019, том 486, № 1, с. 131–134

ОБЩАЯ БИОЛОГИЯ

УДК 591.3+591.4+597.4/.5

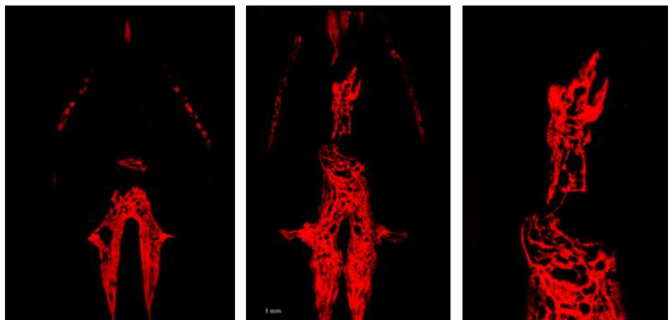
ПРОВИЗОРНЫЕ ДЕРМАЛЬНЫЕ СКЛАДКИ В РОТОВОМ АППАРАТЕ АМЕРИКАНСКОГО ВЕСЛОНОСА *Polyodon spathula* Walbaum, 1858 (Acipenseriformes, Polyodontidae)

А. А. Цессарский

Представлено академиком РАН Д.С. Павловым 31.01.2019 г.

Поступило 31.01.2019 г.

Впервые показано наличие у личинок и постличинок американского веслоноса *Polyodon spathula* Walbaum, 1858 поперечных кожных складок впереди и позади верхней челюсти, которые в ходе развития исчезают. У осетровых гомологичные складки делают возможной протракцию челюстей. Описанные складки у веслоноса, возможно, рекапитулируют предковое для полиодонтид состояние. Вместе с тем их появление можно рассматривать как функциональный компонент провизорного челюстного механизма, действующего у веслоноса на ранних этапах активного питания. Для проверки этой гипотезы необходимо проведение сравнительного анализа кинематики челюстного аппарата постличинок веслоноса и осетровых.



Важнейшие результаты

Hydrobiologia
https://doi.org/10.1007/s10750-020-04296-w

PRIMARY RESEARCH PAPER

Rapid miniaturization of *Salvelinus* fish as an adaptation to the volcanic impact

Evgeny V. Esin · Grigorii N. Markevich · Fedor N. Shkil

Received: 22 February 2020 / Revised: 30 April 2020 / Accepted: 12 May 2020

Abstract Volcanoes serve as natural laboratories expanding our understanding of the recent and past ecological and evolutionary processes. Here, we present data elucidating the developmental and phenotypic transformations providing rapid adaptation for the salmonid fish, *Salvelinus malma*, to volcanic impact. After being isolated by the mudflow in 1996, the locked descendants of sea-run charr managed to survive in the highly turbid and toxic environment. Initially, the population underwent a phase of high developmental instability accompanied by a surge in morphological deviations. Further, selection targeted the fish prone to migrate into the most toxic mainstream favoring a sedentary lifestyle at the less toxic spawning tributaries. In five–seven generations, the sedentary population recovered developmental homeostasis but diverged into a small-sized short-cycled form with low phenotypic variability. In response to toxicosis, the fish displayed an accelerated metabolic rate and precocious maturations. The spawners possessed fry morphology with no spawning dress. Sedentary fish also exhibited a decreased fecundity and did not build spawning nests. Thus, under the volcanic impact, *S. malma* demonstrated a rapid paedomorphic miniaturization, an evolutionary mechanism enabling to complete the reproductive cycle under the conditions of high risks of reaching the adaptive capacity limits.

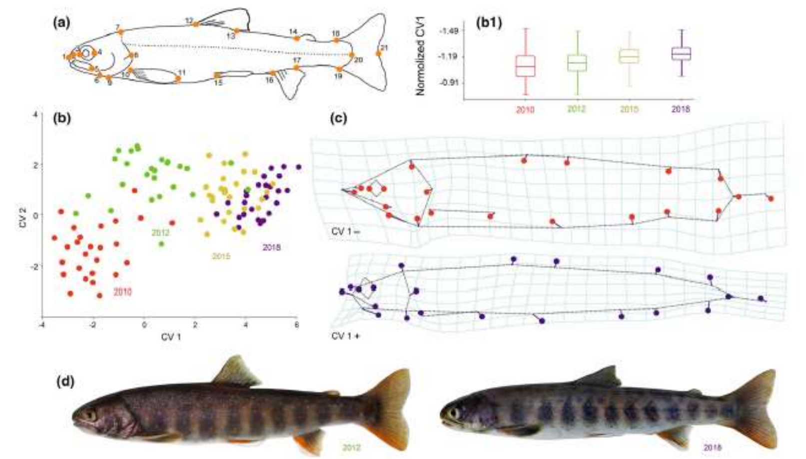
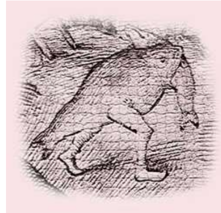


Fig. 3 Results of body shape comparison among the landlocked *Salvelinus malma* spawners of different years derived from CVA. **a** Landmarks used in morphometric analysis; **b** the plot of individual body shape variation in the morphospace, the increase of CV1 values is in accordance ($r = 0.79$) with body mm in 2015—118.0 (100–150) mm in 2018; **c** residuals of CV1 individual scores free from body length effect obtained via log-scaling following Reist (1985) (mean ± SE and min–max values are shown); and **c** the change in body shape along the first canonical root reflecting 76% of variance. External appearance

Важнейшие результаты



Journal of Animal Ecology
BRITISH ECOLOGICAL SOCIETY

RESEARCH ARTICLE

Natural toxic impact and thyroid signalling interplay orchestrates riverine adaptive divergence of salmonid fish

Evgeny V. Esin, Grigorii N. Markevich, Nikolay O. Melnik, Daria V. Kapitanova, Fedor N. Shkil

First published: 22 January 2021 | https://doi.org/10.1111/1365-2656.13429

Funding information:
The transportation costs, as well as expenses for essential expendables, aquaria chemistry and equipment, chemicals for ELISA and biochemical analysis, food for juveniles spent during the field and laboratory works, were covered by the Russian science foundation Grant No 18-74-10085.

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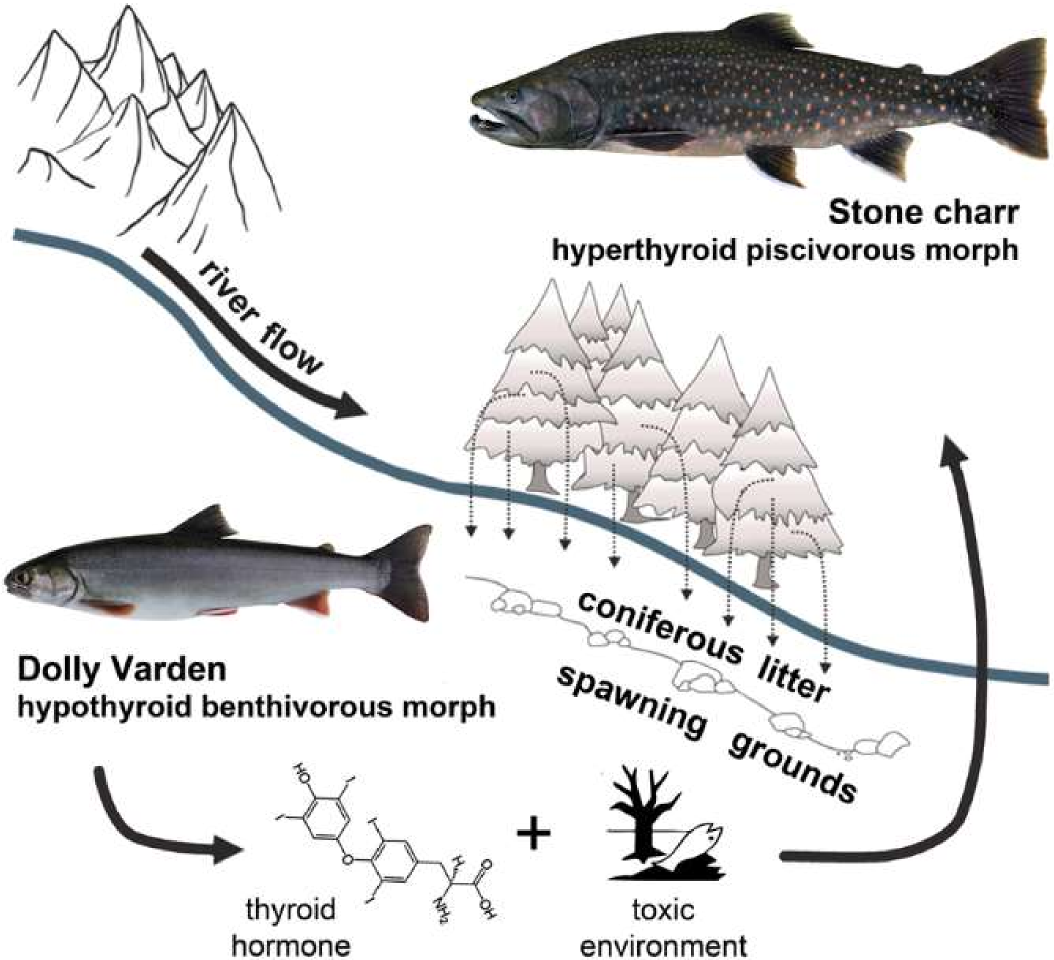
Abstract

1. Adaptive radiation in fishes has been actively investigated over the last decades. Along with numerous well-studied cases of lacustrine radiation, some examples of riverine sympatric divergence have been recently discovered. In contrast to the lakes, the riverine conditions do not provide evident stability in the ecological gradients. Consequently, external factors triggering the radiation, as well as developmental mechanisms underpinning it, remain unclear.
2. Herein, we present the comprehensive study of external and internal drivers of the riverine adaptive divergence of the salmonid fish *Salvelinus malma*. In the Kamchatka River, north-east Asia, this species splits in the reproductively isolated morphs that drastically differ in ecology and morphology: the benthivorous Dolly Varden (DV) and the piscivorous stone charr (SC).
3. To understand why and how these morphs originated, we performed a series of field and experimental work, including common-garden rearing, comparative ontogenetic, physiological and endocrinological analyses, hormonal 'engineering' of phenotypes and acute toxicological tests.
4. We revealed that the type of spawning ground acts as the decisive factor driving the radiation of *S. malma*. In contrast to DV spawning in the leaf krummholz zone, SC reproduces in the zone of coniferous forest, which litter has a toxic impact on developing fishes. SC enhances resistance to the toxicants via metabolism acceleration provided by the elevated thyroid hormone expenditure. These physiological changes lead to the multiple heterochronies resulting in a specific morphology and ecology of SC.
5. *Salvelinus malma* represents a notable example of how the thyroid axis contributes to the generation of diverse phenotypic outcomes underlying the riverine sympatric divergence. Our findings, along with the paleoecology data concerning spruce forest distribution during the Pleistocene, provide an opportunity to reconstruct a scenario of *S. malma* divergence. Taken together, obtained results with the data of the role of thyroid hormones in the ontogeny and diversification of fishes contribute a resource to consider the thyroid axis as a prime director orchestrating the phenotypic plasticity promoting evolutionary diversification under the changing environmental conditions.



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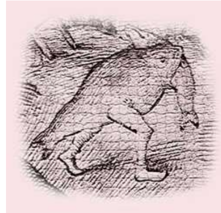

DOI: 10.1111/ede.12272

RESEARCH

WILEY EVOLUTION & DEVELOPMENT

Experimental evidence of the role of heterochrony in evolution of the Mesoamerican cichlids pigment patterns

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[1] Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, Moscow, Russia

[2] Koltzov Institute of Developmental Biology, Russian Academy of Sciences, Moscow, Russia

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Funding information
Russian Foundation for Basic Research, Grant numbers: 14-04-00590, 17-04-01617, 18-34-00685

The Mesoamerican cichlids display a spectacular diversity of pigment patterns, which serve a variety of functions and serve as a strong selective trait for this lineage. The development and variation of coloration in the Mesoamerican cichlids have been detailed by several groups. In particular, Říčan, Musilová, Muška, and Novák (2005) and Říčan, Piálek, Dragová, and Novák (2016) determined homology of pattern and revealed four alternative types of coloration and their ontogeny. In this work, this group posed an "ontogenetic timing hypothesis" proposing heterochronic shifts underlying major transitions in the evolution of the Mesoamerican cichlids. Here, we experimentally test this hypothesis by experimentally altering timing of pigment pattern formation in the convict cichlid *Amatitlania nigrofasciata*, a member of the Mesoamerican cichlids, via manipulations of thyroid hormone (TH) function. The response of different pigment cell lineages to TH-perturbations revealed that the transition from larval to juvenile coloration in the convict cichlid is under the control of TH-signaling. Importantly, hormonally induced changes in the timing of pigment cell lineages' development resulted in shifts of coloration ontogeny type observed between lineages and led to the appearance of phenotypes mimicking those in phylogenetically close and distant species. Thus, our findings support the hypothesis that simple changes in ontogenetic timing underlies species specific patterns in pigmentation and provide new perspectives for studying the role of endocrine signaling in the evolution of cichlids.

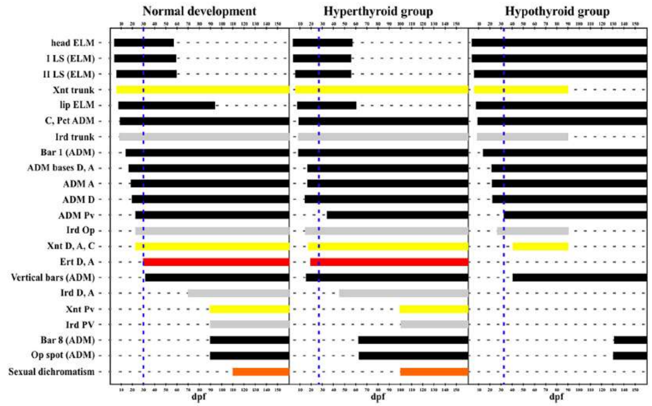


FIGURE 8 The sequence of the pigment cell and pattern element appearance in *A. nigrofasciata* reared under different hormonal regimes: normal development, hyperthyroid and hypothyroid groups. ELM, early larval melanophores (black); ADM, adult melanophores (black); Xnt, xanthophores (yellow); Ird, iridophores (gray); Ert, erythrophores (red); I LS, first lateral stripe; II LS, second lateral stripe; Op spot, opercular spot; A, anal fin; C, caudal fin; D, dorsal fin; Pct, pectoral fins; Pv, pelvic fins; dpf, day postfertilization. Blue vertical dashed lines indicate the onset of juvenile period in each group

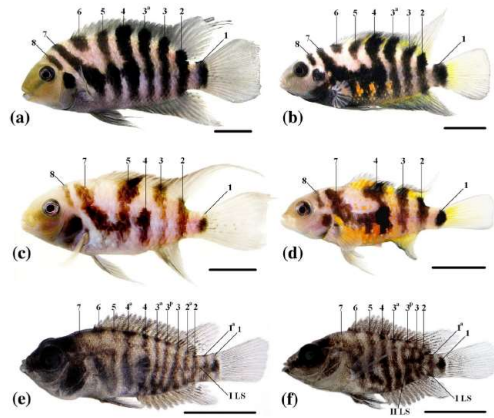
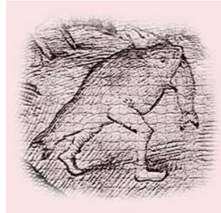
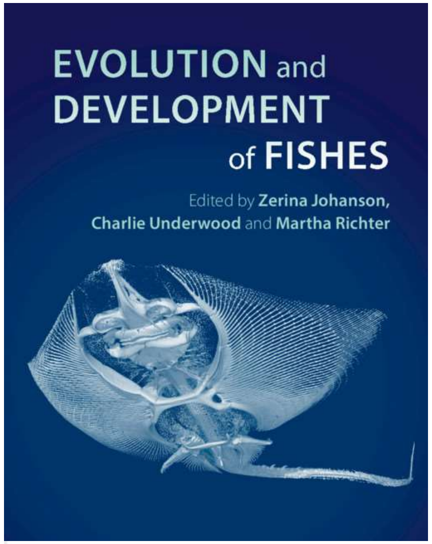


FIGURE 6 Sexual dichromatism in adult *A. nigrofasciata* reared under different hormonal regimes: a and b, male and female from control

Важнейшие результаты





Print publication year: 2019 Online publication date: December 2018

13 - Links between Thyroid Hormone Alterations and Developmental Changes in the Evolution of the Weberian Apparatus

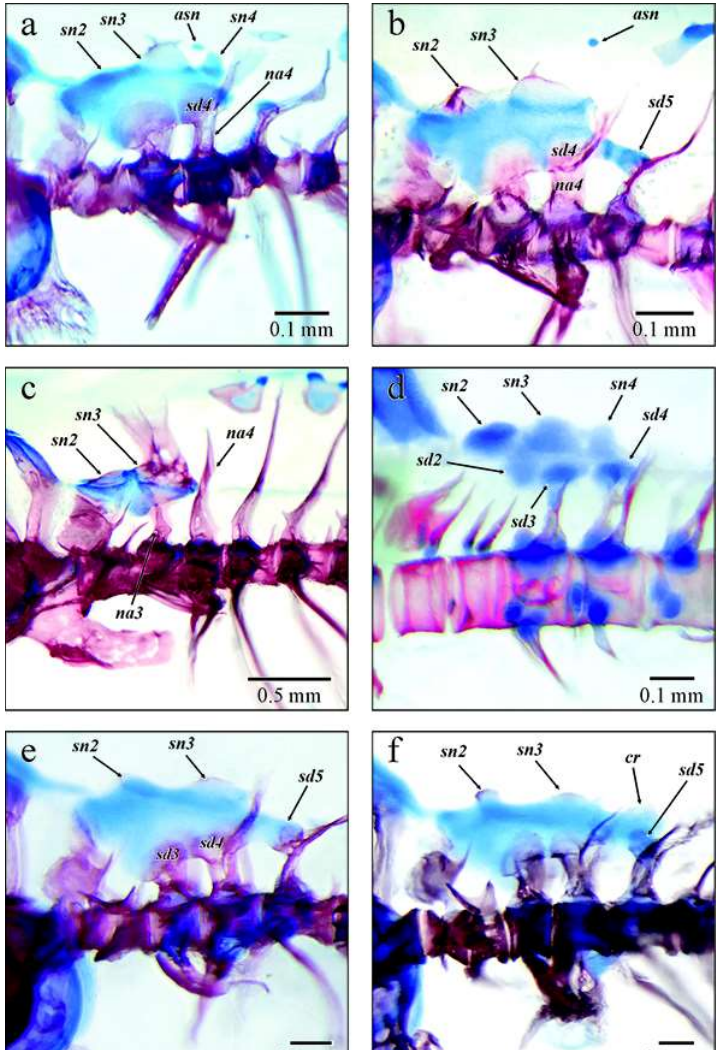
By Fedor N. Shkil, Daria V. Kapitanova
Edited by Zerina Johanson, *Natural History Museum, London*, Charlie Underwood, *Birkbeck, University of London*, Martha Richter, *Natural History Museum, London*

Publisher: Cambridge University Press
DOI: https://doi.org/10.1017/9781316832172.014
pp 227-240

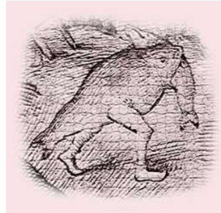
Export citation

Summary

The Weberian apparatus (WA), a structure consisting of the greatly modified four anteriormost vertebral elements, enhances the hearing in Otophysi. Since WA is one of the most spectacular examples of vertebral column transformation and regionalization, the mechanisms underpinning WA origin and evolution have received considerable attention. A number of hypotheses exist, but a consensus has not been reached, primarily due to the relative paucity of experimental data. One of the most plausible propositions concerning the leading role of specific developmental changes in WA evolution, likely constituting differences in gene expression, was offered by Bird and Hernandez (2009). Here, we provide an analysis of developmental and morphological data obtained from experiments with cyprinids, in which developmental deviations were caused by induced hypo- and hyperthyroidism. The synthesis of our results with morphological and developmental data obtained in different teleosts empirically demonstrates the involvement of different developmental changes in WA evolution. Moreover, our results emphasize the potential role of thyroid signaling pathway in bony fish (Osteichthyes) evolution, including the origin of various types of morphological novelties.



Важнейшие результаты



SCIENTIFIC REPORTS

OPEN

Development of zebrafish paired and median fin musculature: basis for comparative, developmental, and macroevolutionary studies

Received: 11 August 2017
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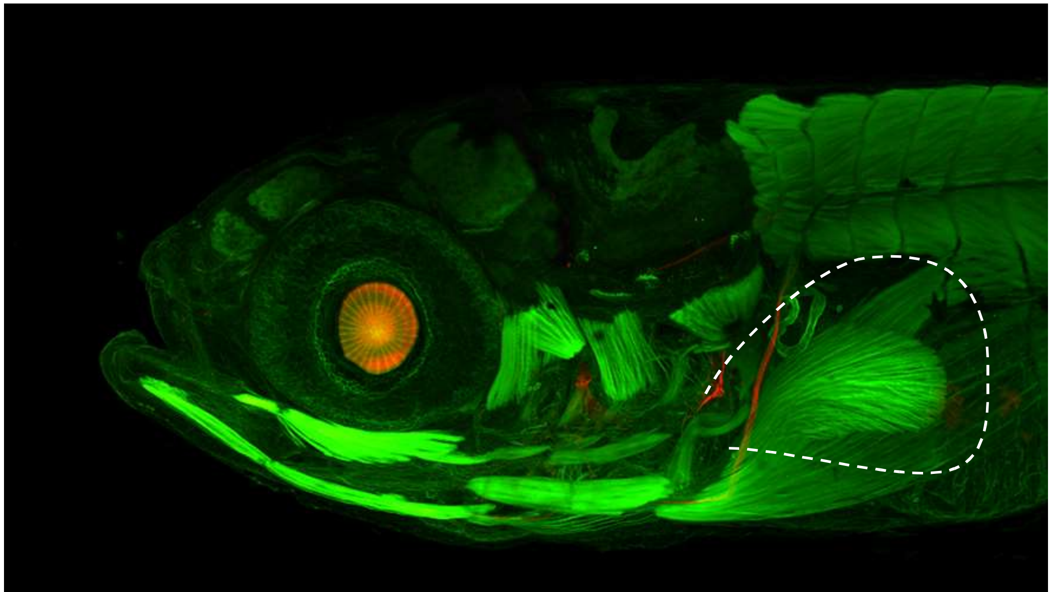
Published online: 21 September 2018

Natalia Siomava[1], Fedor Shkil[2,3], Elena Voronezhskaya[2] & Rui Diogo[1]

The model organism *Dario rerio* (zebrafish) is widely used in evo-devo and comparative studies. Nevertheless, little is known about the development and differentiation of the appendicular musculature in this fish. In this study, we examined the development of the muscles of all five zebrafish fin types (pectoral, pelvic, anal, dorsal and caudal). We describe the development of the muscles of these fins, including some muscles that were never mentioned in the literature, such as the *interhypurales* of the caudal fin. Interestingly, these caudal muscles are present in early stages but absent in adult zebrafishes. We also compare various stages of zebrafish fin muscle development with the configuration found in other extant fishes, including non-teleostean actinopterygians as well as cartilaginous fishes. The present work thus provides a basis for future developmental, comparative, evolutionary and evo-devo studies and emphasizes the importance of developmental works on muscles for a more comprehensive understanding of the origin, development and evolution of the appendicular appendages of vertebrate animals.



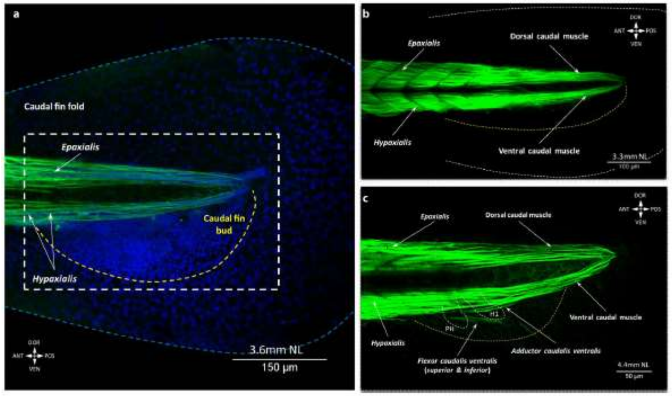


Figure 2. Early development of the caudal fin musculature in the zebrafish. The tip of the tail is shown with the caudal fin fold (dashed blue line) and mesenchyme concentrated in the caudal fin bud (dashed yellow line) (**a**). The white dashed line schematically outlines the area of interest shown in other figures. At 3.3 mm NL, two muscles are present in the caudal fin (**b**). Ventral caudal muscles develop before dorsal muscles. At 4.4 mm NL, PH – parhypural, H1 – hypural 1, and first fibers of ventral caudal muscles can be seen (**c**).

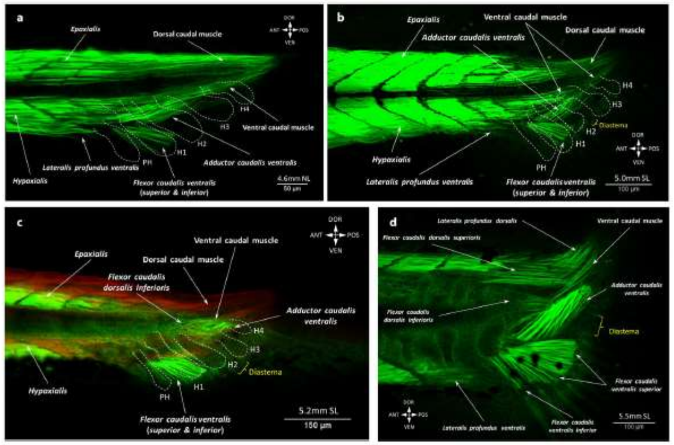
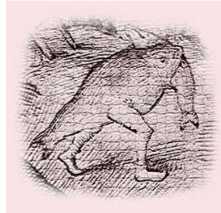


Figure 3. Development of the deep dorsal caudal fin muscles in the zebrafish. At 4.6 mm NL, ventral caudal muscles grow towards the caudal fin rays are present. (**a**) By 5.0 mm SL, ventral caudal muscles reach the caudal fin rays (**b**) and development of the deep dorsal fin muscles starts (**c**,**d**). The flexor caudalis dorsalis inferioris can be seen at 5.2 mm SL (**c**) and the flexor caudalis dorsalis superioris appears at 5.5 mm SL (**d**). Note: different colors in (**c**) do not mean different staining, but were used to contrast the flexor caudalis dorsalis inferioris and the dorsal caudal muscle lodging in different layers. The ventral caudal muscle is still attached to the dorsal

Важнейшие результаты



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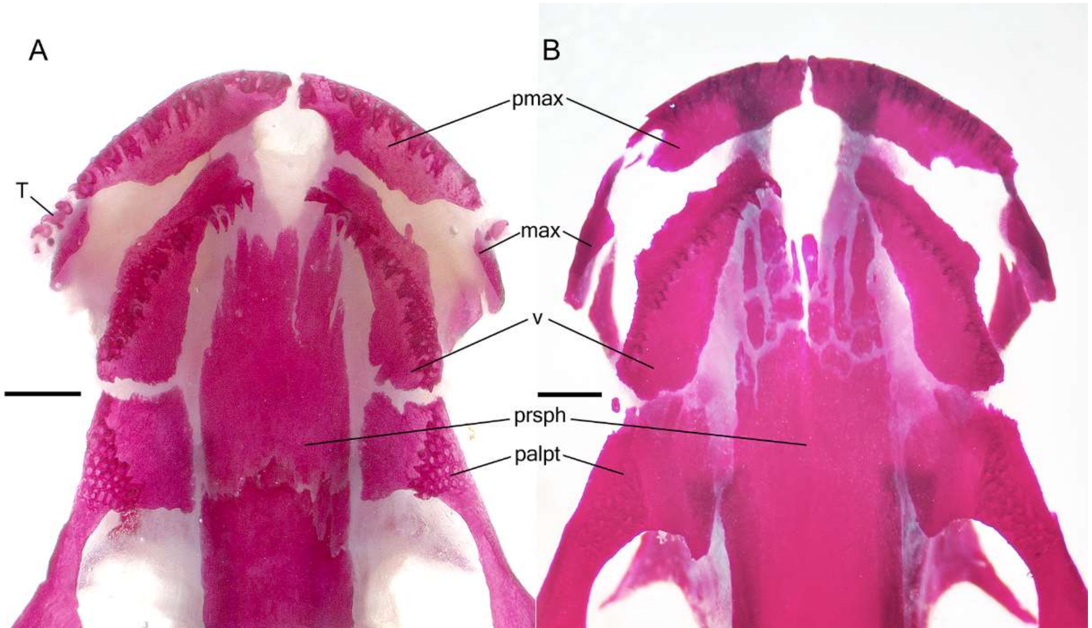
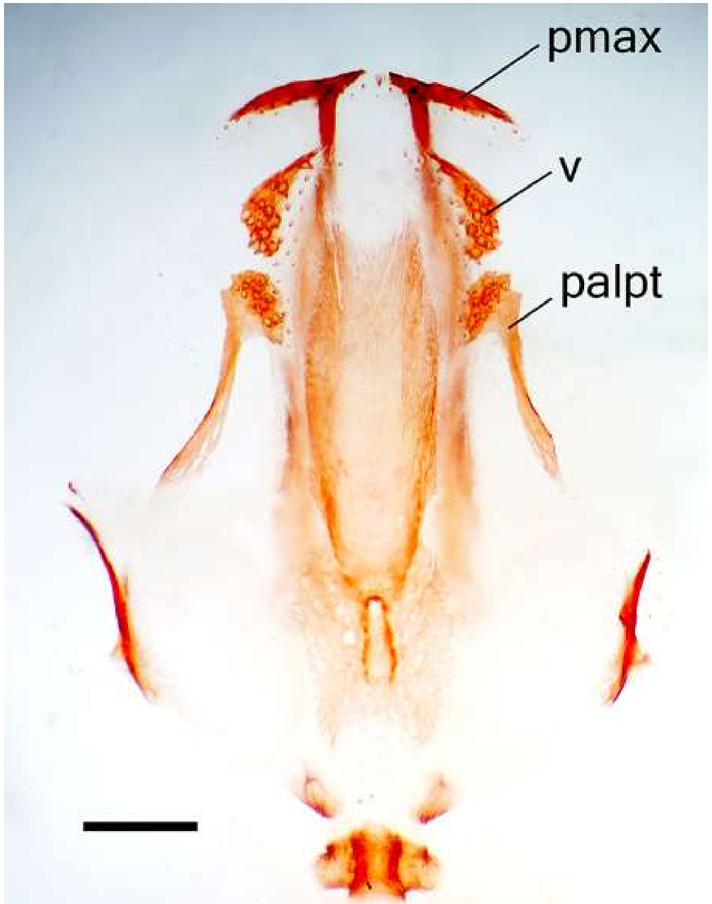
ORIGINAL PAPER

ANATOMICAL SOCIETY Journal of Anatomy WILEY

Skull development in the Iberian newt, *Pleurodeles waltl* (Salamandridae: Caudata: Amphibia): timing, sequence, variations, and thyroid hormone mediation of bone appearance

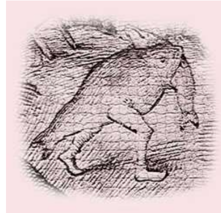
Sergei V. Smirnov | Ksenia M. Merkulova | Anna B. Vassilieva





Развитие черепа испанского тритона *Pleurodeles waltl*

Важнейшие результаты



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Larval morphology of *Hylarana lateralis* (Boulenger) (Anura: Ranidae) from southern Vietnam

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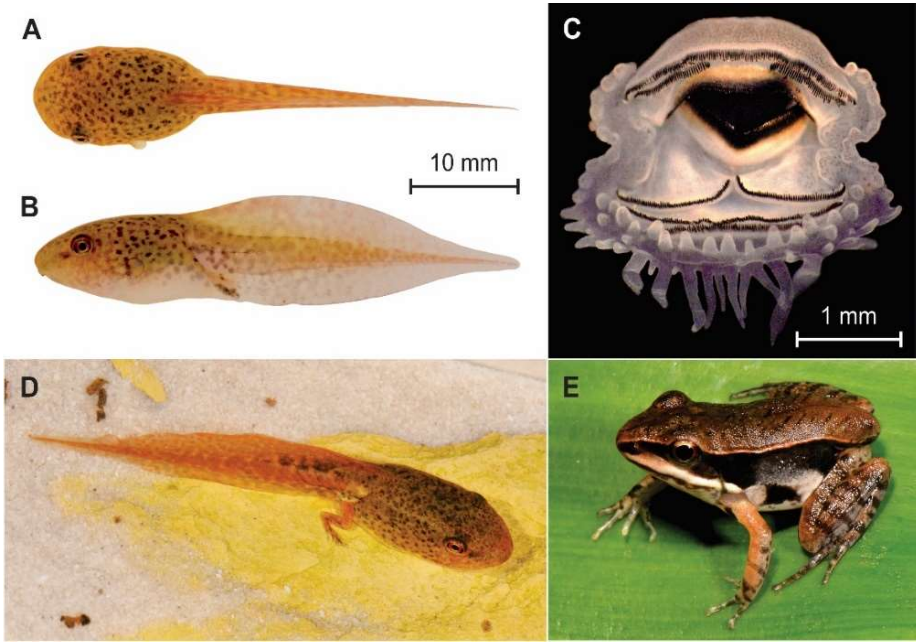

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Tadpole of *Microhyla picta* Shenkel (Anura: Microhylidae), an endemic narrow-mouthed frog from Vietnam

ANNA B. VASSILIEVA[1,2,3,4] & VITALY L. TROUNOV[1,2]
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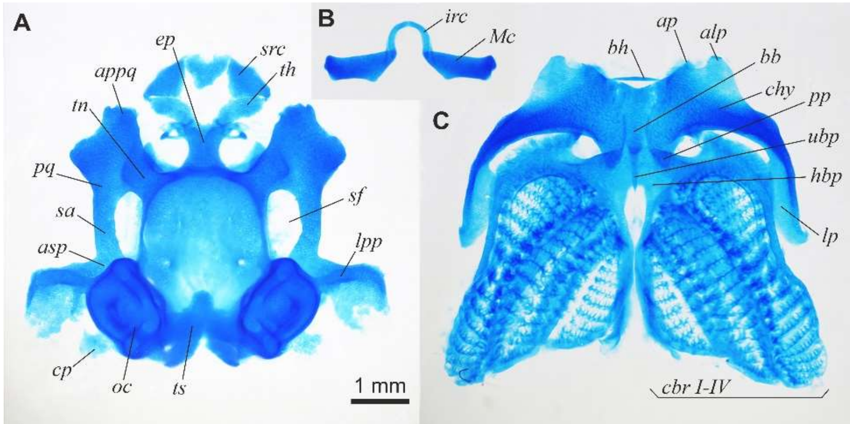
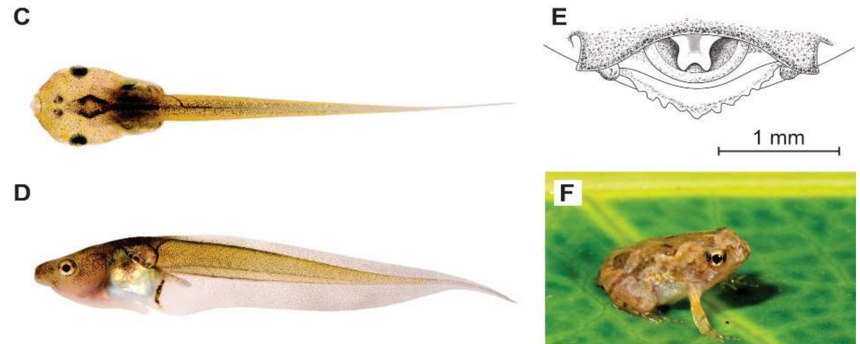
[2]*Joint Russian-Vietnamese Tropical Research and Technological Centre, Nguyen Van Huyen, Nghia Do, Cau Giay, Hanoi, Vietnam*





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Глава в монографии

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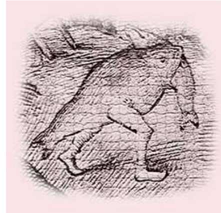
Состав лаборатории и статистика



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		2018	2019	2020	∑(2018-2020)
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Васильева А.Б.	старший научный сотрудник	1	1	1	3
Капитанова Д.В.	старший научный сотрудник	1			1
Меркулова К.М.	младший научный сотрудник			1	1
Цессарский А.А.	старший научный сотрудник		2		2
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Медников Д.Н.	старший инженер				0
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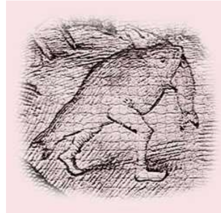

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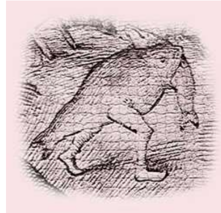
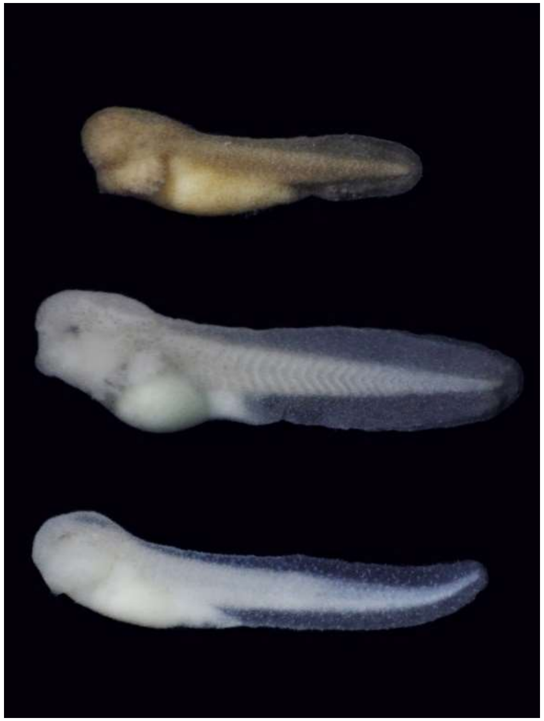
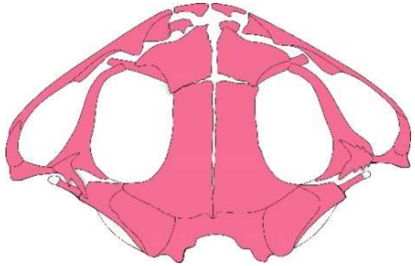
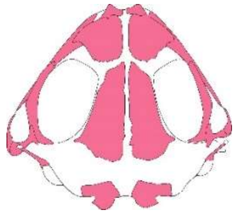
Планируемые исследования.

Репродуктивные стратегии и эволюция онтогенеза в разных экологических группах амфибий









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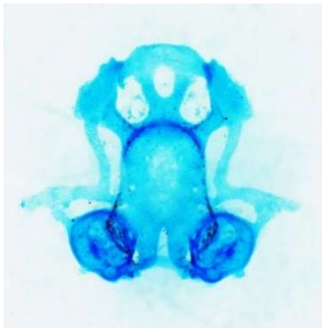
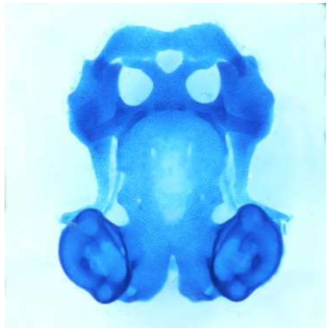
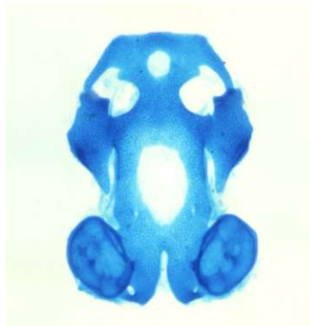
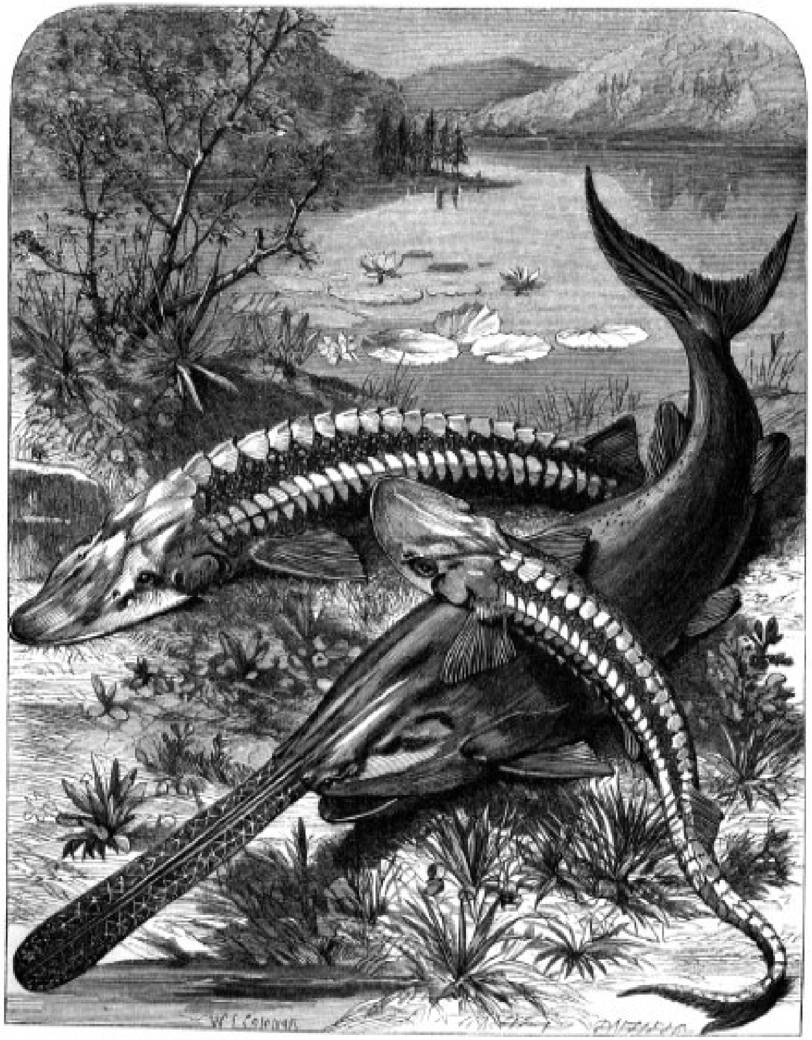




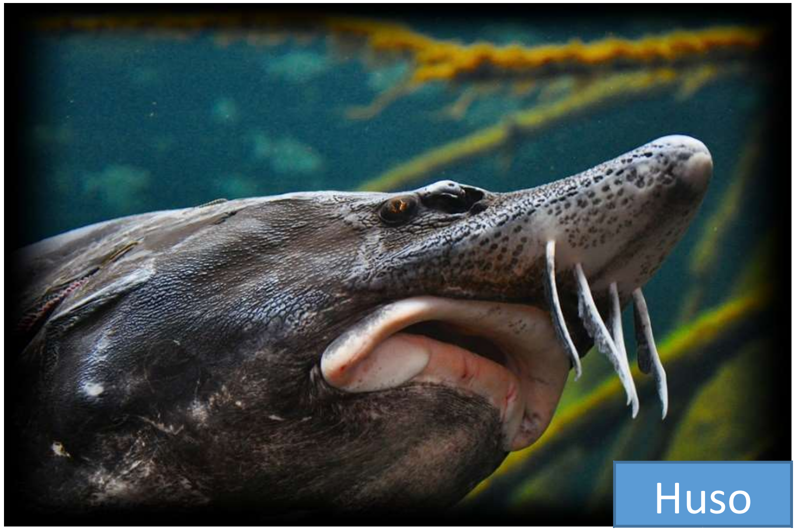


Планируемые исследования.

Гетерохронии в эволюции осетрообразных



An early print of *Polyodon spathula* and *Scaphirhynchus platorynchus* from Wood (1863, p. 201).

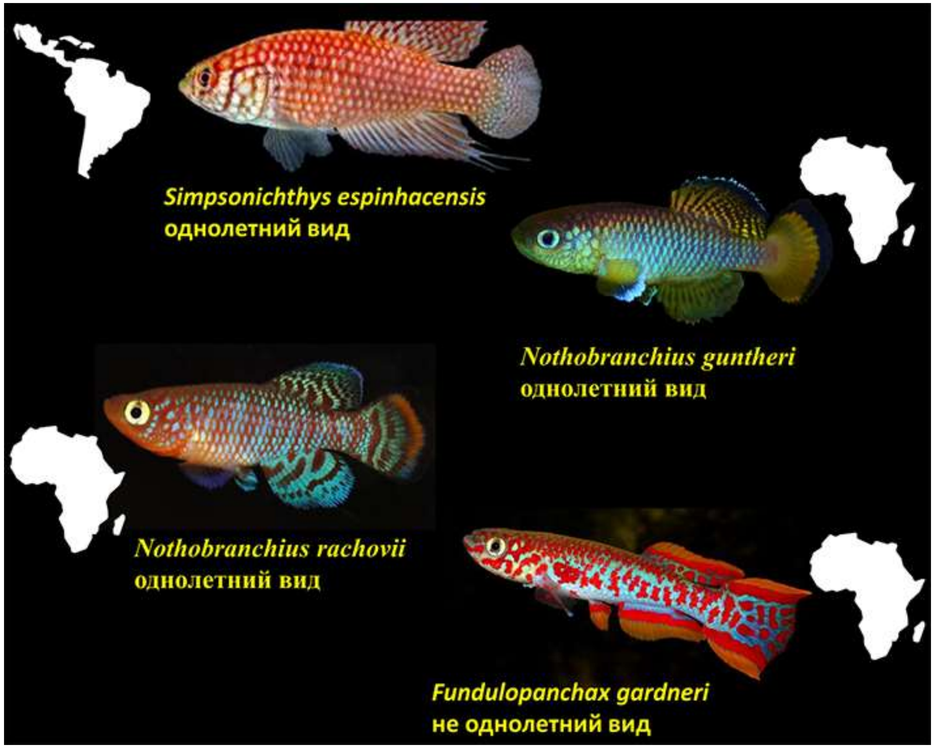


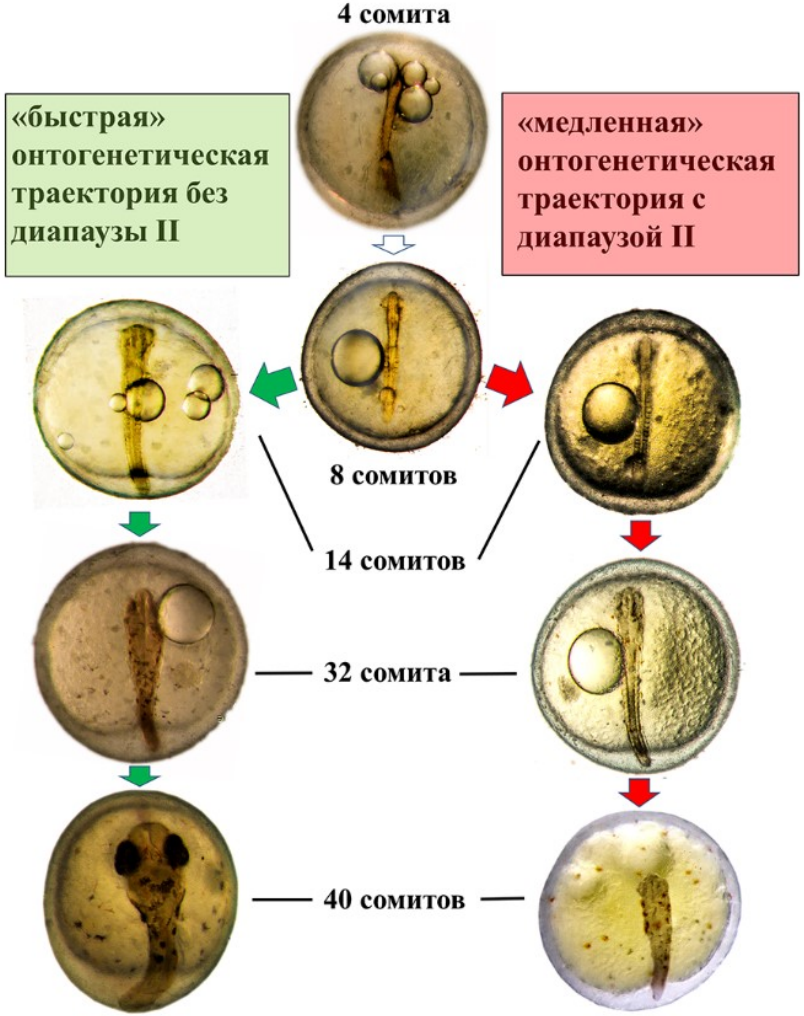
Huso

Polyodon

Планируемые исследования.

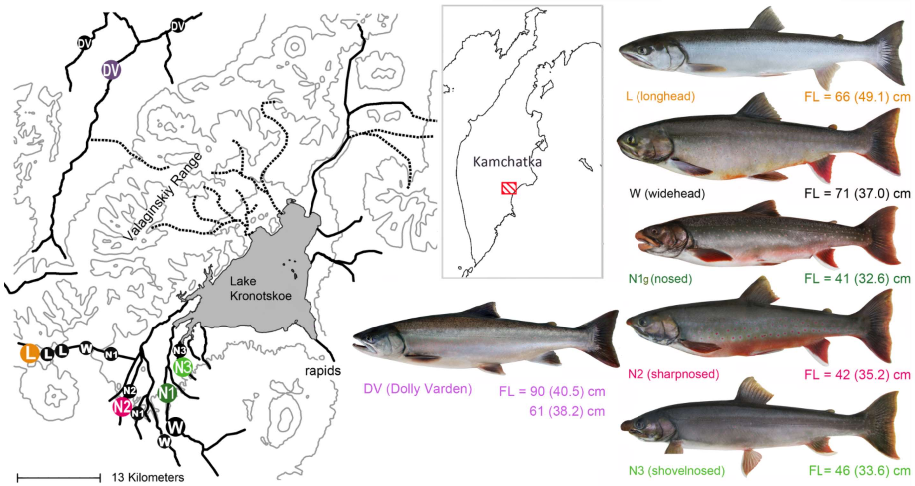
Исследование раннего онтогенеза сезонных и многолетних карпозубых

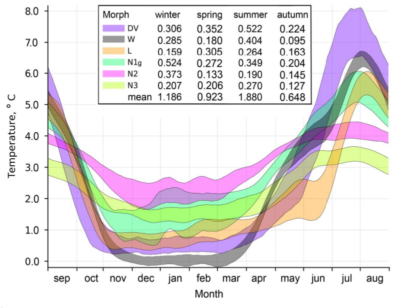


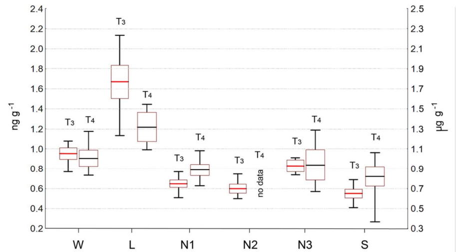


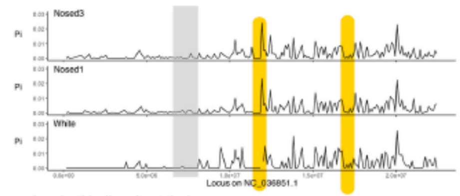
Планируемые исследования.
Изучение лососевых рыб в контексте EcoEvoDevo

Гольцы оз. Кроноцкое (Камчатка)



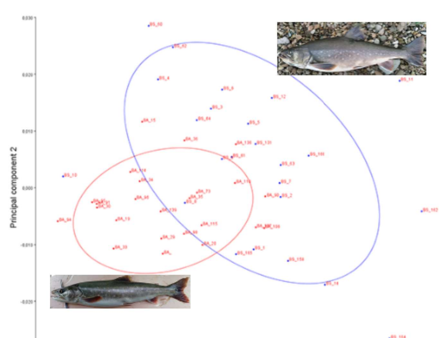


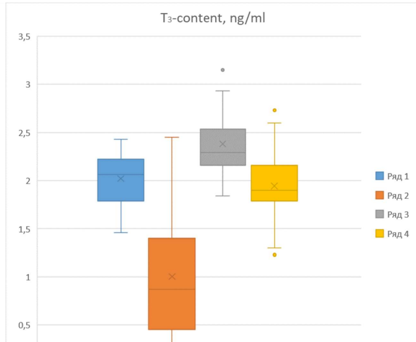




Decreased nucleotide diversity at the locus.

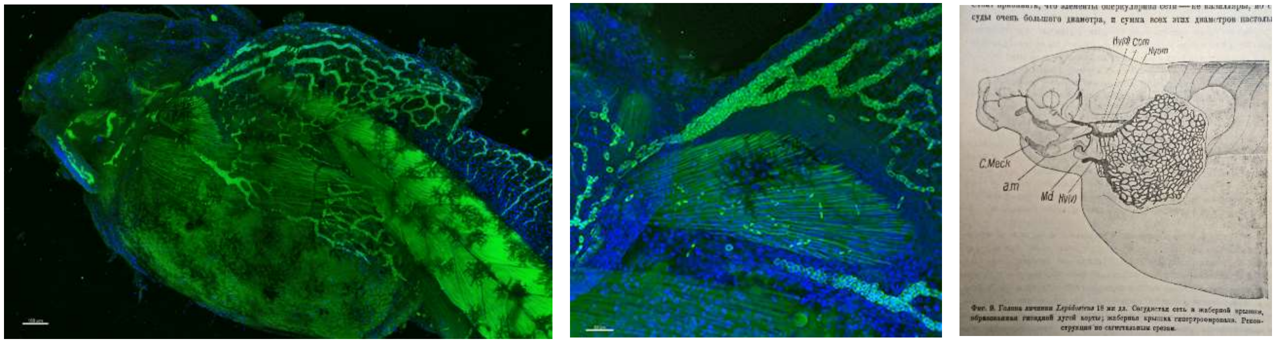
Палии оз. Эльгыгытгын (Чукотка)



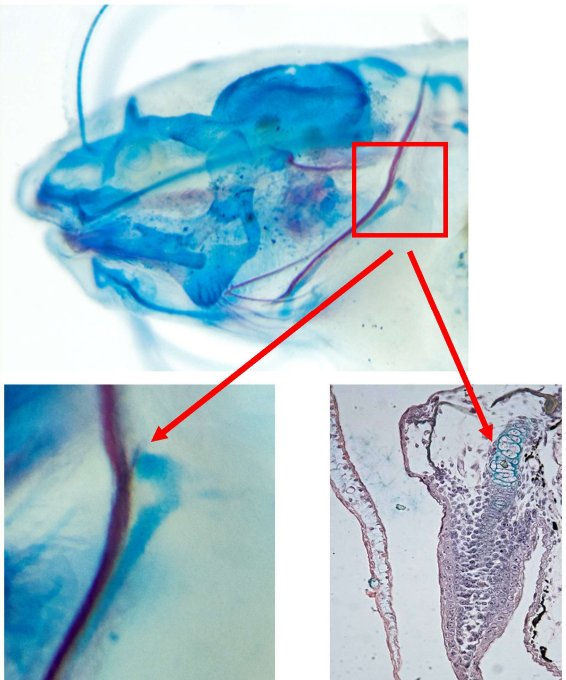


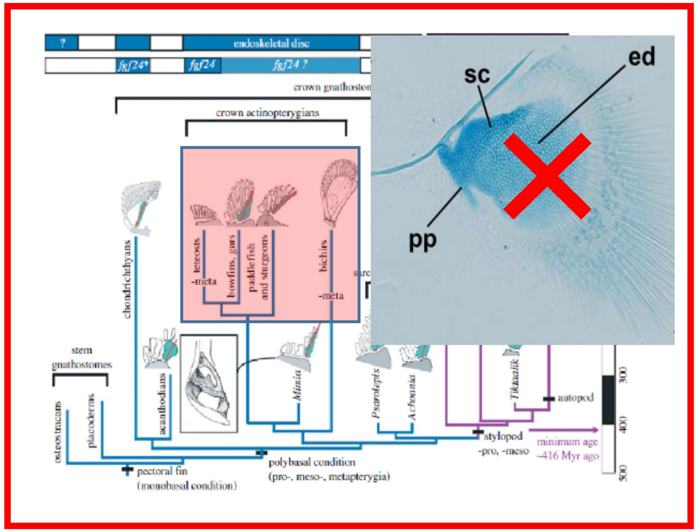
Планируемые исследования.

Изучение сомов в контексте EcoEvoDevo

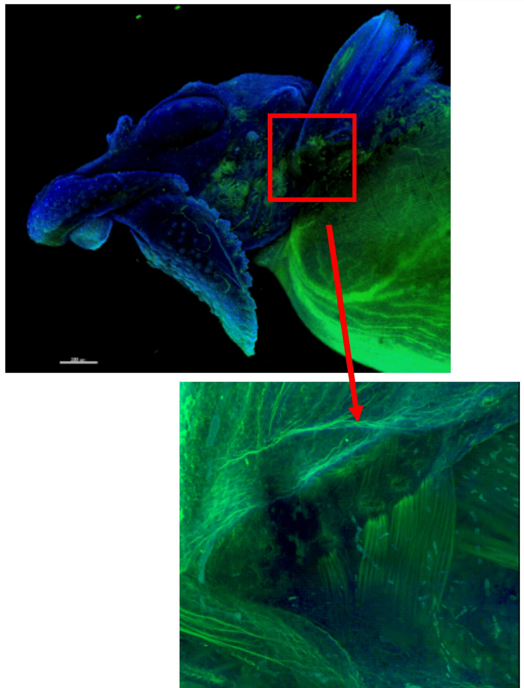


Грудной плавник как респираторный орган





Отсутствие личиночной стадии



Спасибо за внимание!