Model organisms and developmental biology

仲寒冰

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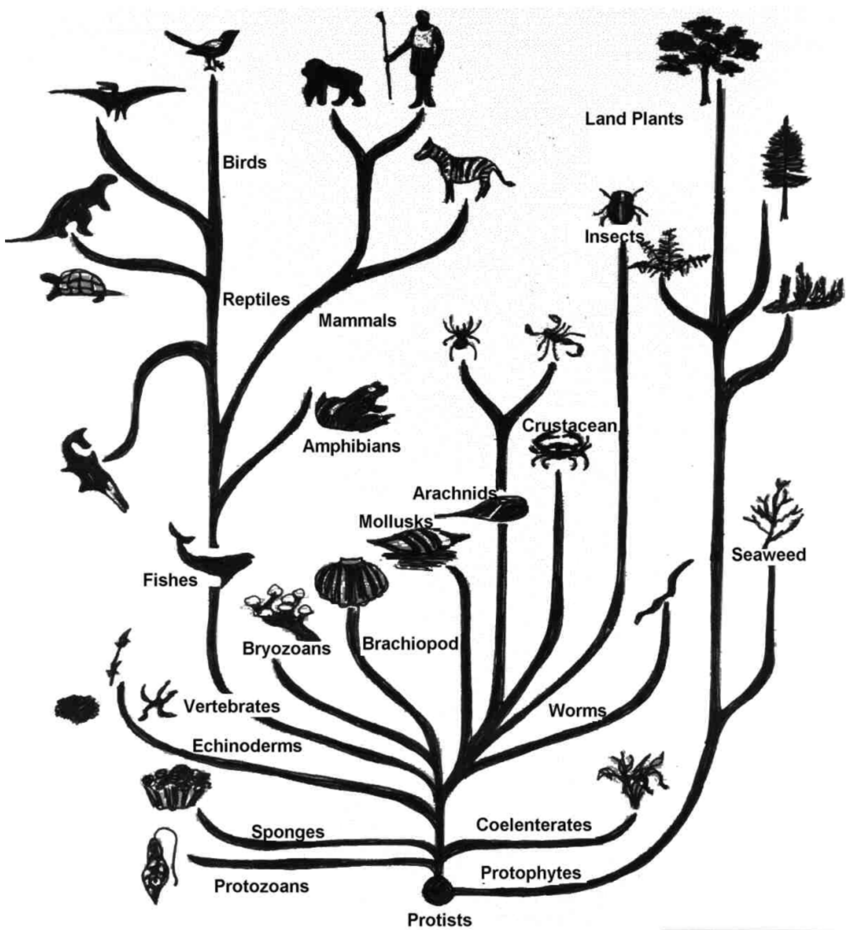
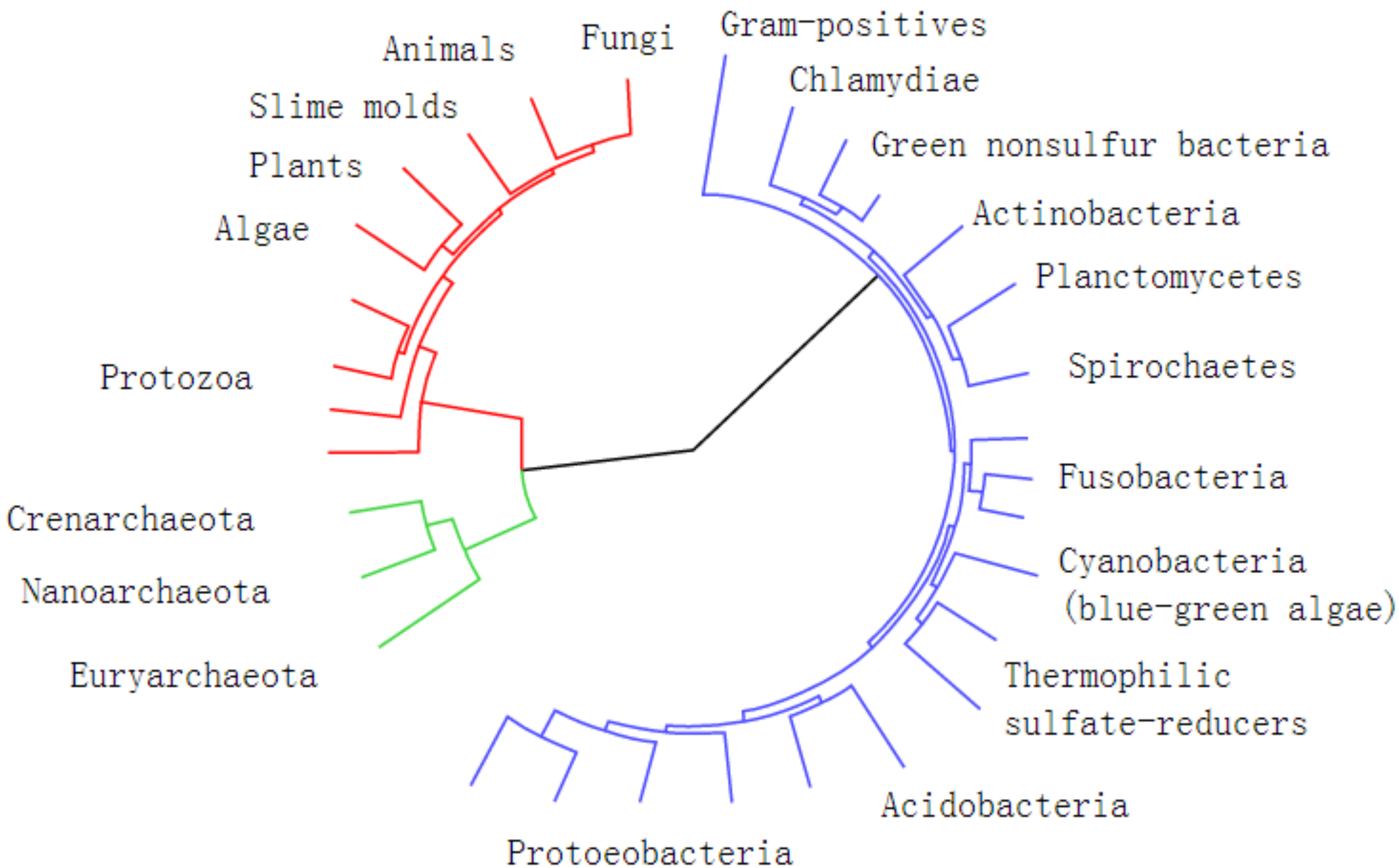
Nothing in Biology Makes Sense Except in the Light of Evolution.

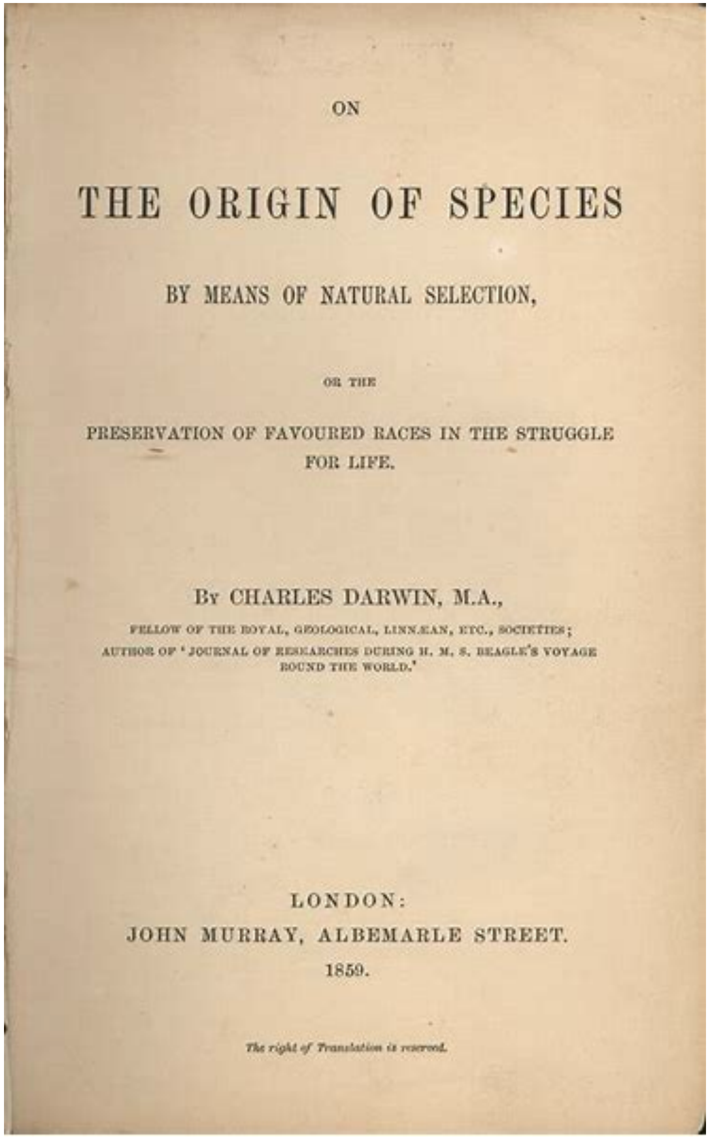
--Theodosius Dobzhansky

Evolution, 进化 VS 演化



Evolution, 进化 VS 演化





ON

THE ORIGIN OF SPECIES

BY MEANS OF NATURAL SELECTION,

OR THE

PRESERVATION OF FAVOURED RACES IN THE STRUGGLE FOR LIFE.

BY CHARLES DARWIN, M.A.,

FELLOW OF THE ROYAL, GEOLOGICAL, LINNÆAN, ETC., SOCIETIES;
AUTHOR OF 'JOURNAL OF RESEARCHES DURING H. M. S. BEAGLE'S VOYAGE ROUND THE WORLD.'

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1859.

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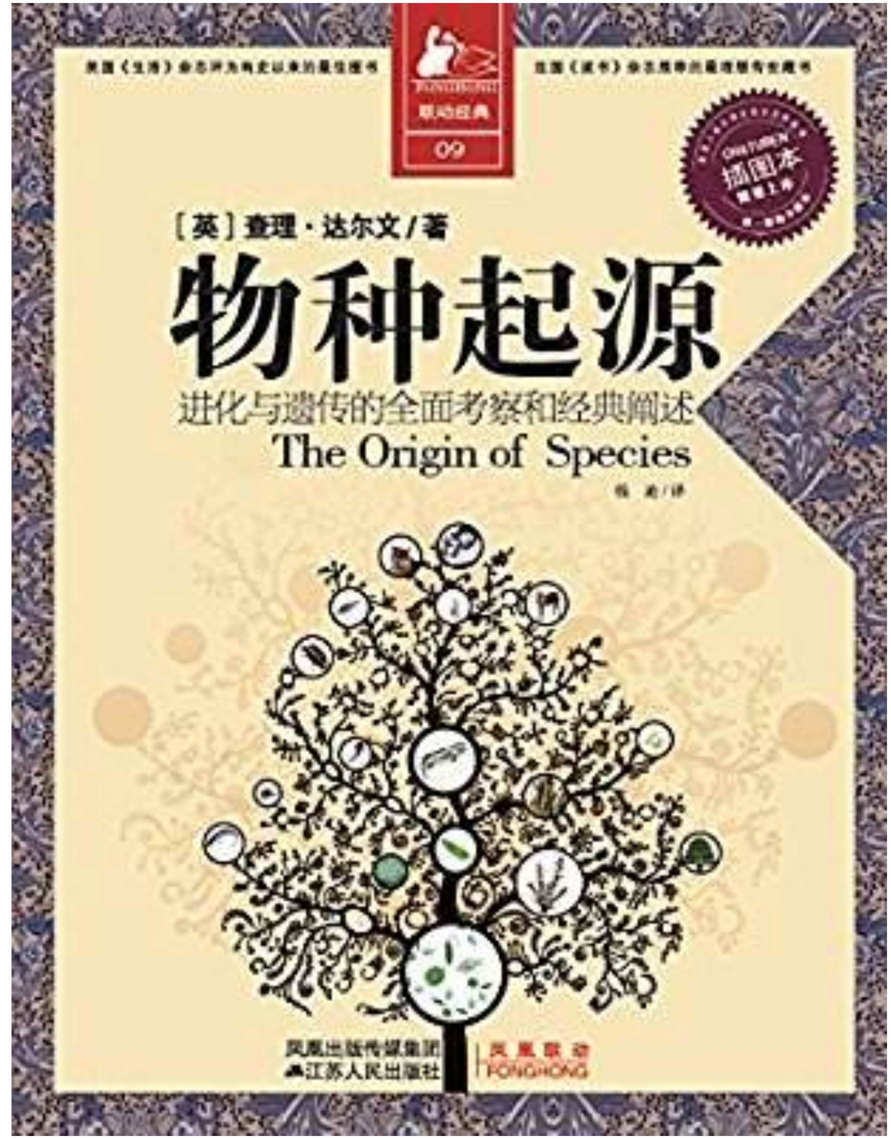


Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life.

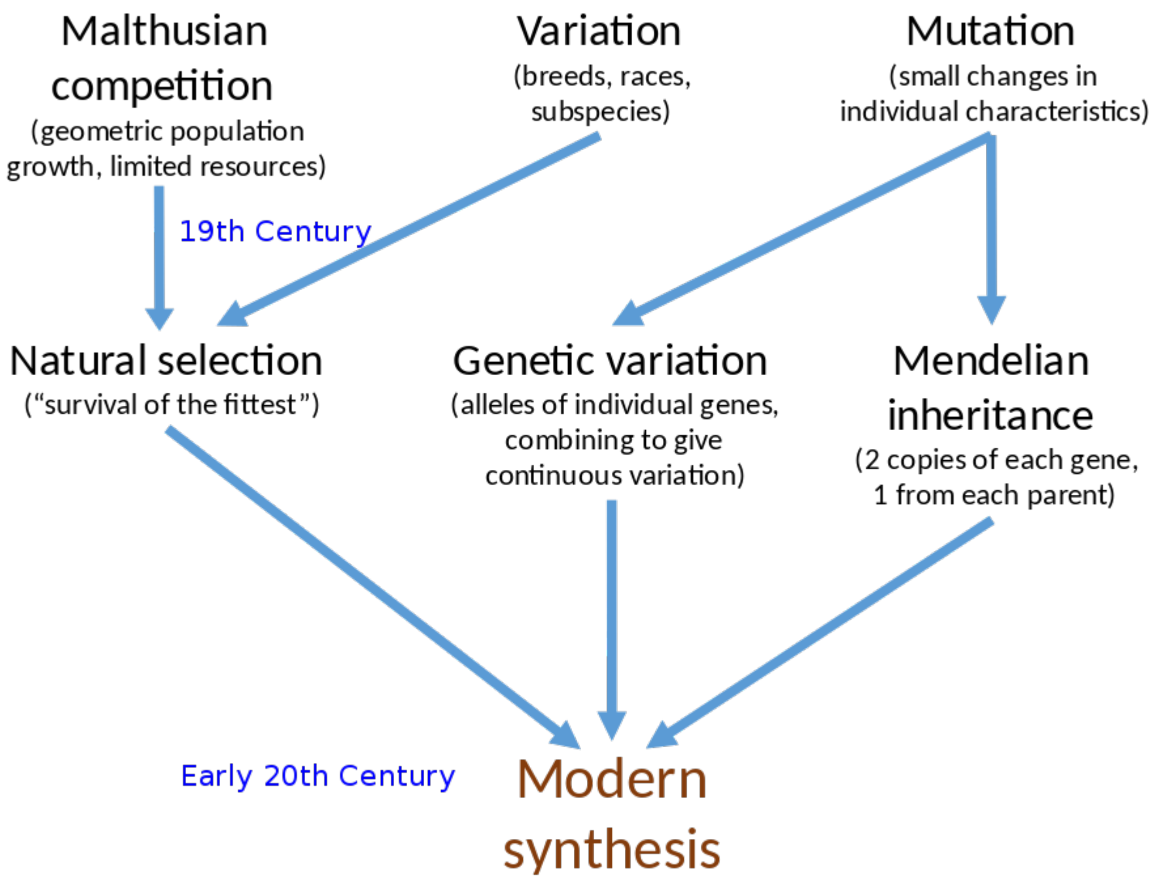
seventy-five years before the authorities started getting offended. Likewise we think that Galileo was a victim in the name of science; in fact, the church didn't take him too seriously. It seems, rather, that Galileo caused the uproar himself by ruffling a few feathers. At the end of the year in which Darwin and Wallace presented their papers on evolution by natural selection that changed the way we view the world, the president of the Linnean society, where the papers were presented, announced that the society saw "no striking discovery," nothing in particular that could revolutionize science.

—— The Black Swan by Taleb

Natural selection

- Heritable variation. Differential reproduction. Descent with modification.
- Fitness, “survival of the fittest”.
- Competition.
- Common ancestor.

Modern synthesis of evolutionary theory



Modern synthesis of evolutionary theory

- Morphological novelty and innovation has been a recurrent theme. The architects of the modern synthesis of evolutionary theory made three claims about evolutionary novelty and innovation:

- First, that all diversifications in the history of life represent adaptive radiations;

- Second, that adaptive radiations are driven principally by ecological opportunity rather than by the supply of new morphological novelties, thus the primary questions about novelty and innovation focus on their ecological and evolutionary success;

- Third, that the rate of morphological divergence between taxa was more rapid early in the history of a clade but slowed over time as ecological opportunities declined.

The extended evolutionary synthesis

- The extended evolutionary synthesis is a set of extensions of the earlier modern synthesis of evolutionary biology that took place between 1918 and 1942. The extended evolutionary synthesis was called for in the 1950s by C. H. Waddington, argued for on the basis of punctuated equilibrium by Stephen Jay Gould and Niles Eldredge in the 1980s, and relaunched in 2007 by Massimo Pigliucci.
- The extended evolutionary synthesis revisits the relative importance of different factors at play, examining several assumptions of the earlier synthesis, and augmenting it with additional causative factors. It includes multilevel selection, transgenerational epigenetic inheritance, niche construction, and evolvability.
- Not all biologists have agreed on the need for, or the scope of, an extended synthesis. Many have collaborated on a different synthesis in evolutionary developmental biology, which integrates embryology with molecular genetics and evolution to understand how natural selection operated on developmental processes and deep homologies between organisms at the level of highly conserved genes.

Evolutionary developmental biology (evo-devo)

- Contemporary evolutionary developmental biology is analyzing how changes in development can create the diverse variation that natural selection can act on.

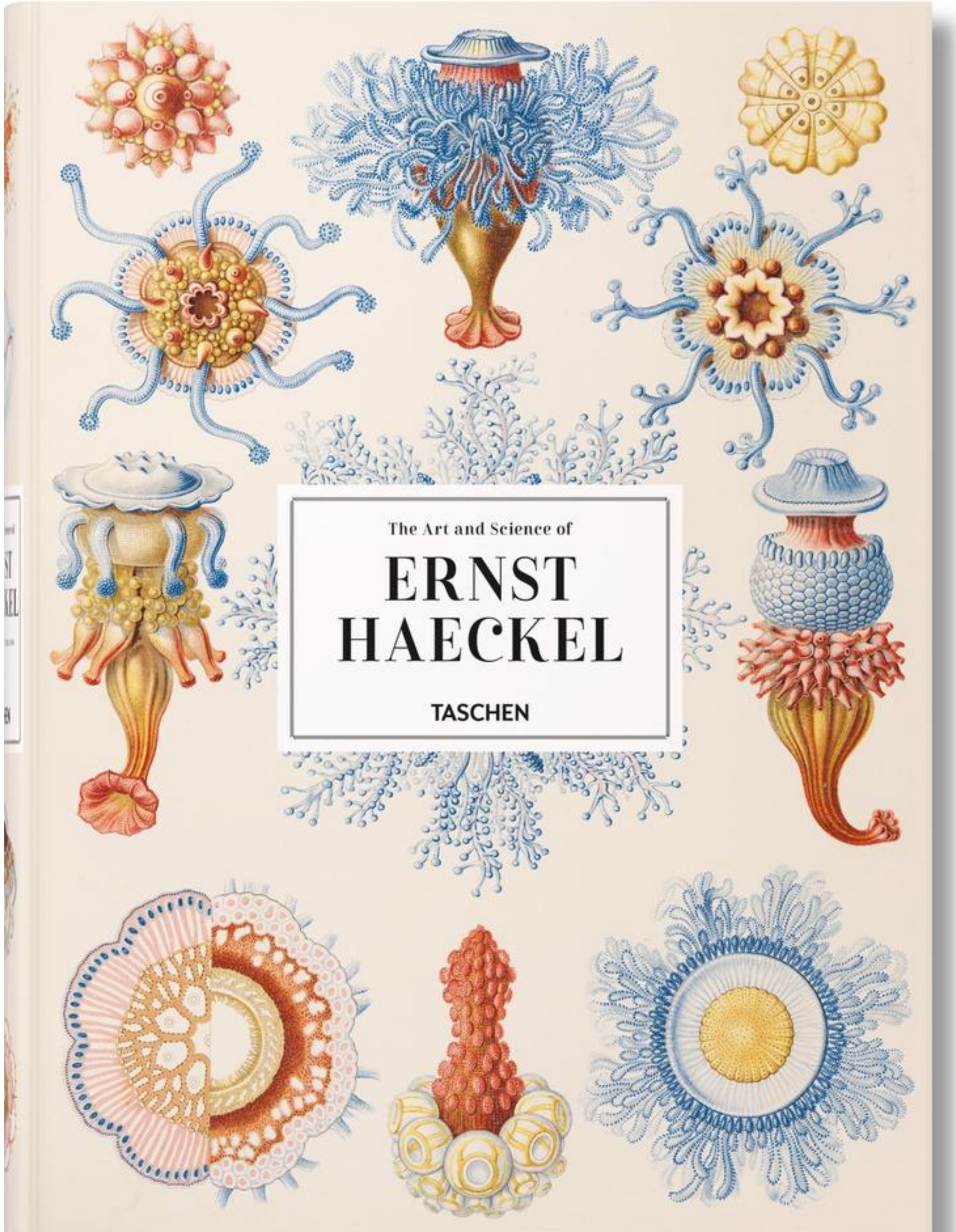
- Evolutionary developmental biology views evolution as the result of changes in development.

- If development is the change of gene expression and cell position over time, then evolution is the change of development over time.

- Rather than concentrating on the “survival of the fittest,” evolutionary developmental biology gives us new insights into the “arrival of the fittest”.

Recapitulation theory, ontogeny recapitulates phylogeny!

Ernst Haeckel, *The evolution of man*, 1903


The Art and Science of
ERNST
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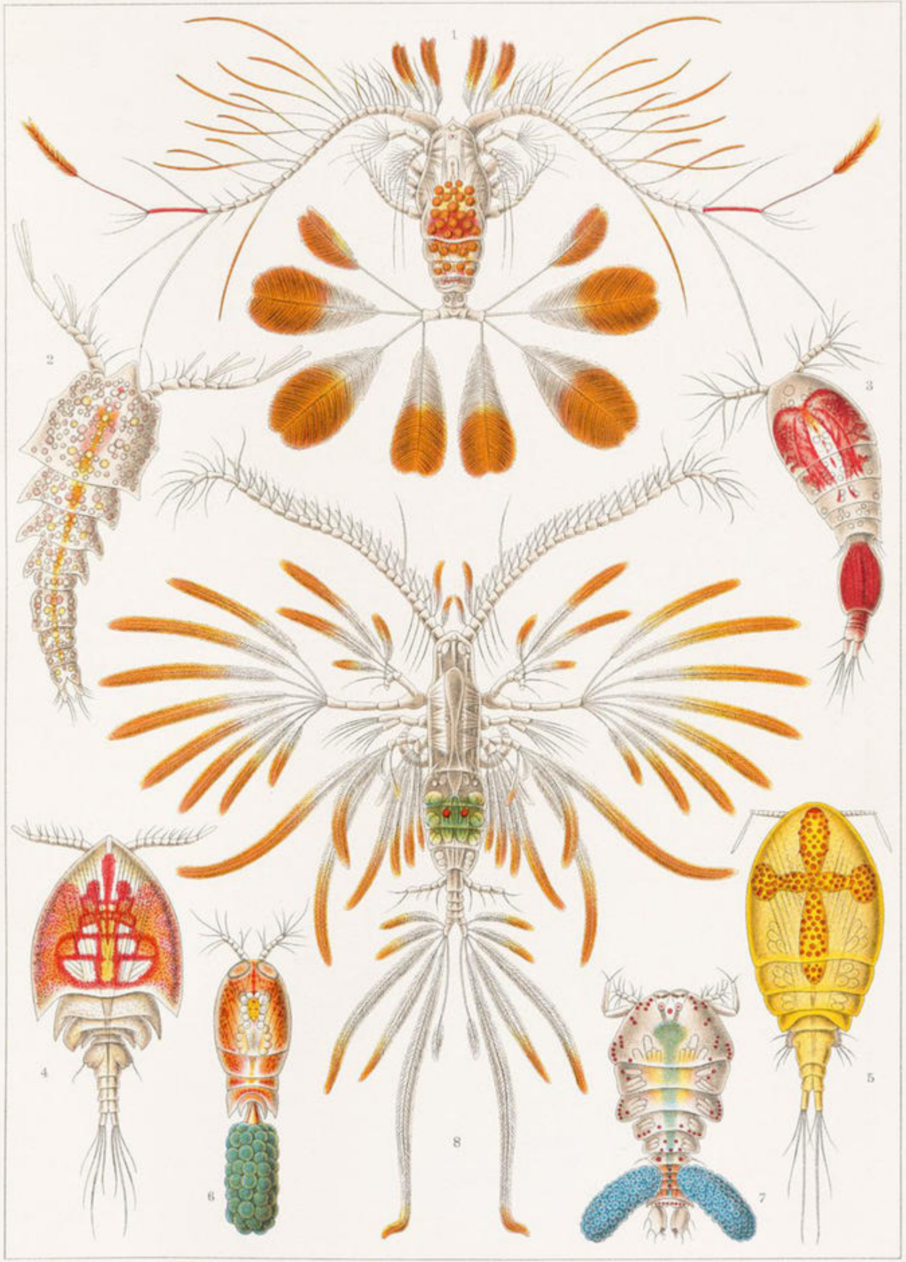
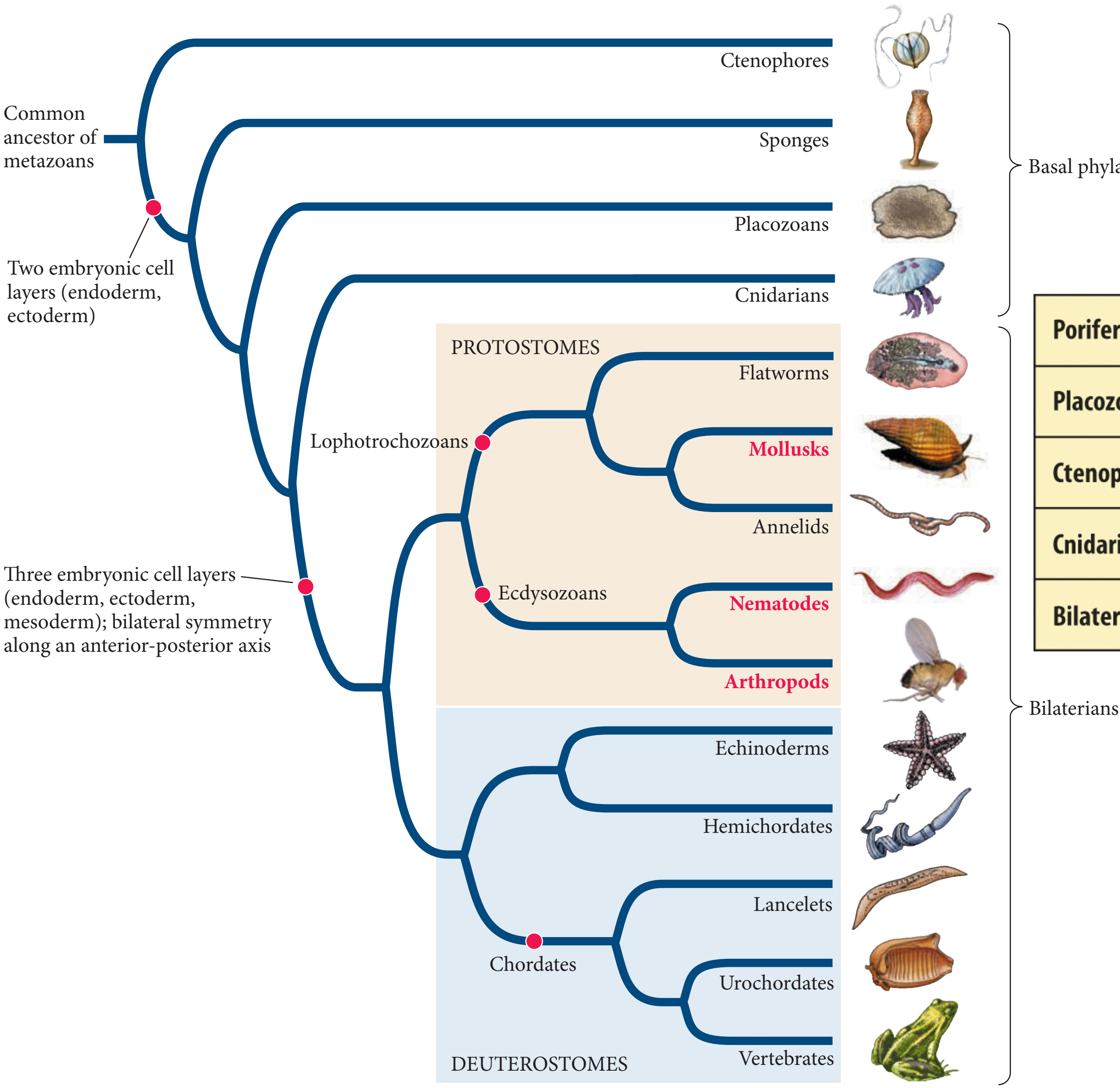


Copepoda. — Ruderkrebse.

Some questions

- The origin of the first gene
- The emerging of “central dogma”
- The origin of the first cell
- The origin of the first multi-cellular organism

The tree of metazoan (animal) life



	Wnt	Notch	Nodal	BMP	Shh
Porifera	■	■	■	□	□
Placozoa	■	■	□	□	□
Ctenophora	■	□	□	□	□
Cnidaria	■	■	■	■	■
Bilateria	■	■	■	■	■

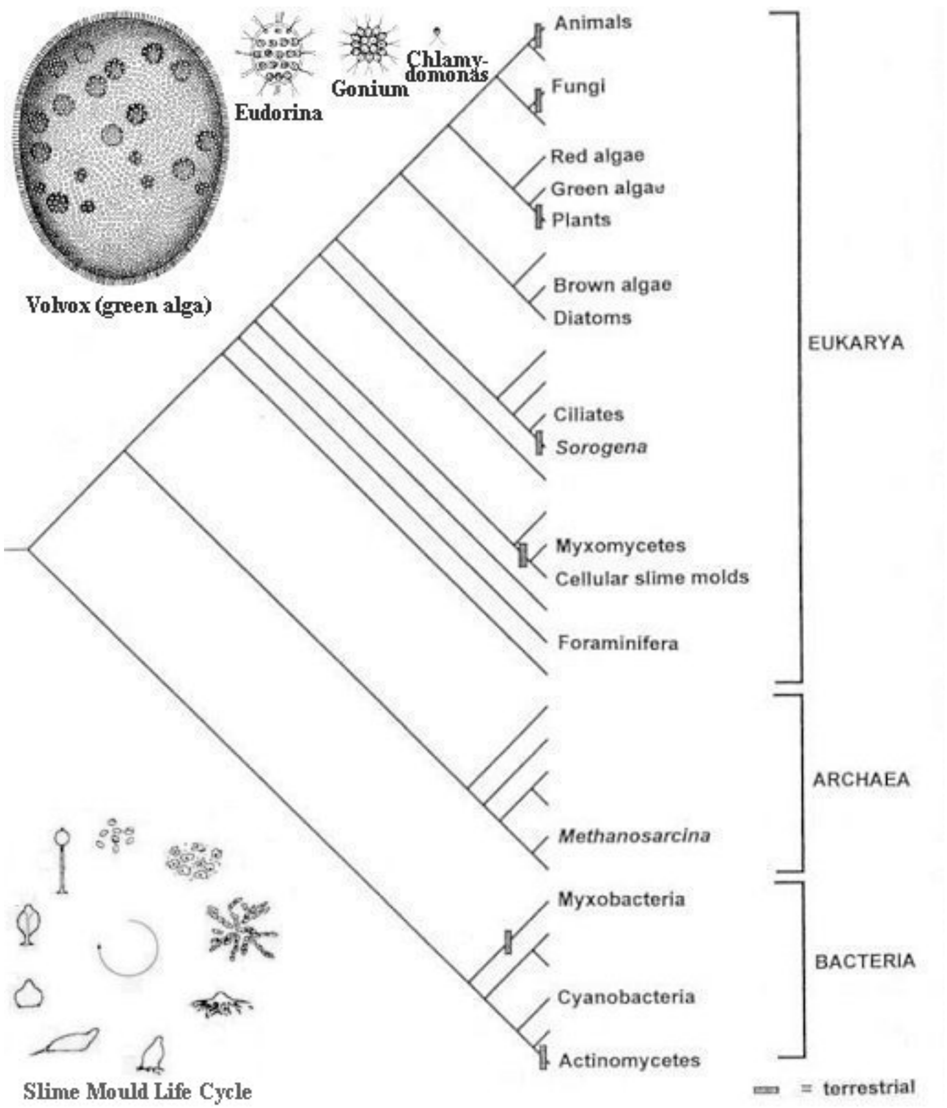
The origin of multicellular organisms

The origin of multicellular organisms

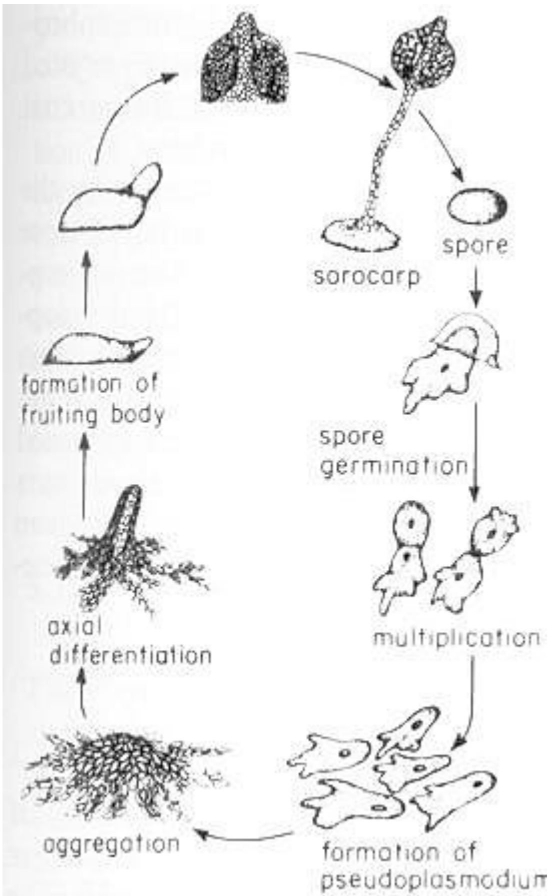
- One **possibility**, and it is highly **speculative**, is that mutations resulted in the progeny of a single-celled organism not separating after cell division, leading to a loose colony of identical cells that occasionally fragmented to give new ‘individual’.

- One advantage of a colony might originally have been that when food was in short supply, the cells could feed off each other, and so the colony survived. This could have been the origin of both multicellularity and the requirement for cell death in multicellular organisms. In sponges, for example, the egg phagocytoses neighboring cells.

Slime Moulds



The slime mould life cycle



- They begin their life from spore germination and multiplication.
- The basic units of slime moulds are haploid amoebae, usually prowling around on the forest floor consuming bacteria.
- Once the supply of food is exhausted, individual amoebae begin to move together. They form streams of cells calledpseudoplasmodium moving slowly at about one millimeter/hour. It is now known that the process is initiated with thecAMP[1] signaling molecules released by the starving amoebae.
- Eventually the streams come together and form an aggregation which is at the spot with high concentration of cAMP. The mass can number a hundred thousand cells and might reach a size of a few millimeters.
- Then they stick together by secreting adhesion molecules and creating a slime sheath (cap) which covers all the cells in the mass. The polarity defined by the anterior (front), posterior (back) ends is established by oxygen gradient. The responsible gene for adhesion can be identified by blocking its expression. The resulting mass becomes a loose rubble that is incapable of further development

Cambrian explosion

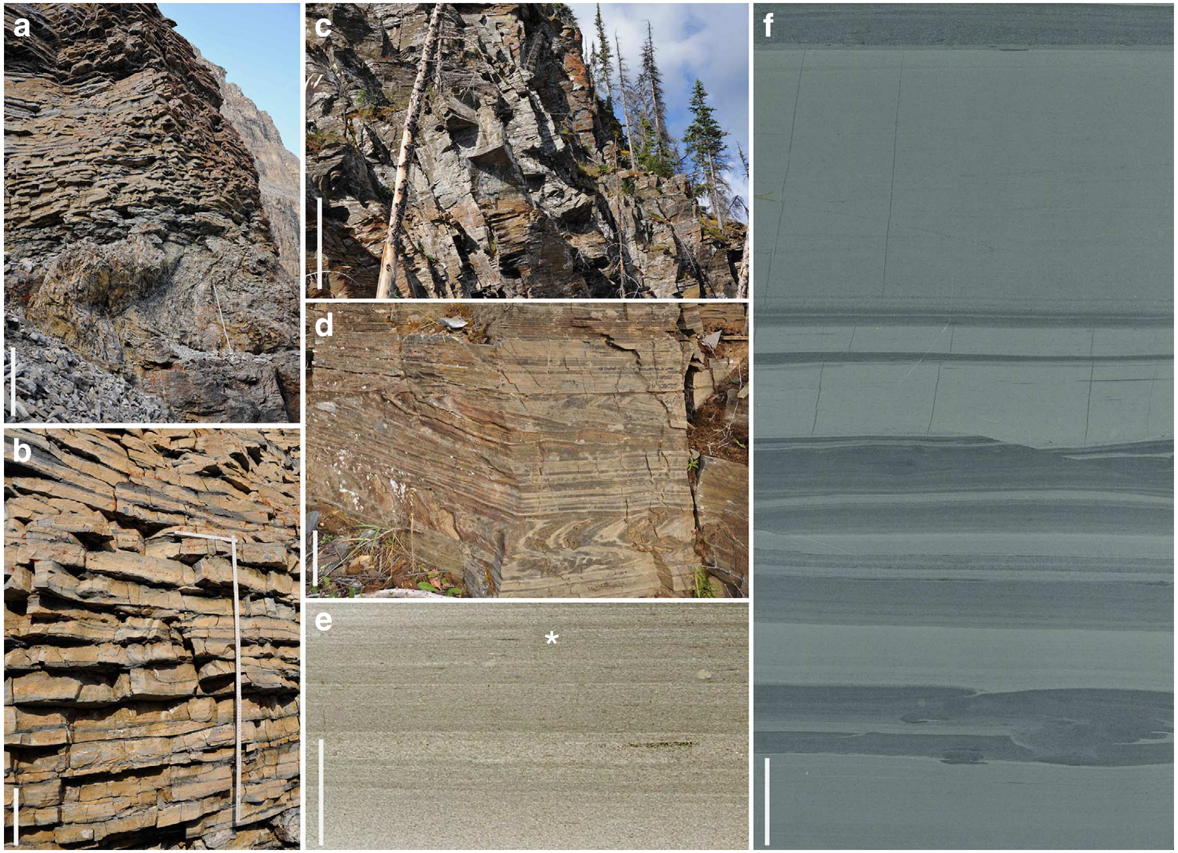
- The “Cambrian Explosion” refers to the appearance in the fossil record of most major animal body plans about 543 million years ago. The new fossils appear in an interval of 20 million years or less. On evolutionary time scales, 20 million years is a rapid burst that appears to be inconsistent with the gradual pace of evolutionary change. However, rapid changes like this appear at other times in the fossil record, often following times of major extinction. The Cambrian Explosion does present a number of interesting and important research questions. It does not, however, challenge the fundamental correctness of the central thesis of evolution.

- Before the Cambrian explosion, most organisms were simple, composed of individual cells occasionally organized into colonies. Over the following 70 to 80 million years, the rate of diversification accelerated, and the variety of life began to resemble that of today. Almost all present animal phyla appeared during this period.

Cambrian fossils

- Ediacaran biota, Australia
- Chengjiang (澄江) biota, Yunnan, China
- Burges shale biota, Canada

Sedimentary facies of the Stephen Formation at the Marble Canyon locality



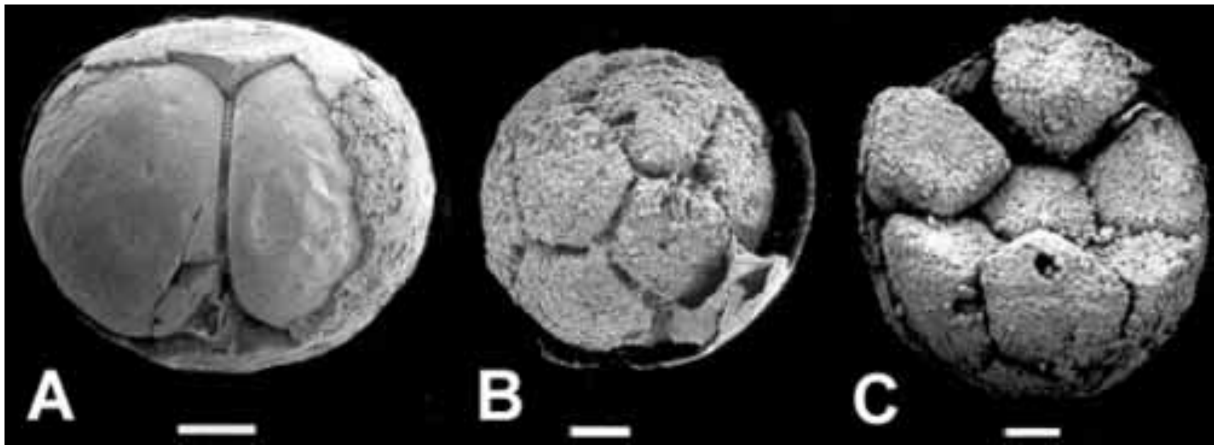
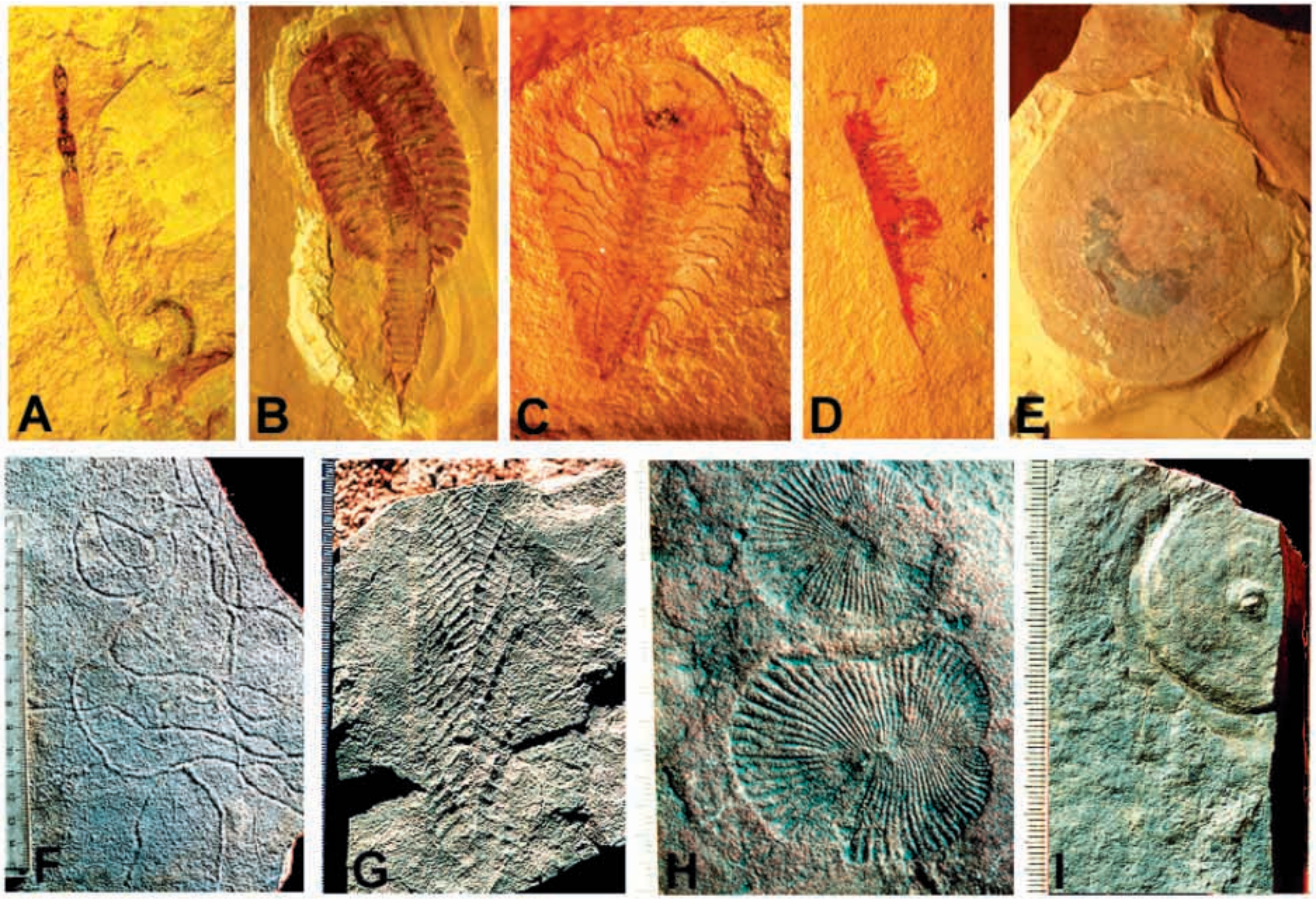


Fig. 2. Phosphatized fossil embryos from the Neoproterozoic, 570±20 million years old. (A) 2-cell stage. (B,C) Later cleavage stages, with internal geometry of cells visible in C. From Xiao et al. (1998).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k
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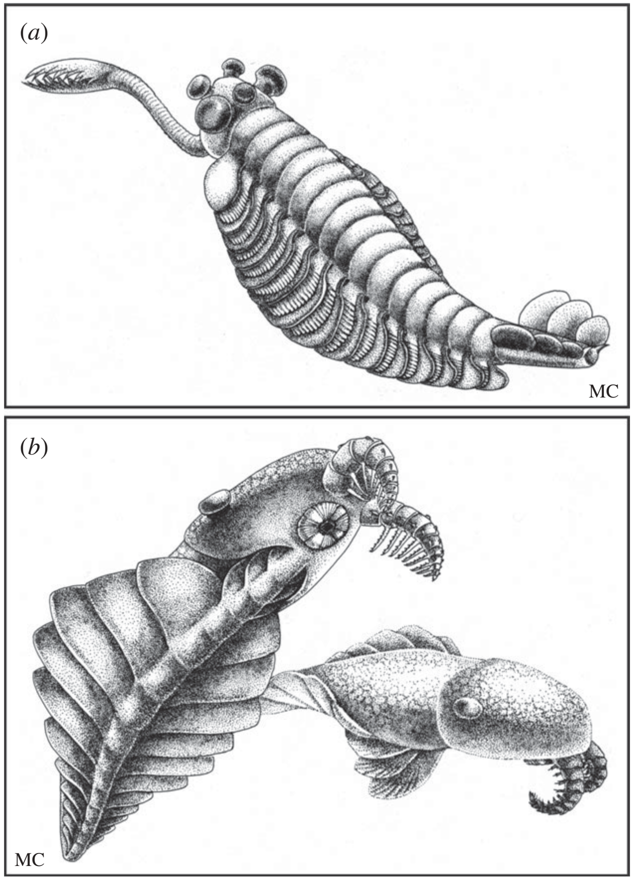
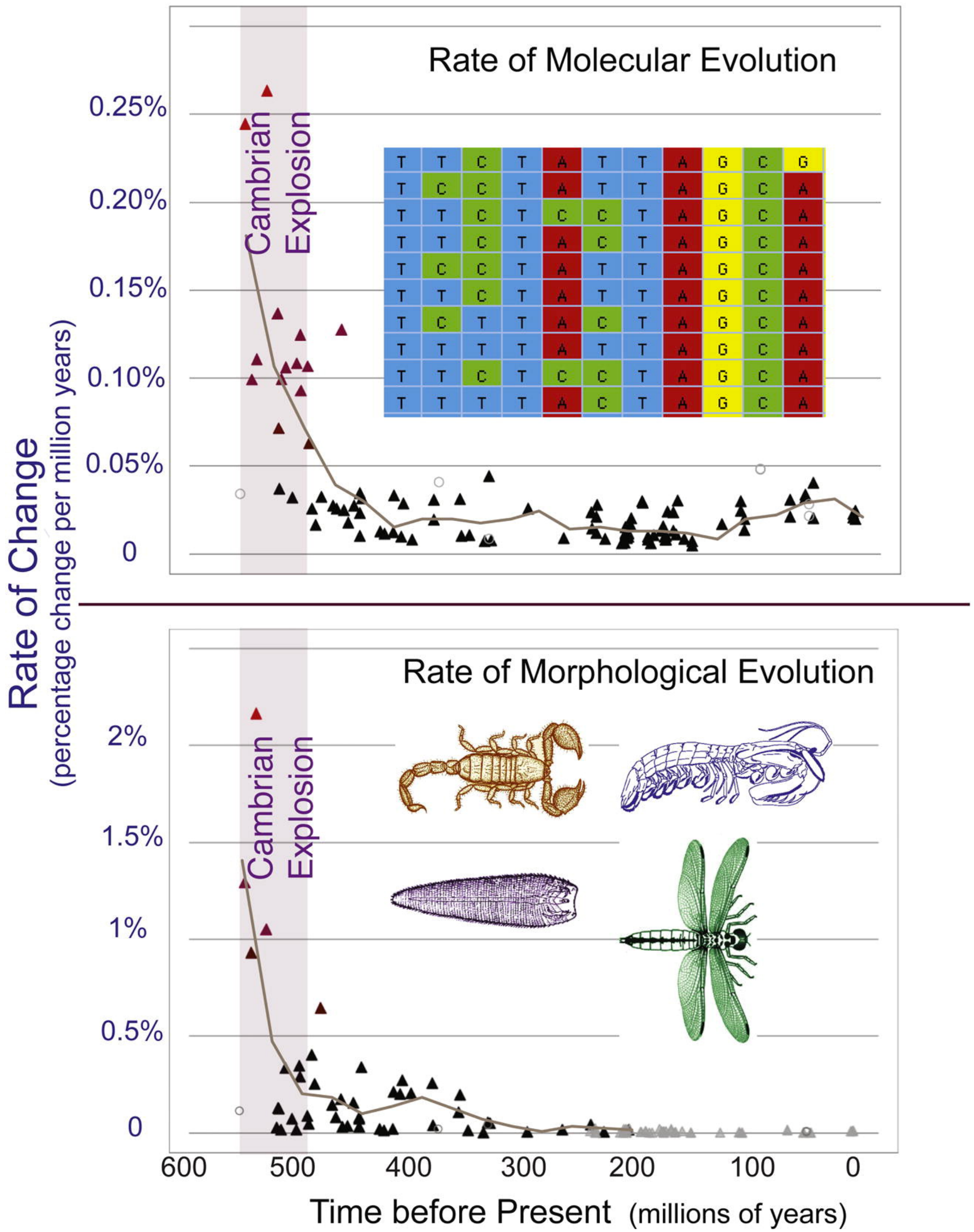
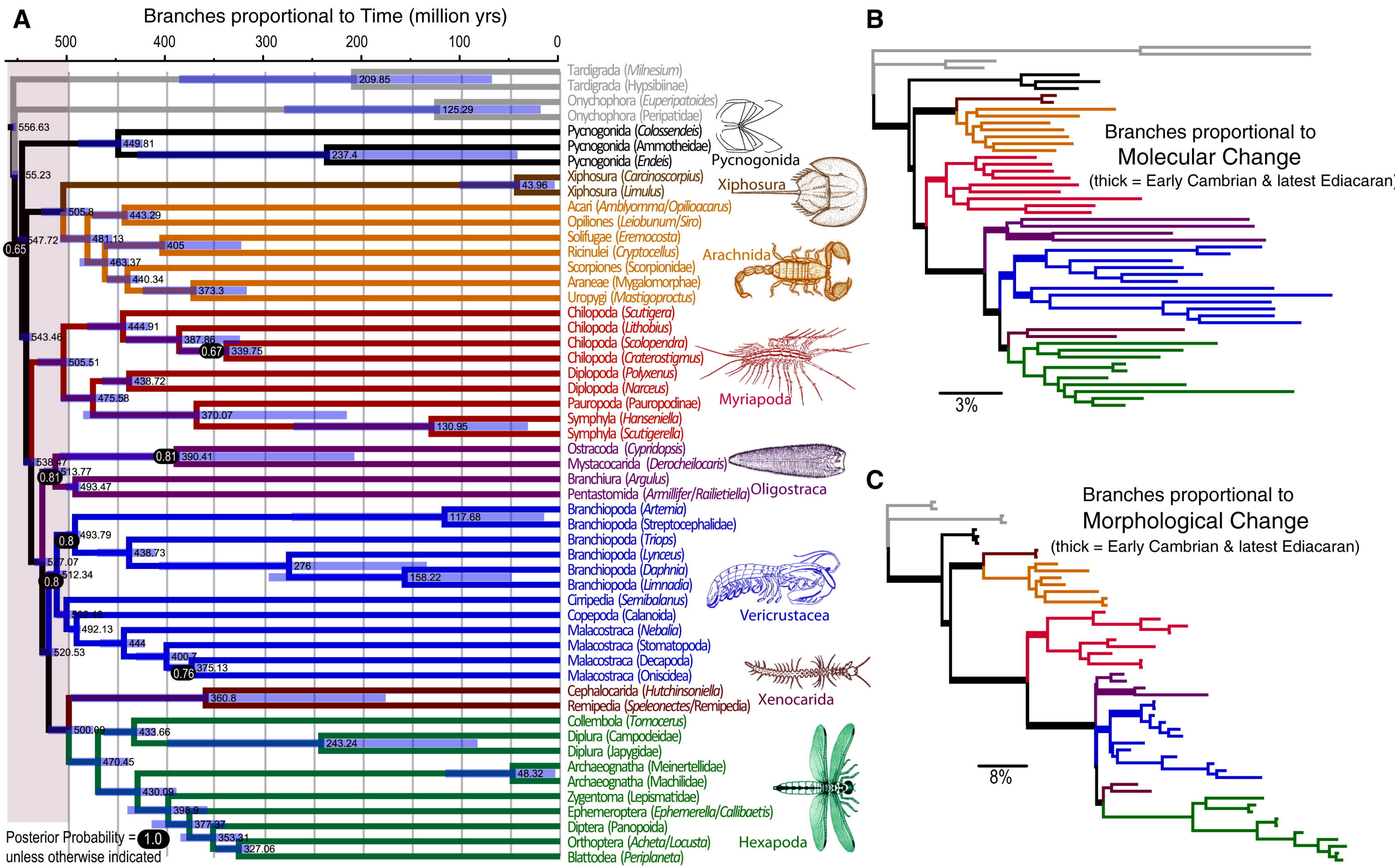
Opabinia (欧巴宾海蝎) and *Anomalocaris*



A menagerie of strange creatures emerged during the Cambrian explosion



Rate of Molecular Evolution
Rate of Morphological Evolution
Cambrian Explosion
Rate of Change
(percentage change per million years)
0.25%
0.20%
0.15%
0.10%
0.05%
0
2%
1.5%
1%
0.5%
0
600
500
400
300
200
100
0
Time before Present (millions of years)


A
Branches proportional to Time (million yrs)
500
400
300
200
100
0
Tardigrada (Milnesium)
Tardigrada (Hypsibiinae)
Onychophora (Euperipatoides)
Onychophora (Peripatidae)
Pycnogonida (Colossendeis)
Pycnogonida (Ammotheidae)
Pycnogonida (Endeis)
Xiphosura (Carcinoscorpius)
Xiphosura (Limulus)
Acari (Amblyomma/Opilioacarus)
Opiliones (Leiobunum/Siro)
Solifugae (Eremocosta)
Ricinulei (Cryptocellus)
Scorpiones (Scorpionidae)
Araneae (Mygalomorphae)
Uropygi (Mastigoproctus)
Chilopoda (Scutigera)
Chilopoda (Lithobius)
Chilopoda (Scolopendra)
Chilopoda (Craterostigmus)
Diplopoda (Polyxenus)
Diplopoda (Narceus)
Pauropoda (Pauropodinae)
Symphyla (Hanseniella)
Symphyla (Scutigerella)
Ostracoda (Cypridopsis)
Mystacocarida (Derocheilocaris)
Branchiura (Argulus)
Pentastomida (Armillifer/Railietiella)
Branchiopoda (Artemia)
Branchiopoda (Streptocephalidae)
Branchiopoda (Triops)
Branchiopoda (Lynceus)
Branchiopoda (Daphnia)
Branchiopoda (Limnadia)
Cirripedia (Semibalanus)
Copepoda (Calanoida)
Malacostraca (Nebalia)
Malacostraca (Stomatopoda)
Malacostraca (Decapoda)
Malacostraca (Oniscidea)
Cephalocarida (Hutchinsoniella)
Remipedia (Speleonectes/Remipedia)
Collembola (Tomocerus)
Diplura (Campodeidae)
Diplura (Japygidae)
Archaeognatha (Meinertellidae)
Archaeognatha (Machilidae)
Zygentoma (Lepismatidae)
Ephemeroptera (Ephemerella/Callibaetis)
Diptera (Panopoida)
Orthoptera (Acheta/Locusta)
Blattodea (Periplaneta)
Pycnogonida
Xiphosura
Arachnida
Myriapoda
Oligostraca
Vericrustacea
Xenocarida
Hexapoda
209.85
125.29
556.63
449.81
237.4
55.23
43.96
505.8
443.29
547.72
0.65
481.13
405
463.37
440.34
373.3
444.91
543.46
387.86
0.67
339.75
505.51
438.72
475.58
370.07
130.95
0.81
390.41
538.47
513.77
0.81
493.47
117.68
0.8
493.79
438.73
527.07
276
0.8
512.34
158.22
492.13
444
400.7
520.53
0.76
375.13
360.8
500.09
433.66
243.24
470.45
48.32
430.09
398.9
377.37
353.31
327.06
Posterior Probability = 1.0
unless otherwise indicated
B
Branches proportional to
Molecular Change
(thick = Early Cambrian & latest Ediacaran)
3%
C
Branches proportional to
Morphological Change
(thick = Early Cambrian & latest Ediacaran)
8%

Current Biology

CellPress

Volume 7, Issue 2, February 1997, Pages R71-R74

Dispatch

Molecular clocks: Defusing the Cambrian 'explosion'?

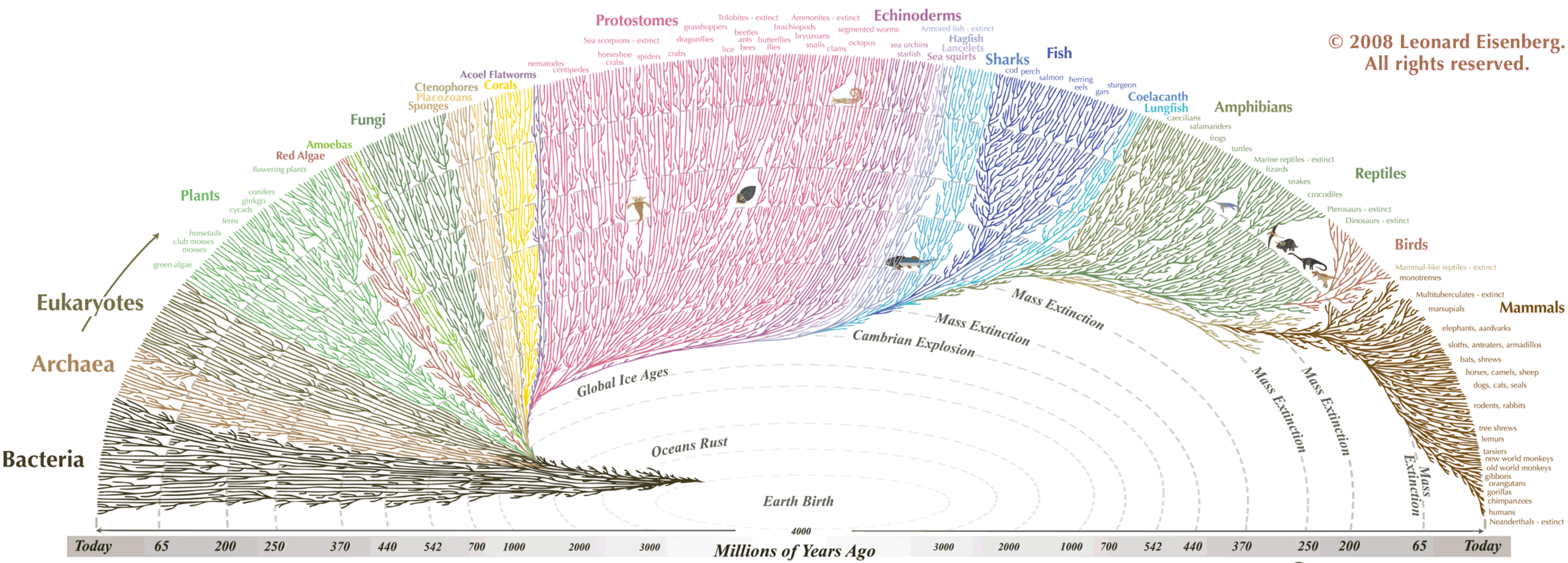
Simon Conway Morris [1]

Show more

https://doi.org/10.1016/S0960-9822(06)00039-X

Abstract

A recent molecular phylogenetic study argues against the orthodox view that metazoan phyla emerged abruptly during the Cambrian 'explosion', pointing instead to a protracted history for metazoans that arguably stretches back a billion years or more; the fossils, however, seem to tell a different story.



All the major and many of the minor living branches of life are shown on this diagram, but only a few of those that have gone extinct are shown. Example: Dinosaurs - extinct

TREE OF LIFE web project

Explore the Tree of Life

Browse the Site

Root of the Tree
Popular Pages
Sample Pages
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Treehouses
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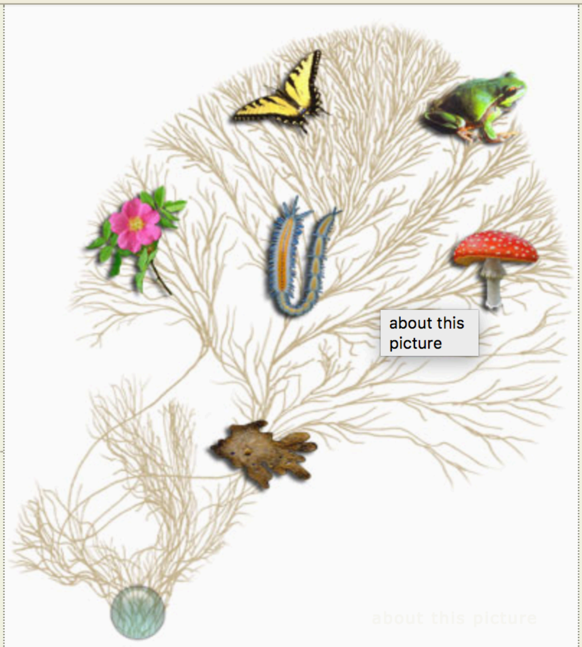
Search



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Agaricales
(a group of fungi)

image info

The Agaricales, or euagarics clade, is a monophyletic group of approximately 8500 mushroom species...

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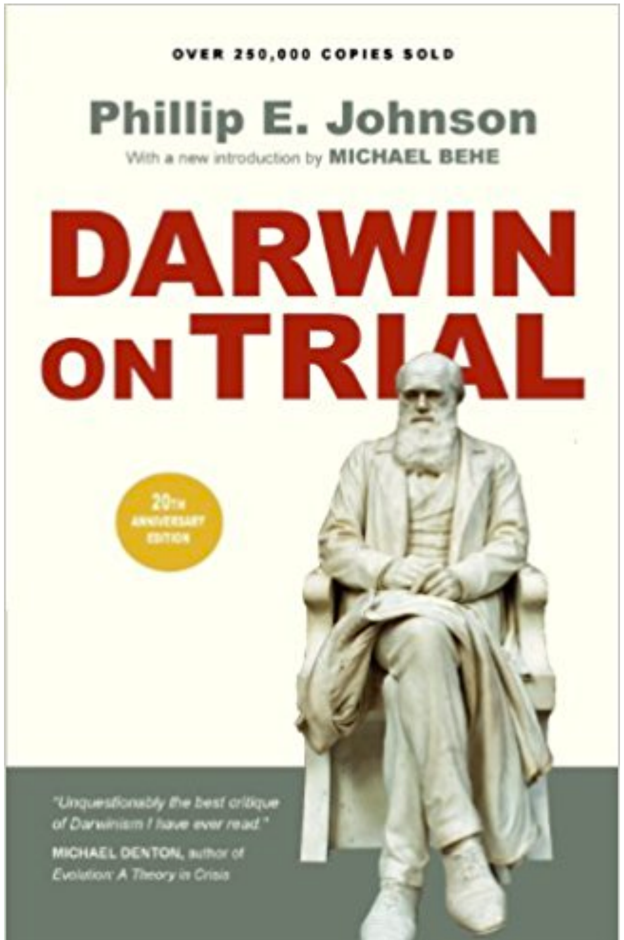
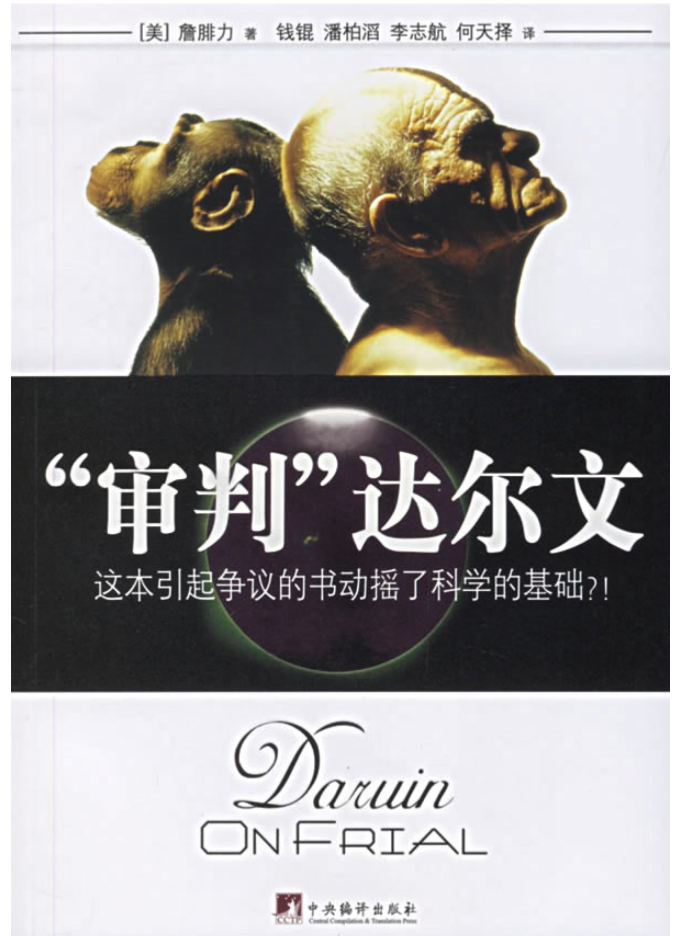
The Tree of Life Web Project (ToL) is a collaborative effort of biologists and nature enthusiasts from around the world. On more than 10,000 World Wide Web pages, the project provides information about biodiversity, the characteristics of different groups of organisms, and their evolutionary history (phylogeny).

Each page contains information about a particular group, e.g., salamanders, segmented worms, phlox flowers, tyrannosaurs, euglenids, *Heliconius* butterflies, club fungi, or the vampire squid. ToL pages are linked one to another hierarchically, in the form of the evolutionary tree of life. Starting with the root of all Life on Earth and moving out along diverging branches to individual species, the structure of the ToL project thus illustrates the genetic connections between all living things.

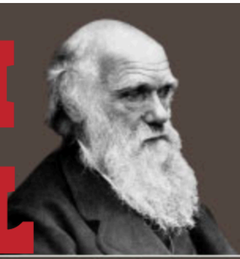
read more about the Tree of Life Web Project...

Debates over theory of evolution





DARWIN ON TRIAL



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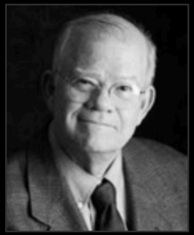
Phillip E. Johnson

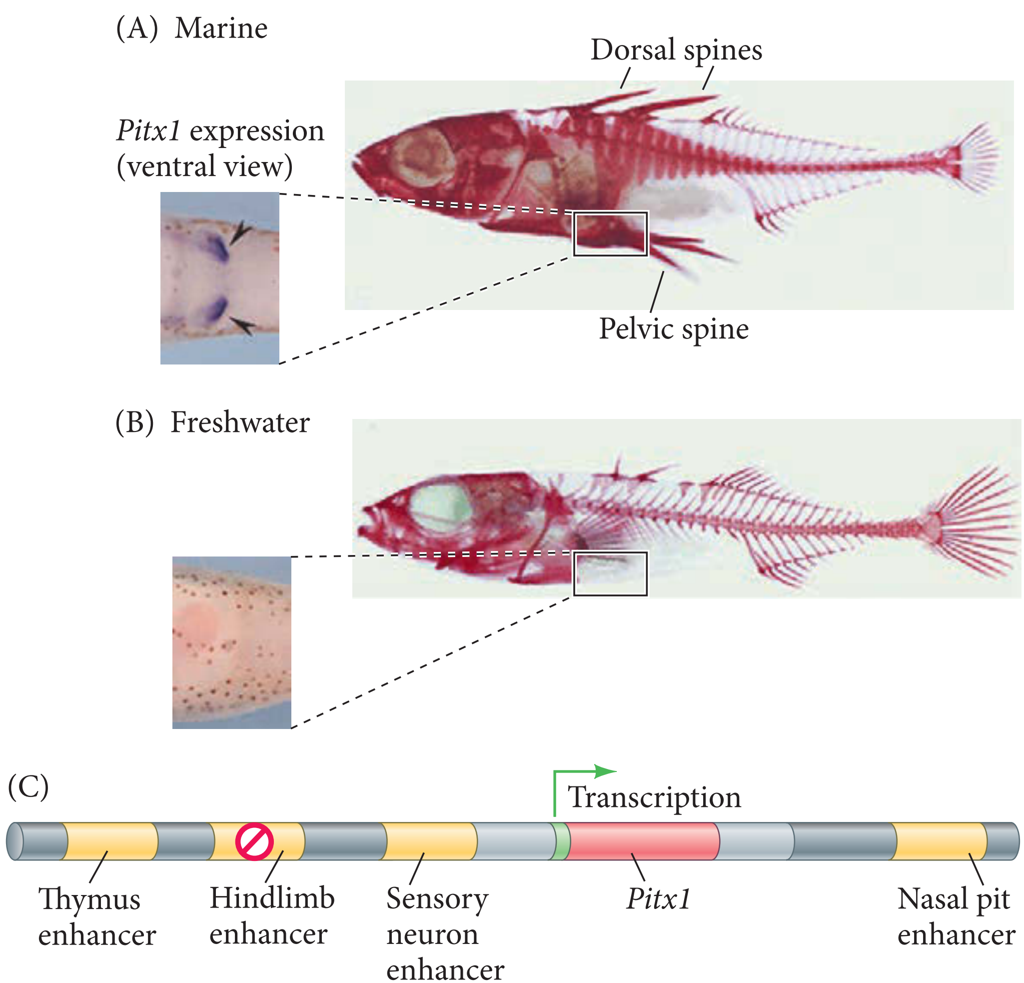


This website explores the life and writings of **Phillip E. Johnson**, Professor of Law, Emeritus at the University of California, Berkeley School of Law and author of *Darwin on Trial* and other books. Here you will find links to Professor Johnson's articles, reviews of his books, and multimedia files of his interviews and lectures.

Modularity (模块化)

- Discrete units (modules) , eg. segments and somites.
- Duplication of modules, eg. somites of snake.
- Divergence of modules, eg. wing and holtere, forelimb and hindlimb.
- Both anatomical units and DNA elements are modular.

Pitx1 and stickleback evolution



Recruitment or “co-option”

(A)

(B)

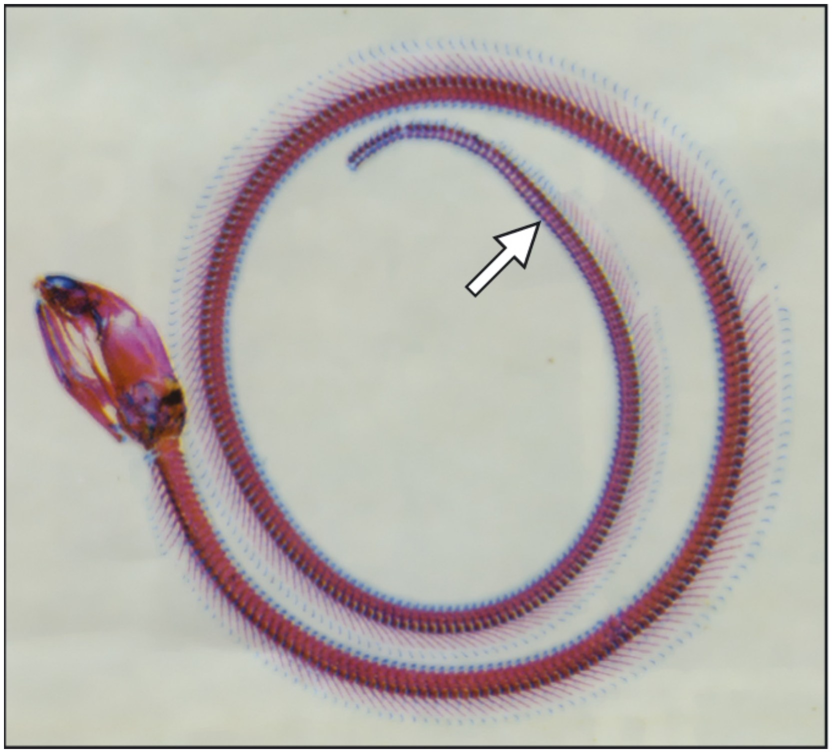
However, in beetles (and in no other known insect), Apterous protein also activates the exoskeleton genes in the forewing while repressing them in the hindwing (Tomoyasu et al. 2009).

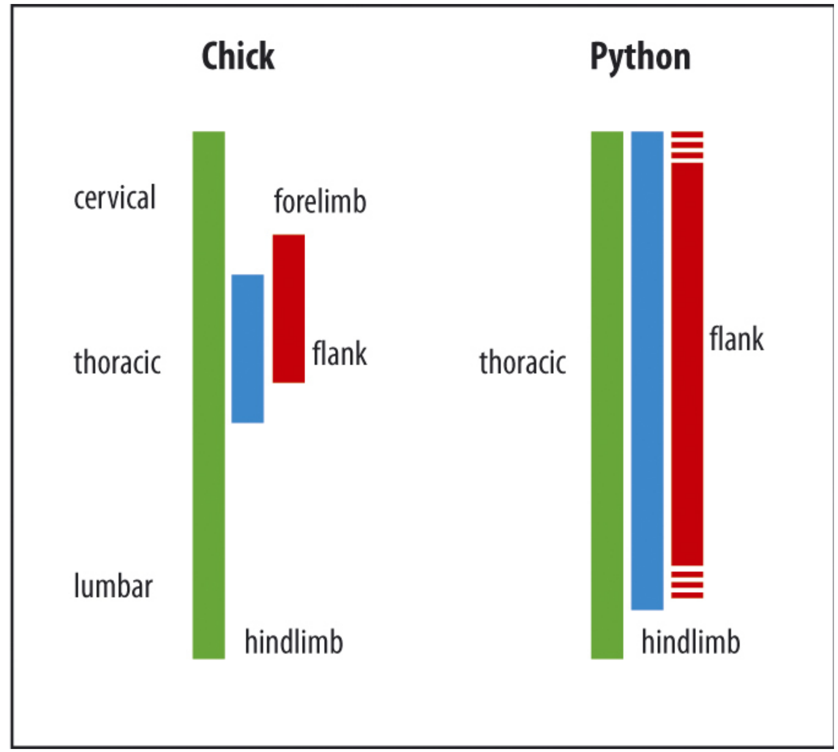
Mechanisms of Evolutionary Change

- François Jacob, the Nobel laureate who helped establish the operon model of gene regulation.
- First, Jacob said, evolution works with what it has: it combines existing parts in new ways rather than creating new parts.
- Second, he predicted that such “tinkering” would be most likely to occur in those genes that construct the embryo, not in the genes that function in adults (Jacob 1977).

- Wallace Arthur (2004) catalogued four ways in which Jacob’s “tinkering” can take place at the level of gene expression to generate phenotypic variation available for natural selection:

- 1. Heterotopy (change in location)
- 2. Heterochrony (change in time)
- 3. Heterometry (change in amount)
- 4. Heterotypy (change in kind)

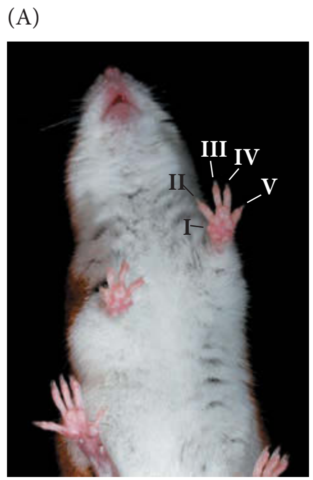




Chick
Python
cervical
forelimb
thoracic
flank
lumbar
hindlimb
thoracic
flank
hindlimb

Heterotopy (change in location)

How the bat got its wings? By blocking the BMPs that would otherwise cause the inter- digital cells to undergo apoptosis.



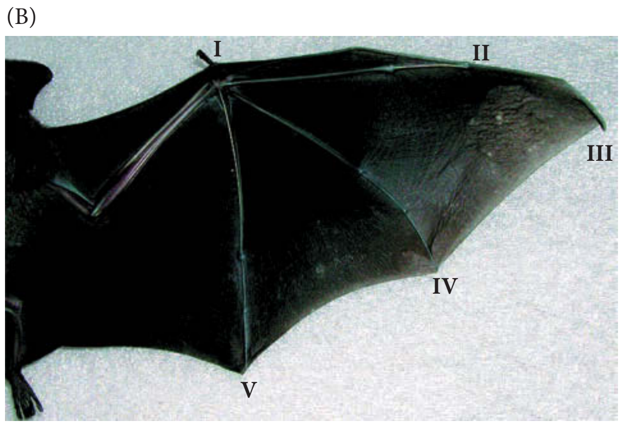
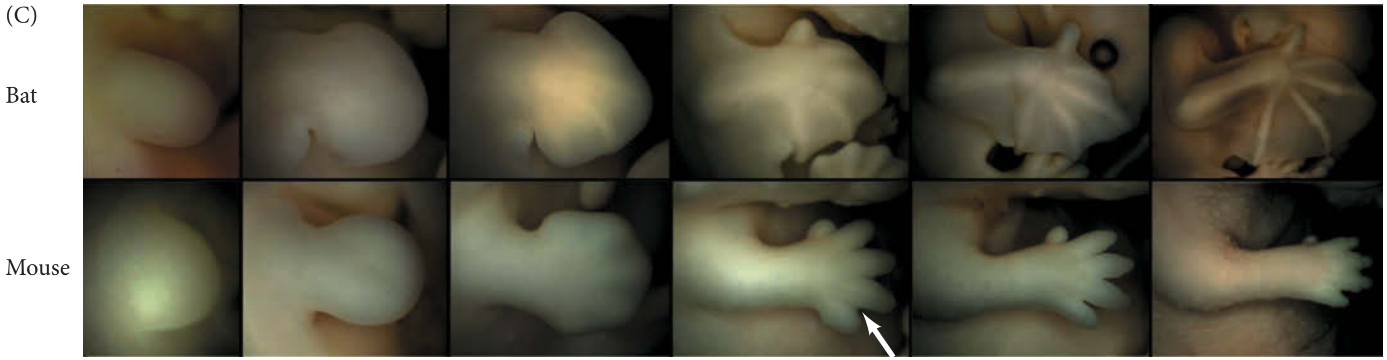


FIGURE 1.19 Development of bat and mouse forelimbs. (A,B) Mouse and bat torsos, showing the mouse forelimb and the elongated fingers and prominent webbing in the bat wing. The digits are numbered on both animals (I, thumb; V, "pinky"). (C) Comparison of mouse and bat forelimb morphogenesis. Both limbs start as webbed appendages, but the webbing between the mouse's digits dies at embryonic day 14 (arrow). The webbing in the bat forelimb does not die and is sustained as the fingers grow. (A courtesy of D. McIntyre; B,C from Cretekos et al. 2008, courtesy of C. J. Cretekos.)



Heterochrony (change in time)

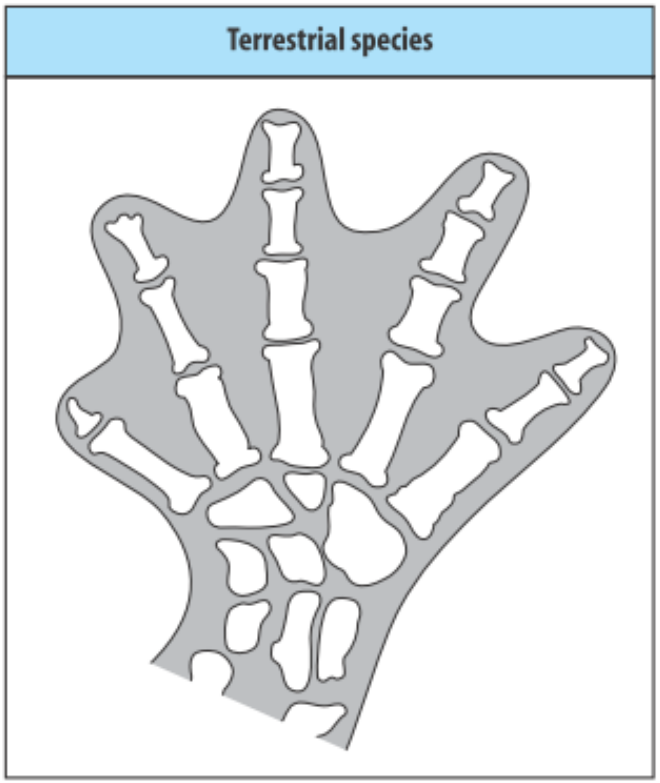
- Heterochrony (Greek, “different time”) is a shift in the relative order or timing of two developmental processes.

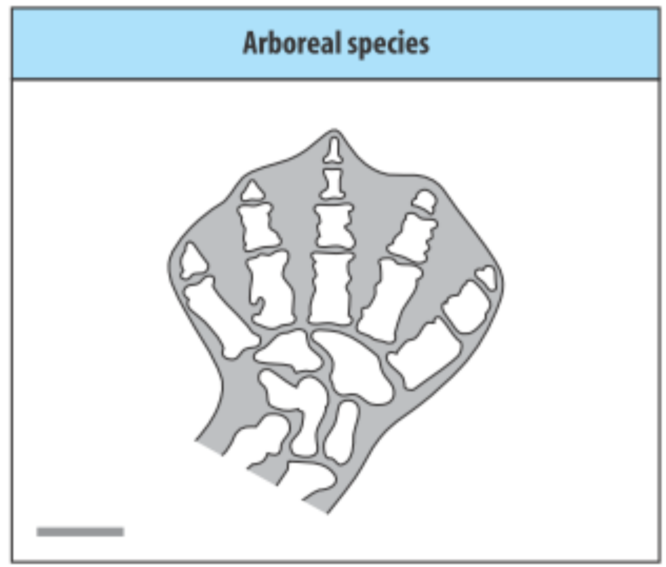
- As Darwin noted, “we may confidently believe that many modifications, wholly due to the laws of growth, and at first in no way advantageous to a species, have been subsequently taken advantage of by the still further modified descendants of this species."

Heterochrony in frogs, larval stages can be skipped

Frogs of the genus Eleutherodactylus, develop directly into an adult frog and there is no aquatic tadpole stage, the eggs being laid on land. Typical tadpole features, such as gills and cement glands, do not develop, and prominent limb buds appear shortly after the formation of the neural tube.

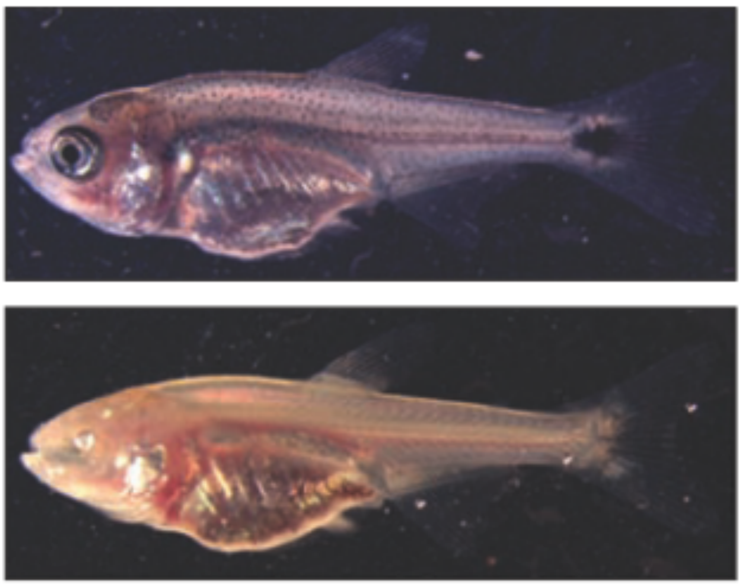
Heterochrony (differences in timing) in salamanders

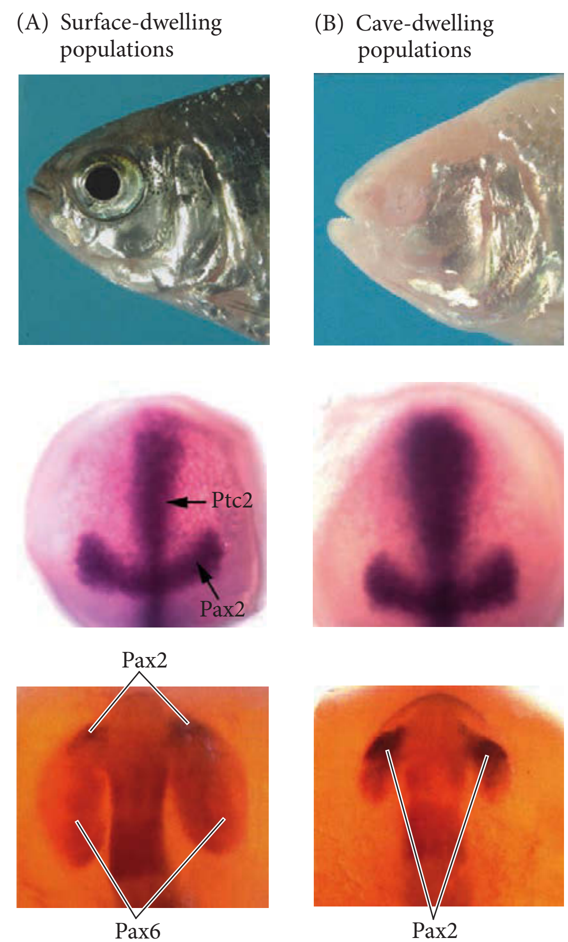




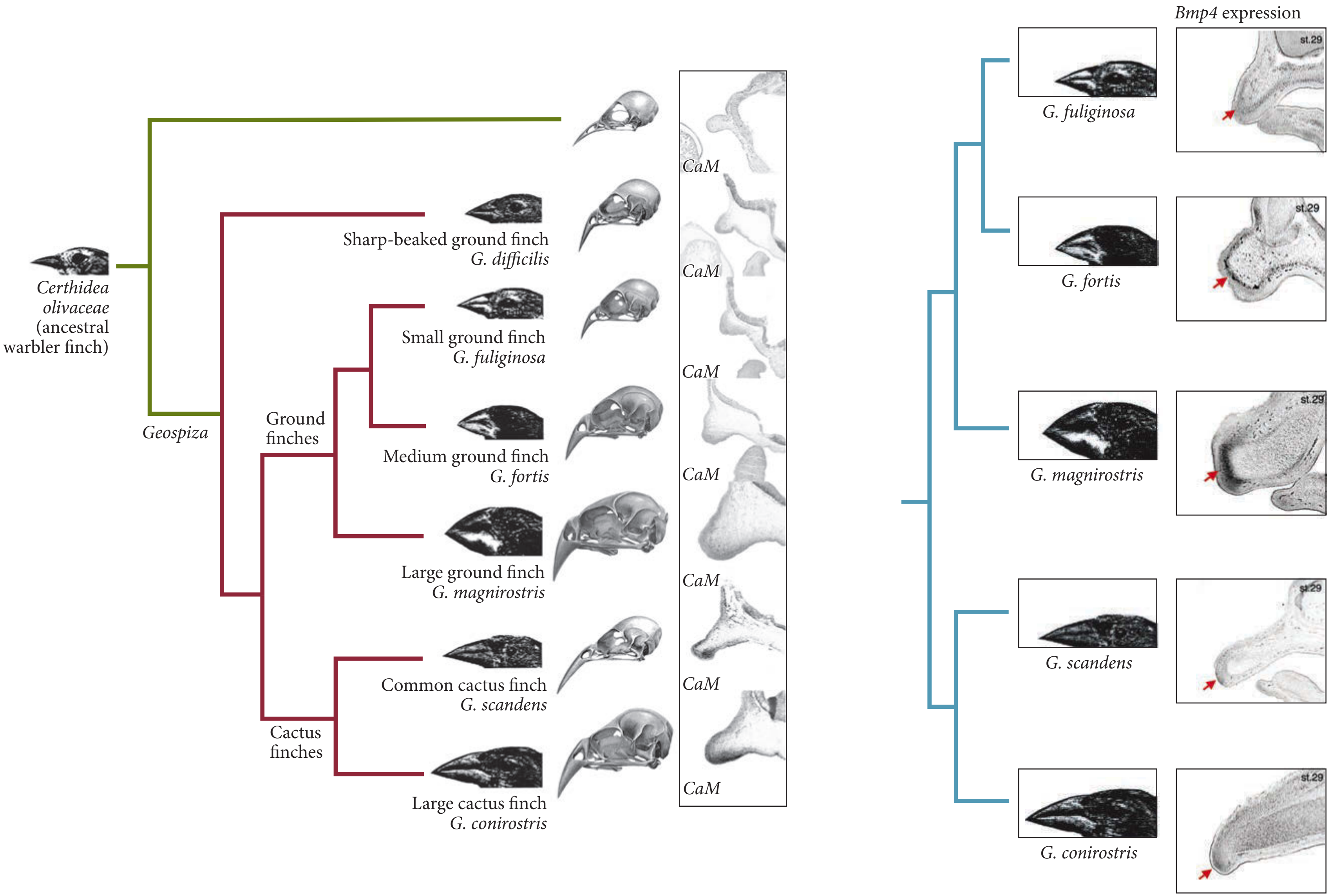
Heterometry (change in amount)

The two different forms of *Astyanax mexicanus*





Darwin’s finches



Heterotypy (change in kind)

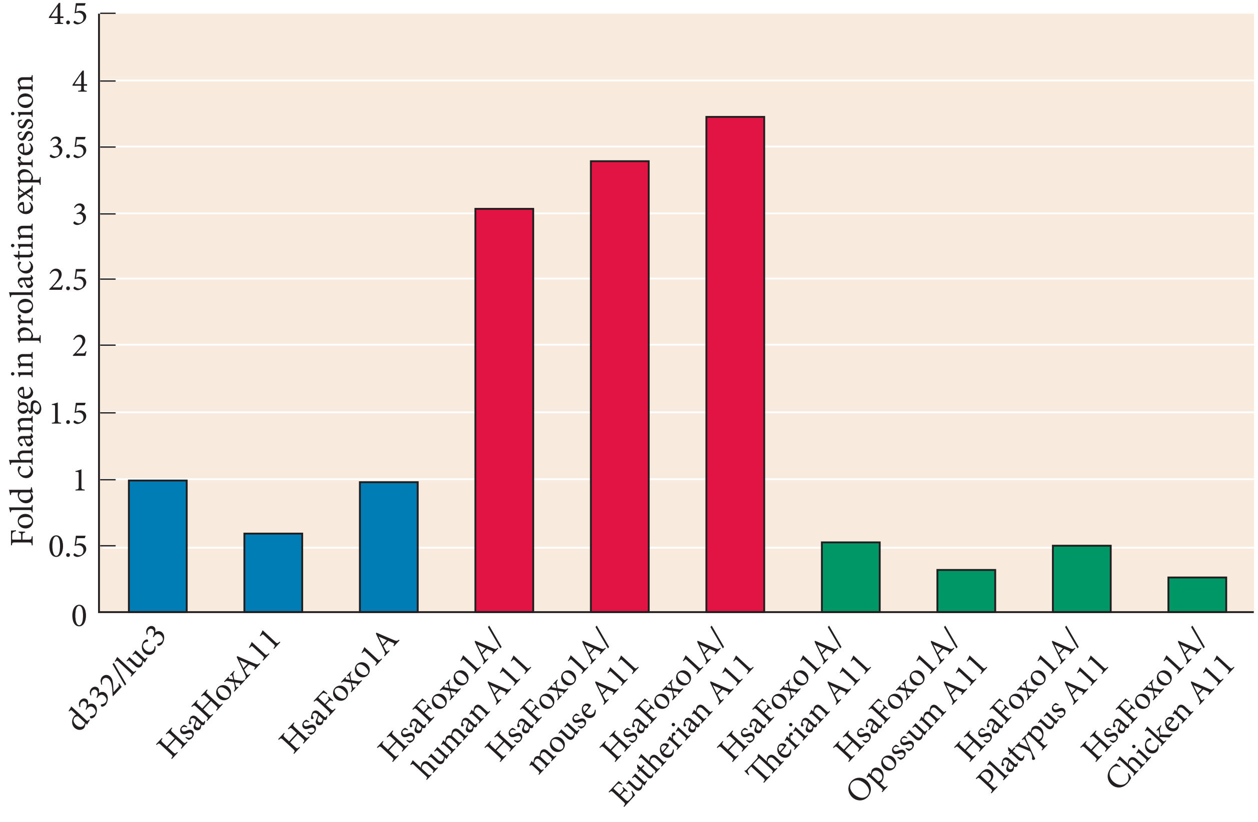
- The changes of heterotypy affect the actual coding region of the gene, and thus can change the functional properties of the protein being synthesized. These changes in the protein- encoding regions of the gene are usually seen in genes that are expressed in only one or a few tissues, suggesting that pleiotropy (see below) constrains such changes in broadly expressed genes.

How pregnancy may have evolved in mammals

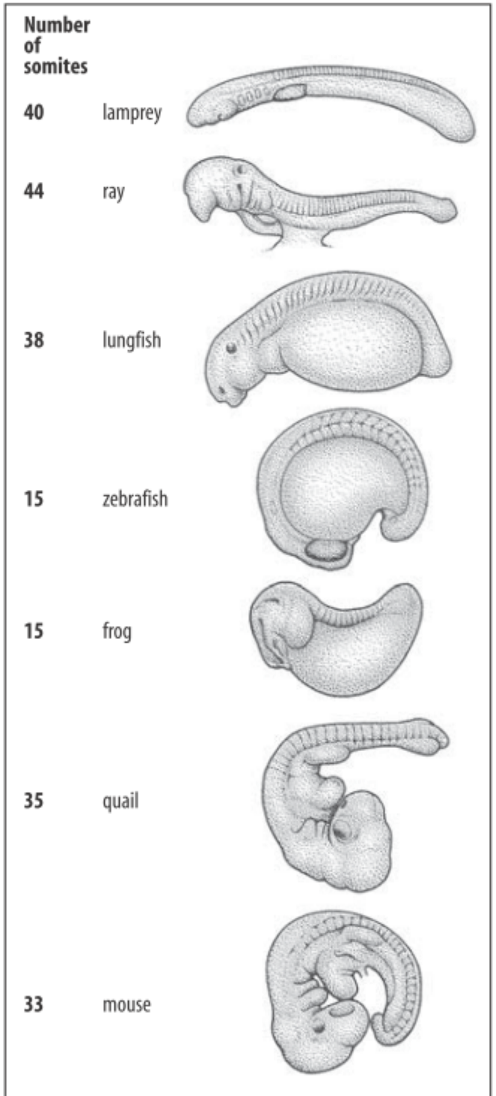
- One of the key proteins enabling this internal gestation is prolactin.

- Prolactin promotes differentiation of the uterine epithelial cells, regulates trophoblast growth, allows blood vessels to spread toward the embryo, and helps downregulate the immune and inflammatory responses so the mother’s body does not perceive the embryo as a “foreign body” and reject it.

Ability of the mammalian Hoxa11 protein, in combination with Foxo1a, to promote expression of the uterine *Prolactin* enhancer



Phylotypic stage/period



- All vertebrate embryos pass through a phylotypic stage at which they all more or less resemble each other and show the specific embryonic features of the phylum to which they belong.

Phylotypic stage/period between phyla

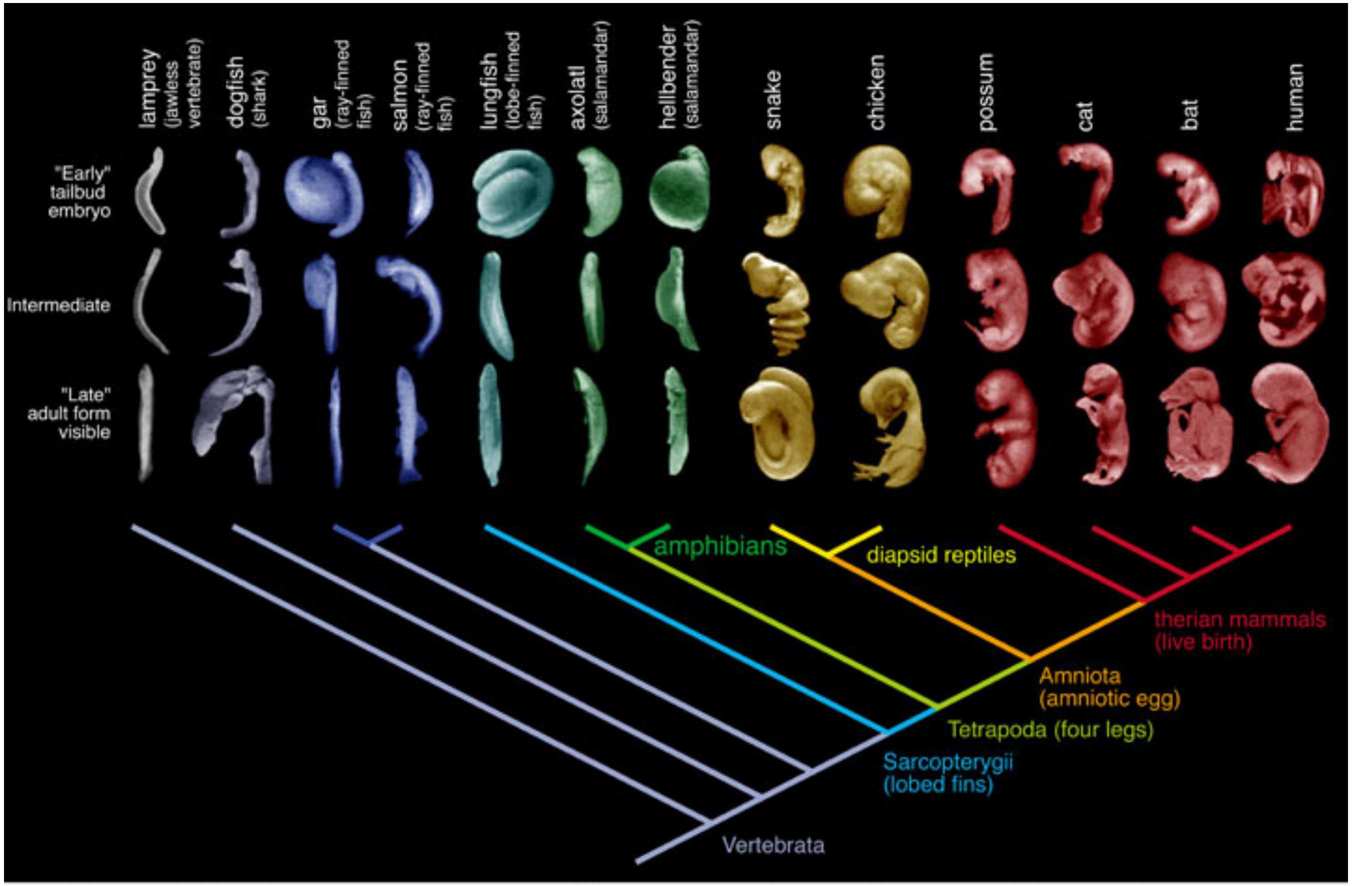
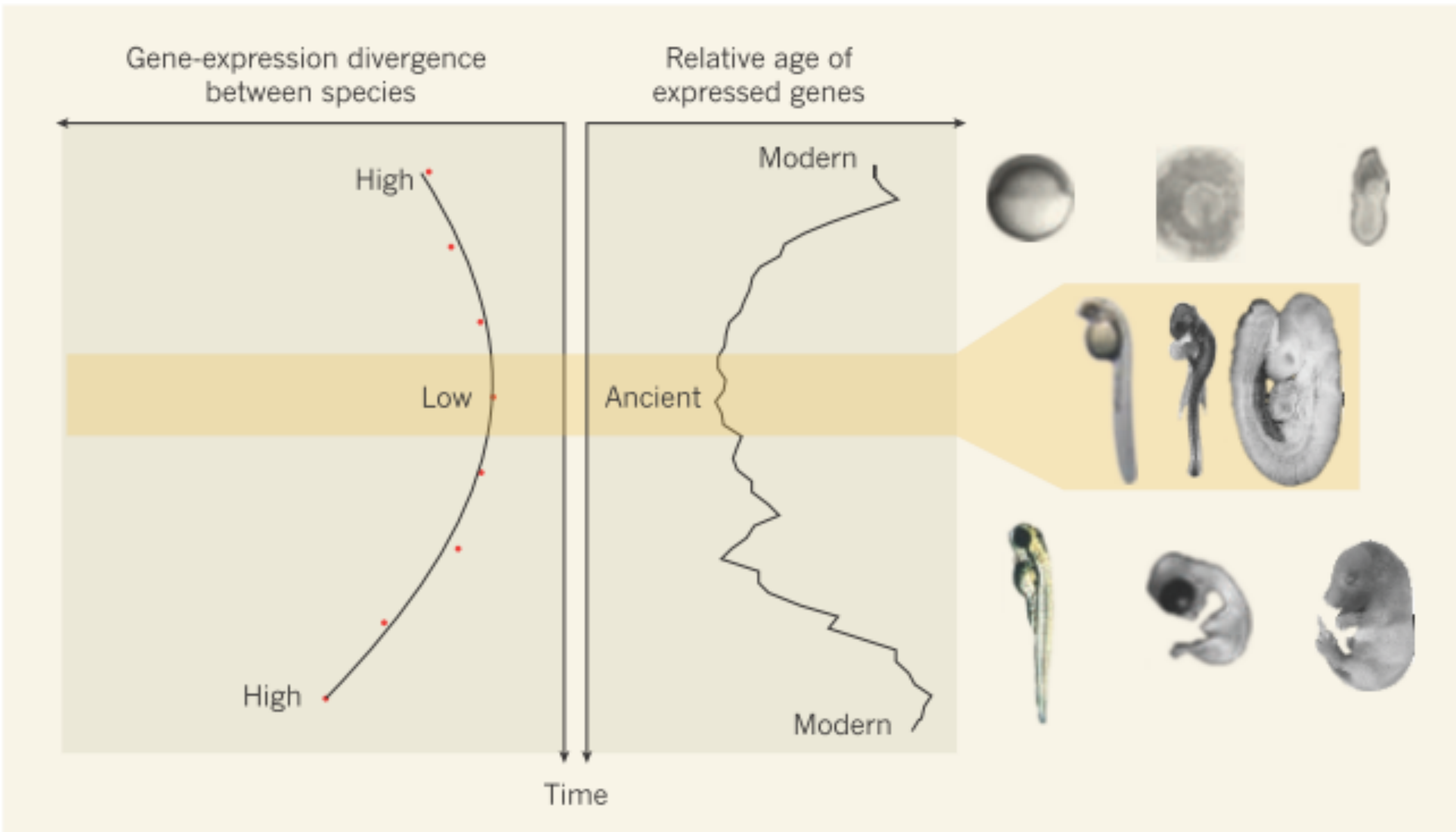


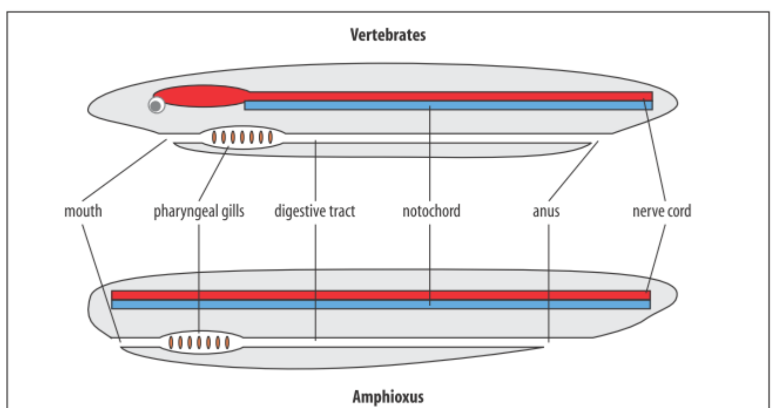
Figure 8. Developmental sequences of various vertebrates shown in phylogenetic context. Note the shared similarities of some closely related taxa, particularly the amniotes (modified from Richardson et al. 1998.)

The developmental hourglass, as revealed by comparative genomics

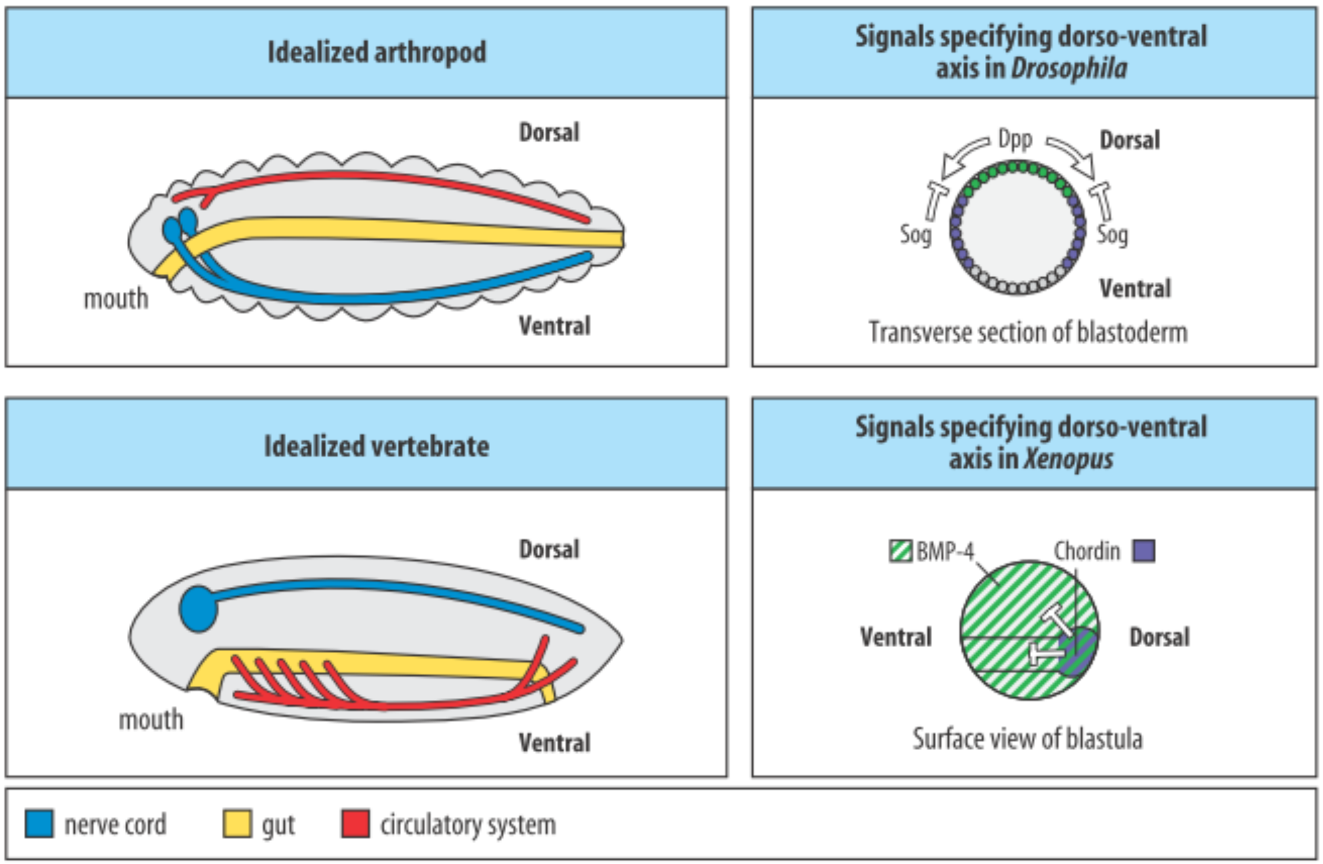


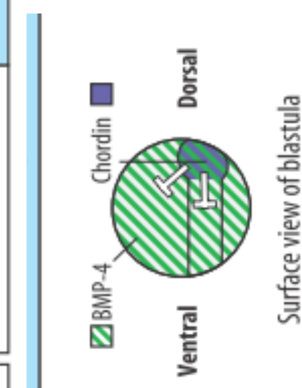
The evolutionary modification of embryonic development

- The more general characteristics of a group of animals (that is, those shared by all members of the group) usually appear earlier in their embryos than the more specialized ones, and arose earlier in evolution.
- In the vertebrates, a good example of a general characteristic would be the notochord, which is common to all vertebrates and is also found in other chordate embryos. Paired appendages, such as limbs, which develop later as special characters

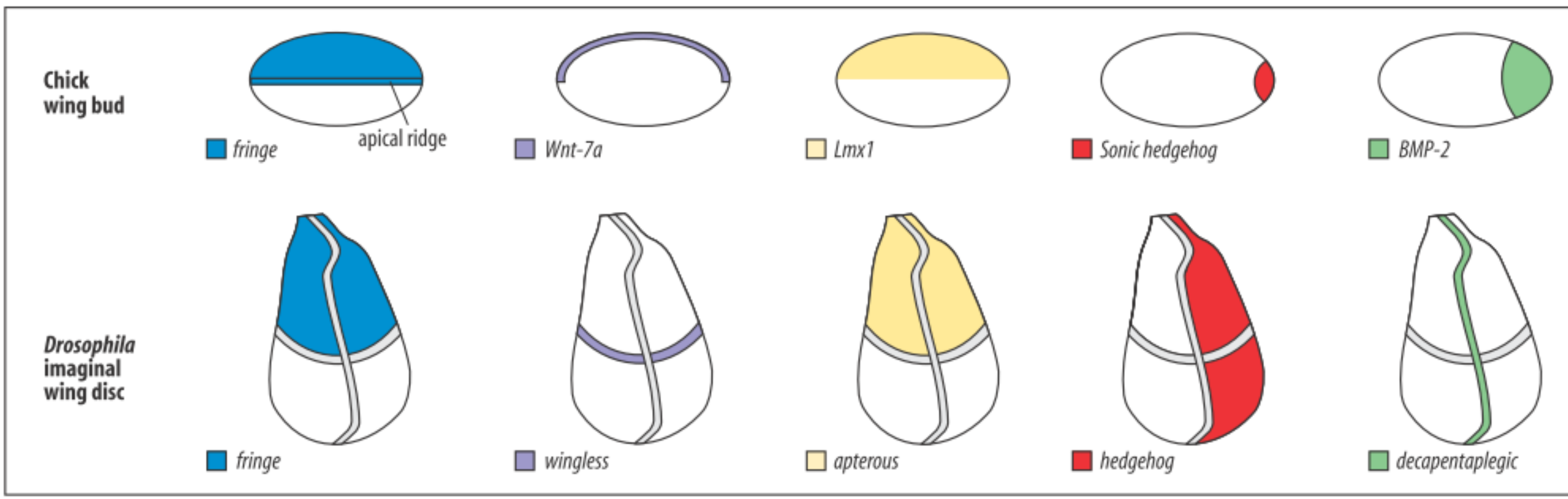


The vertebrate and *Drosophila* dorso-ventral axes are related but inverted



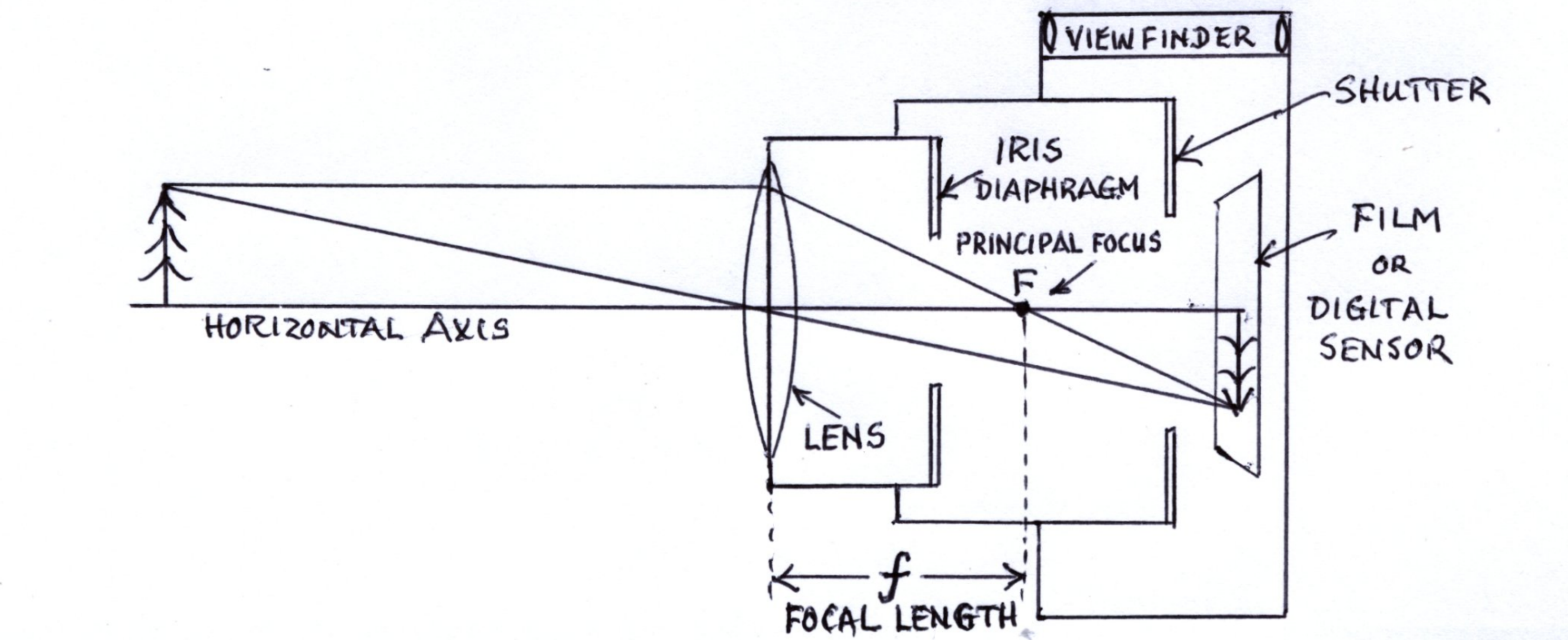


Comparison of developmental signals in the chick wing bud and *Drosophila* wing imaginal disc

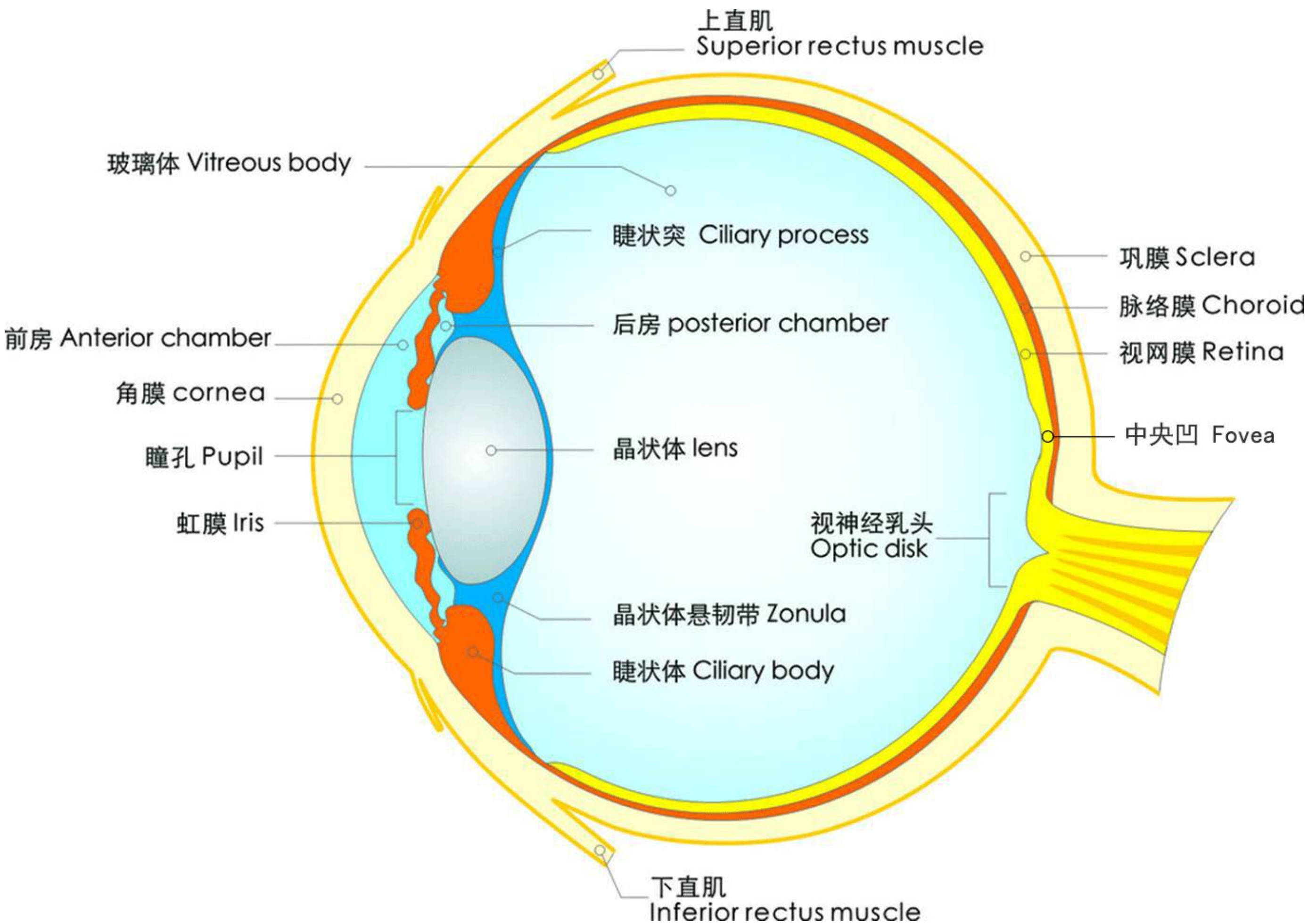


Vertebrate eye evolution

Camera diagram

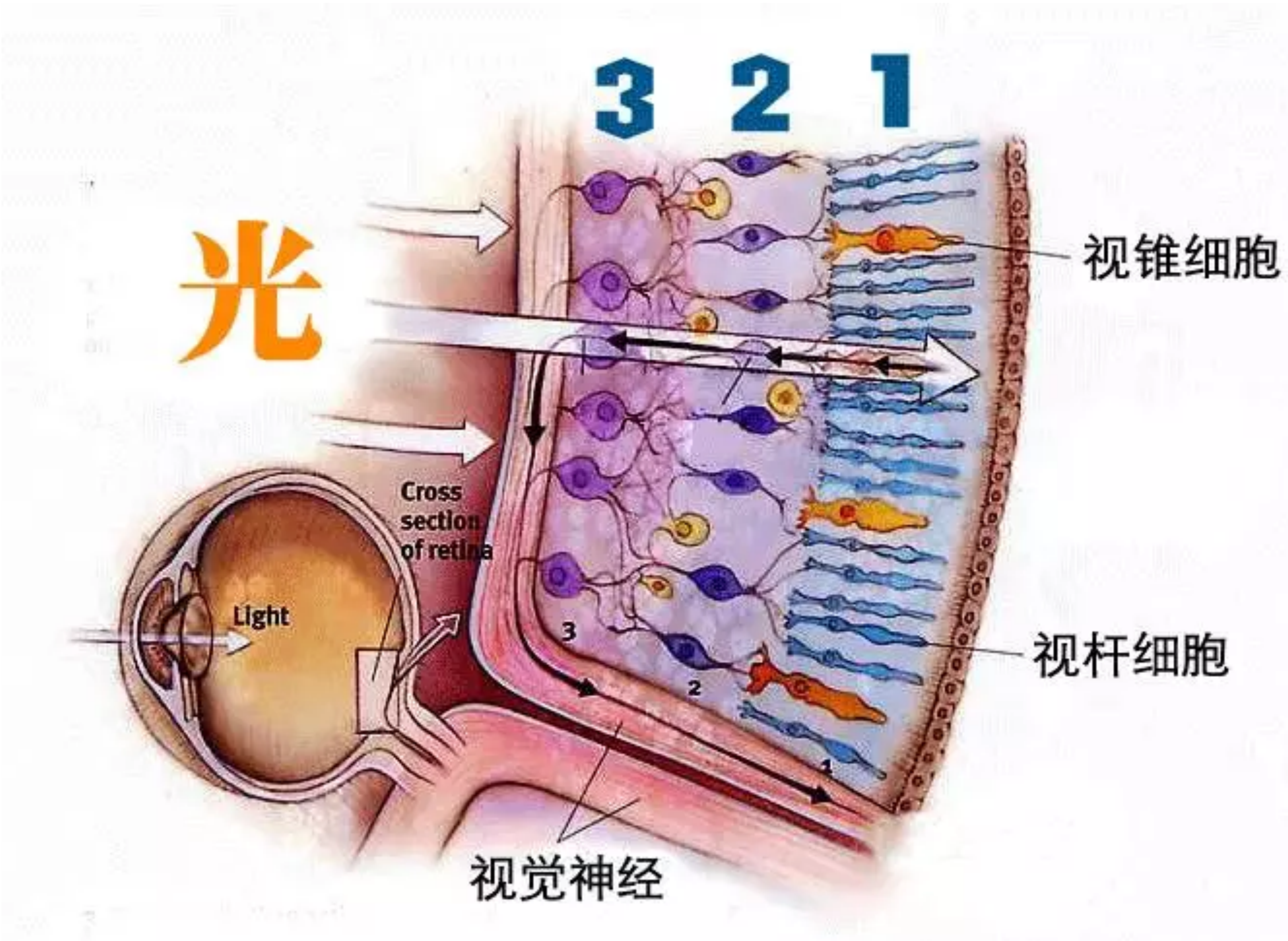


Human eyes

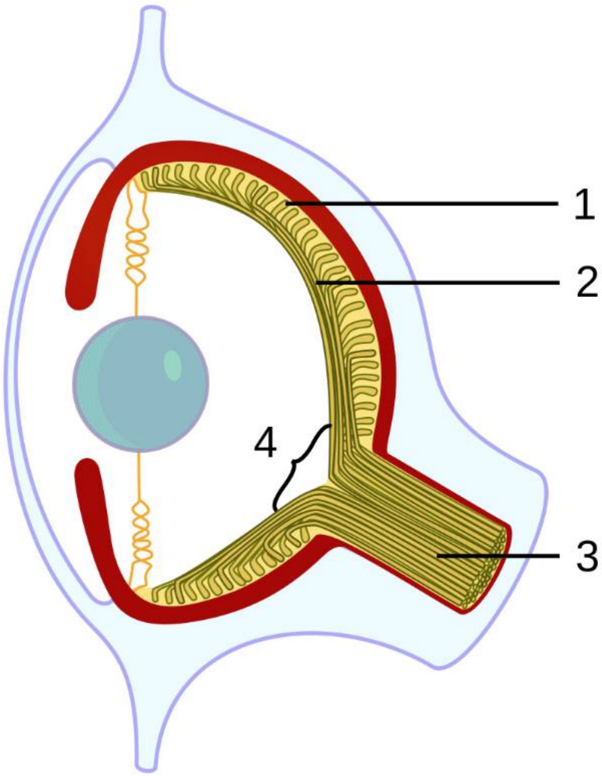


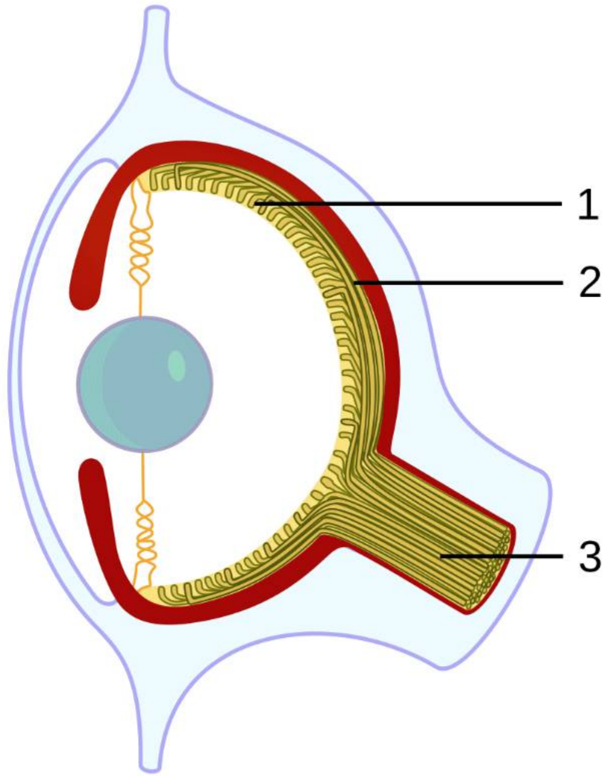
上直肌
Superior rectus muscle
玻璃体 Vitreous body
睫状突 Ciliary process
巩膜 Sclera
脉络膜 Choroid
前房 Anterior chamber
后房 posterior chamber
视网膜 Retina
角膜 cornea
中央凹 Fovea
瞳孔 Pupil
晶状体 lens
视神经乳头
Optic disk
虹膜 Iris
晶状体悬韧带 Zonula
睫状体 Ciliary body
下直肌
Inferior rectus muscle

Confusing ‘design’

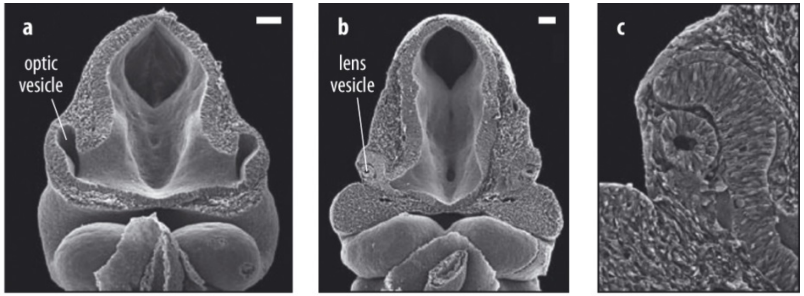


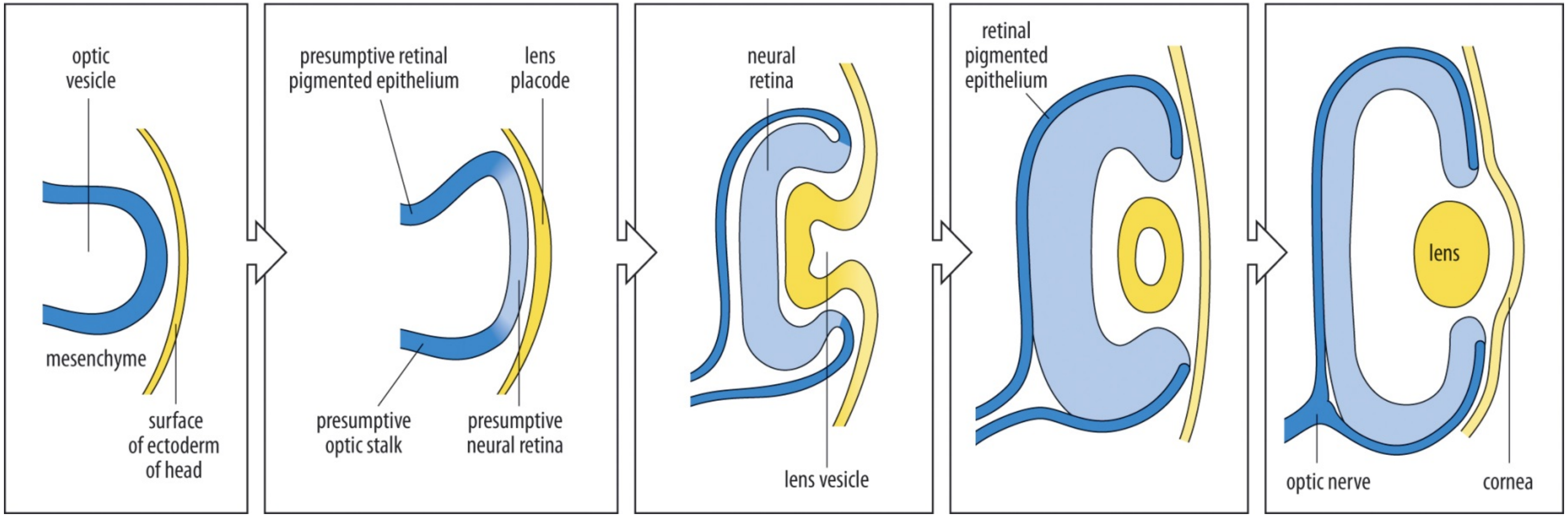
Human eyes VS octopus eyes



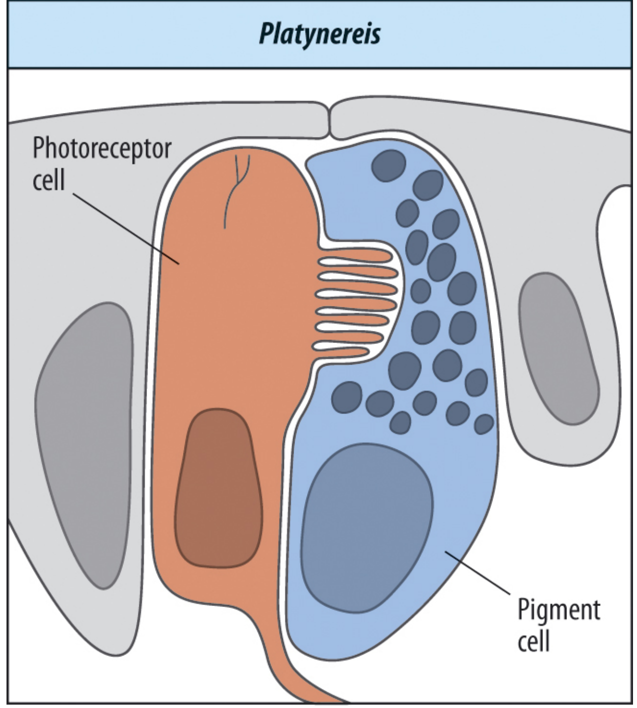


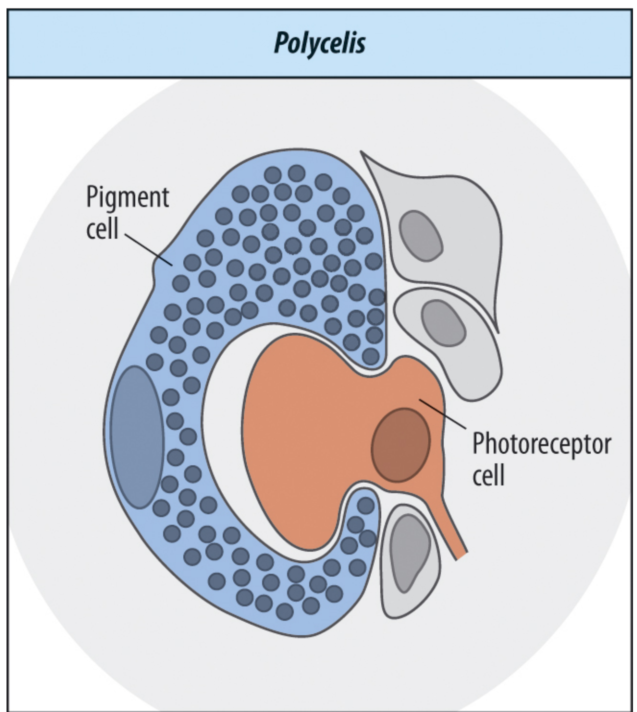
The main stages in the development of the vertebrate eye



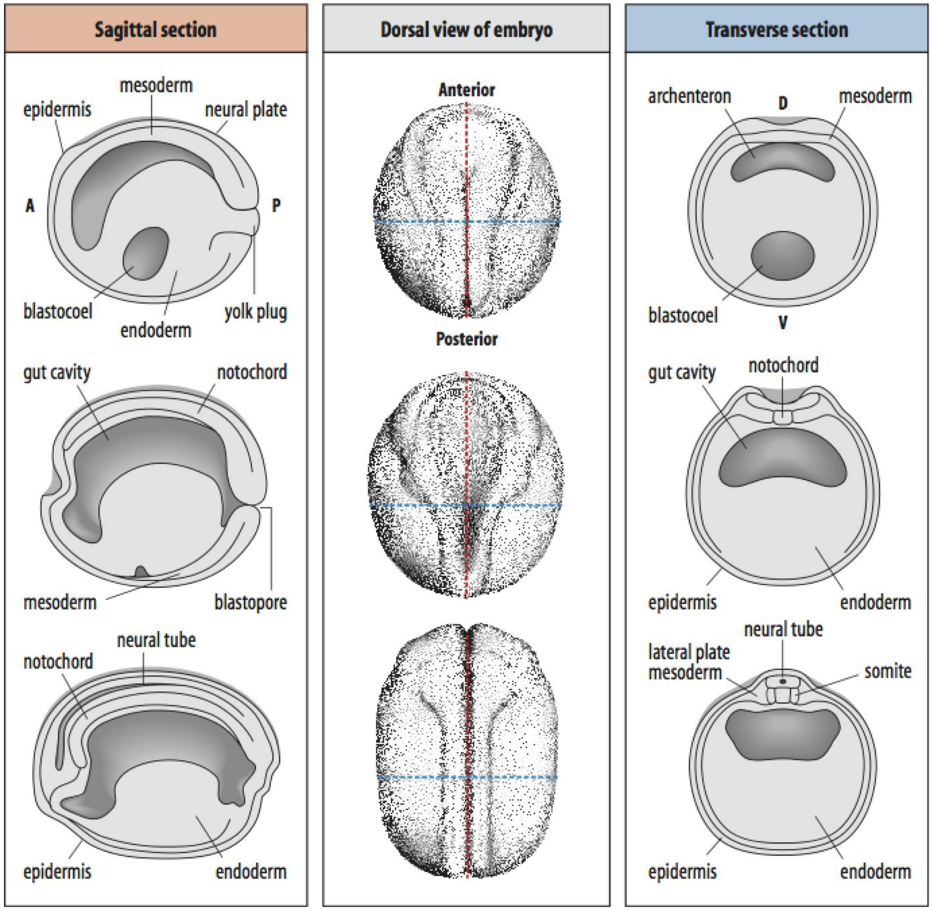


The pair of black dots on the head of the flatworm *Dugesia dorotocephala* represent some of the simplest true eyes


Platynereis
Photoreceptor cell
Pigment cell

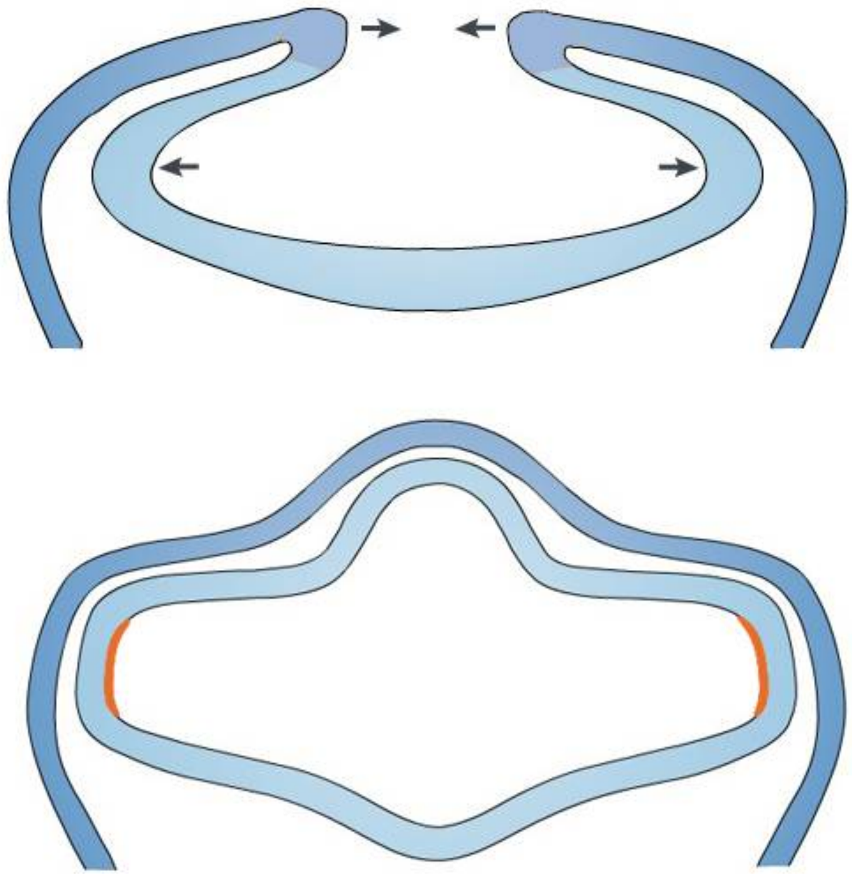

Polycelis
Pigment cell
Photoreceptor cell

Neuralation in amphibians

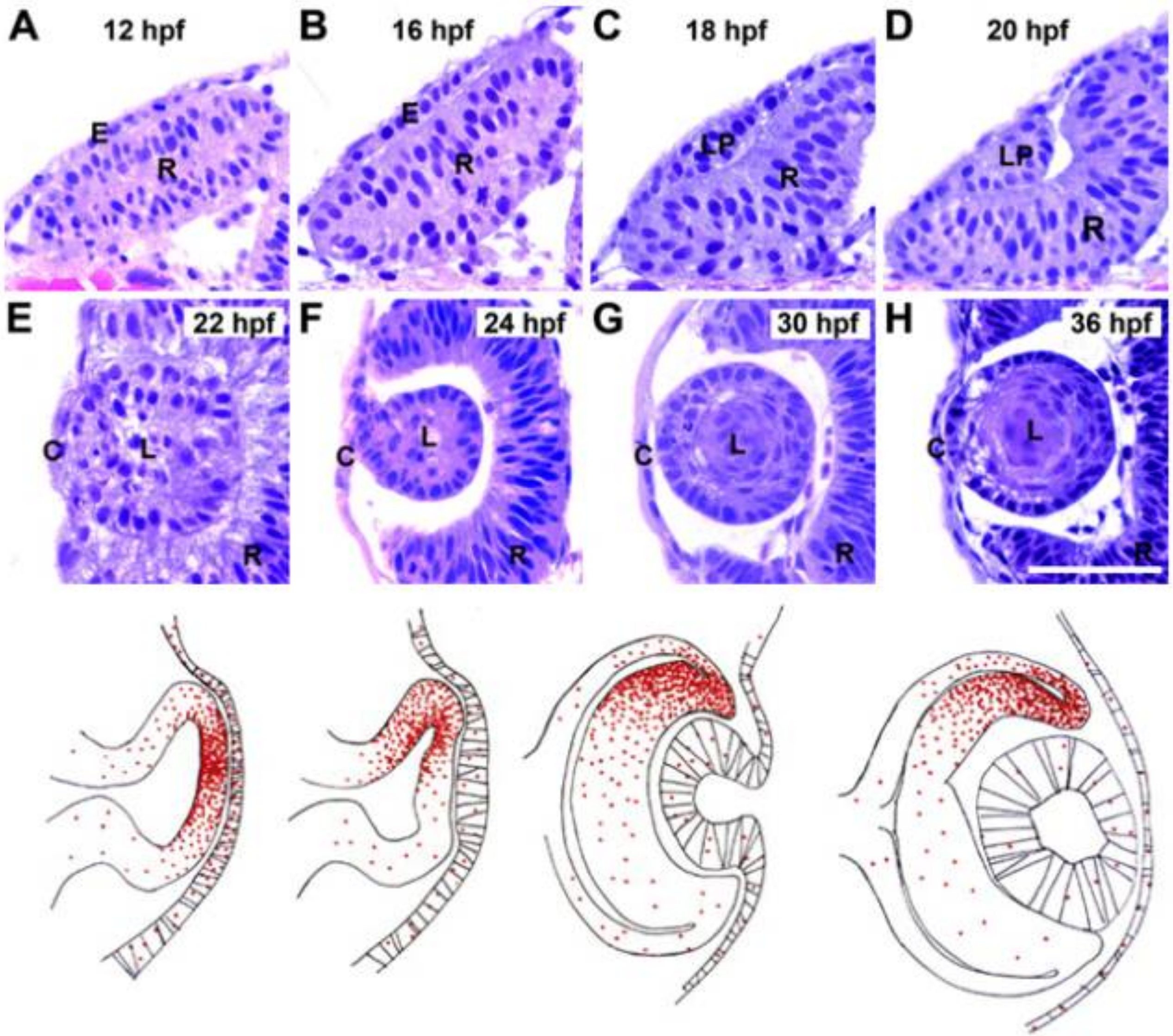


Neuroectoderm = neural plate

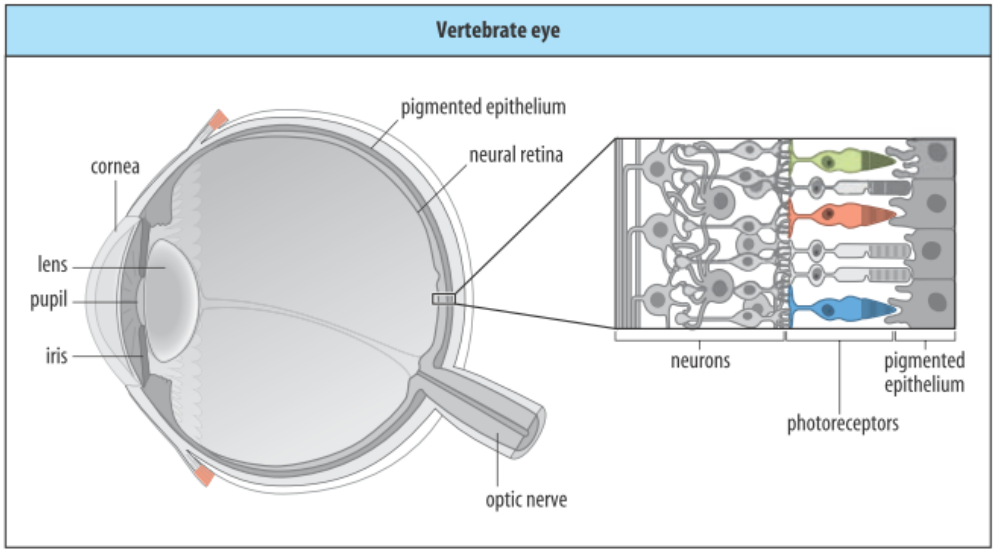
Primitive retina is folded inside

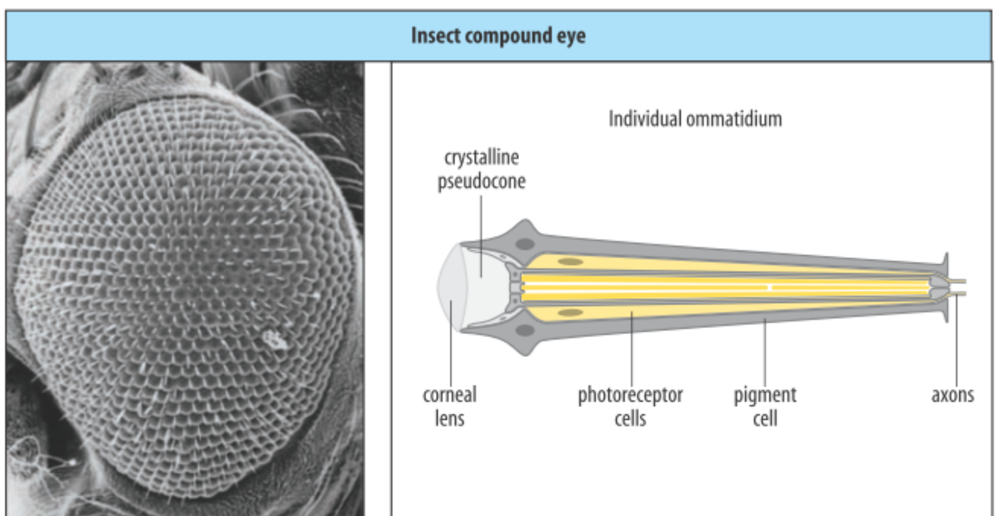


The formation of zebrafish eyes shows the reversal folding of retina



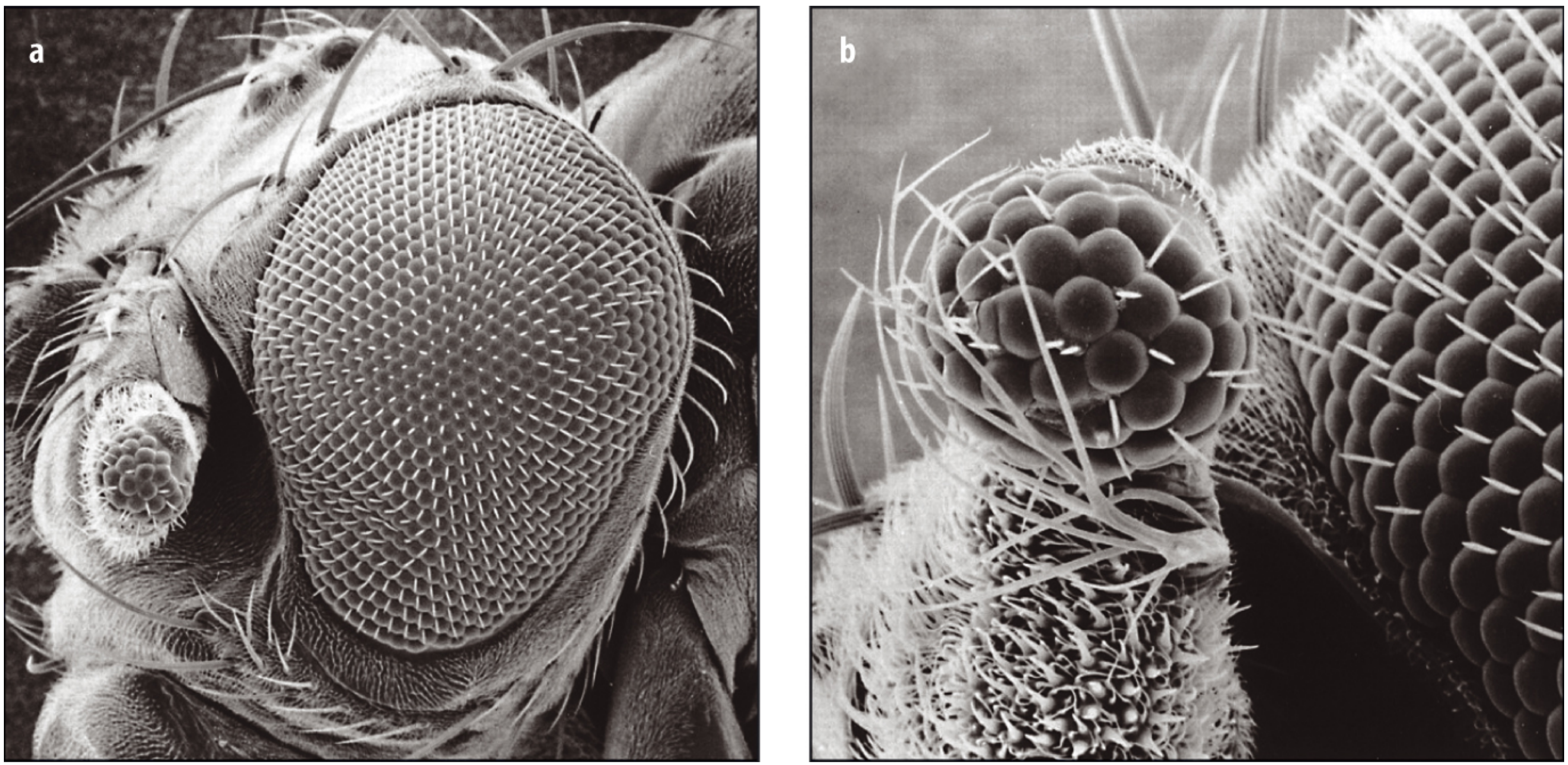
Vertebrate and insect eyes

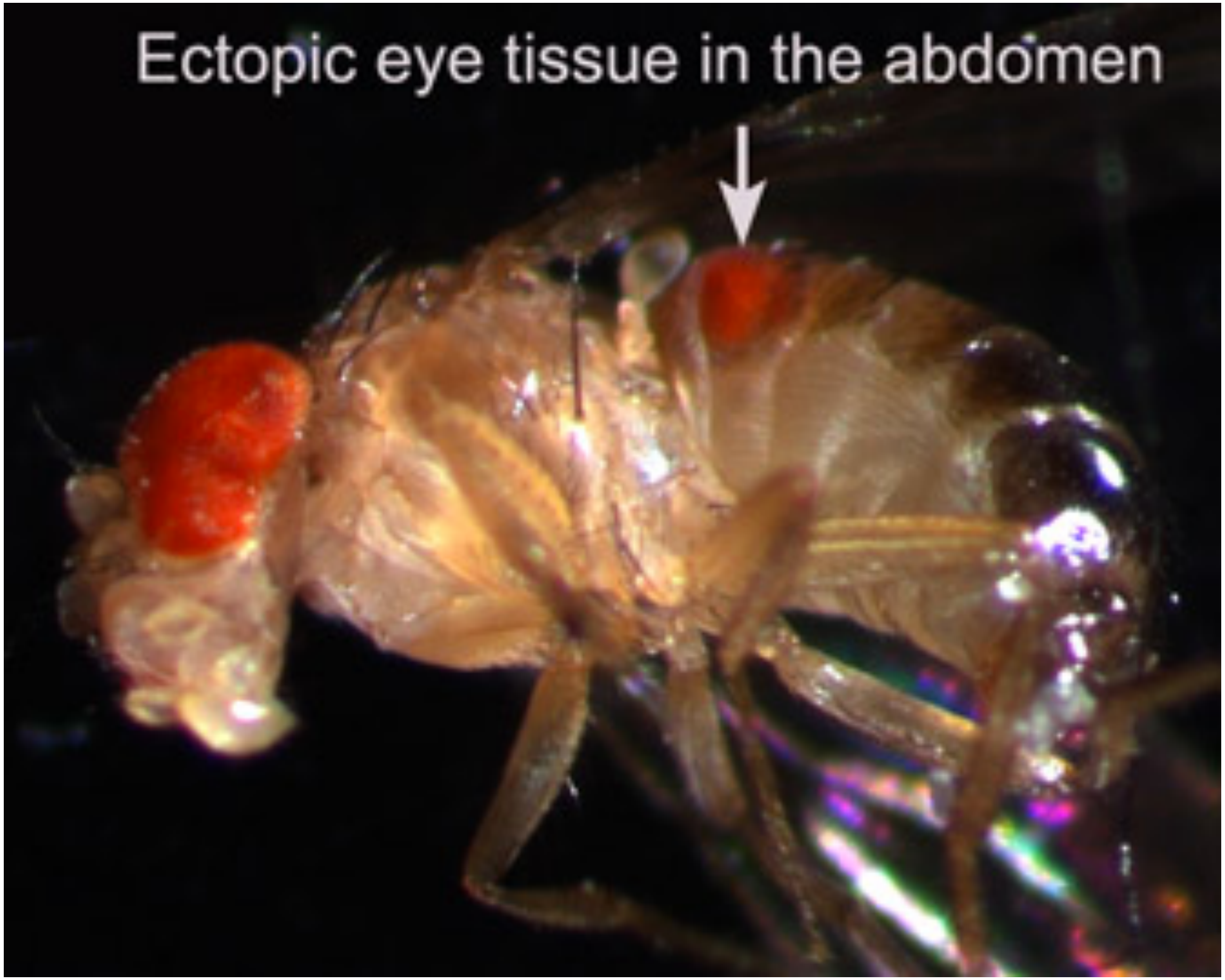


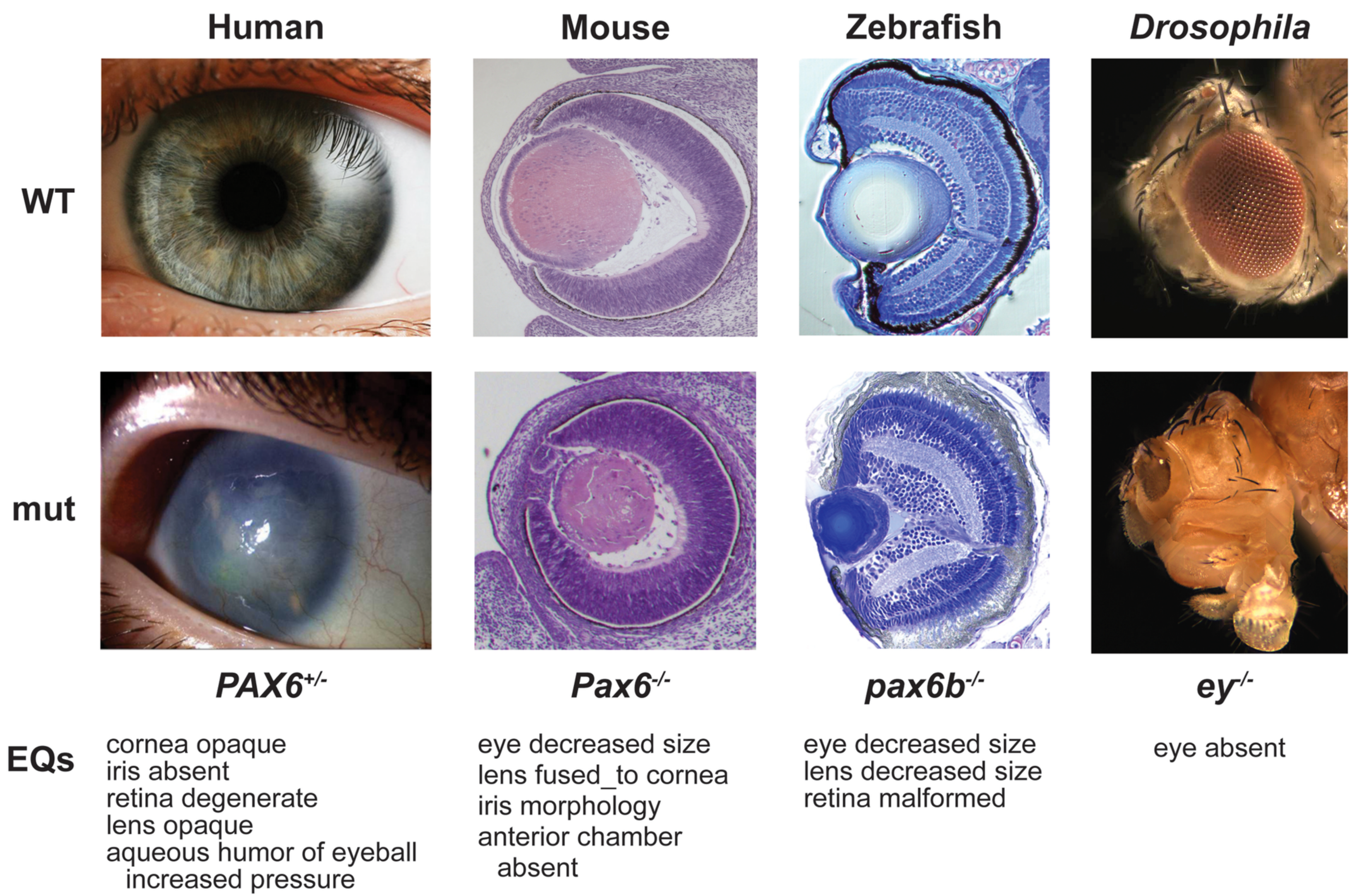


Human vision VS insect vision

Pax6 is a master gene for eye development

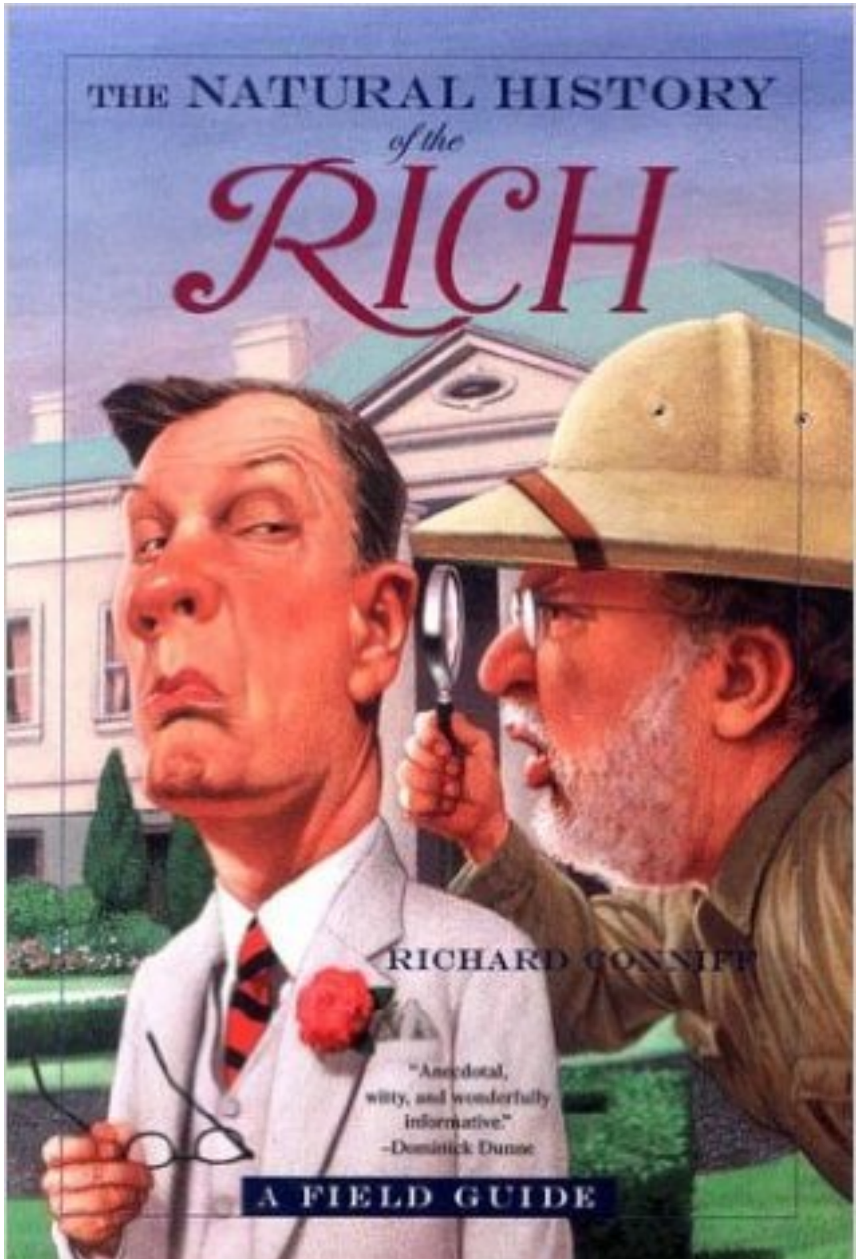



Ectopic eye tissue in the abdomen



Human
Mouse
Zebrafish
Drosophila
WT
mut
PAX6+/-
Pax6-/-
pax6b-/-
ey-/-
EQs
cornea opaque
iris absent
retina degenerate
lens opaque
aqueous humor of eyeball increased pressure
eye decreased size
lens fused_to cornea
iris morphology
anterior chamber absent
eye decreased size
lens decreased size
retina malformed
eye absent

Thanks!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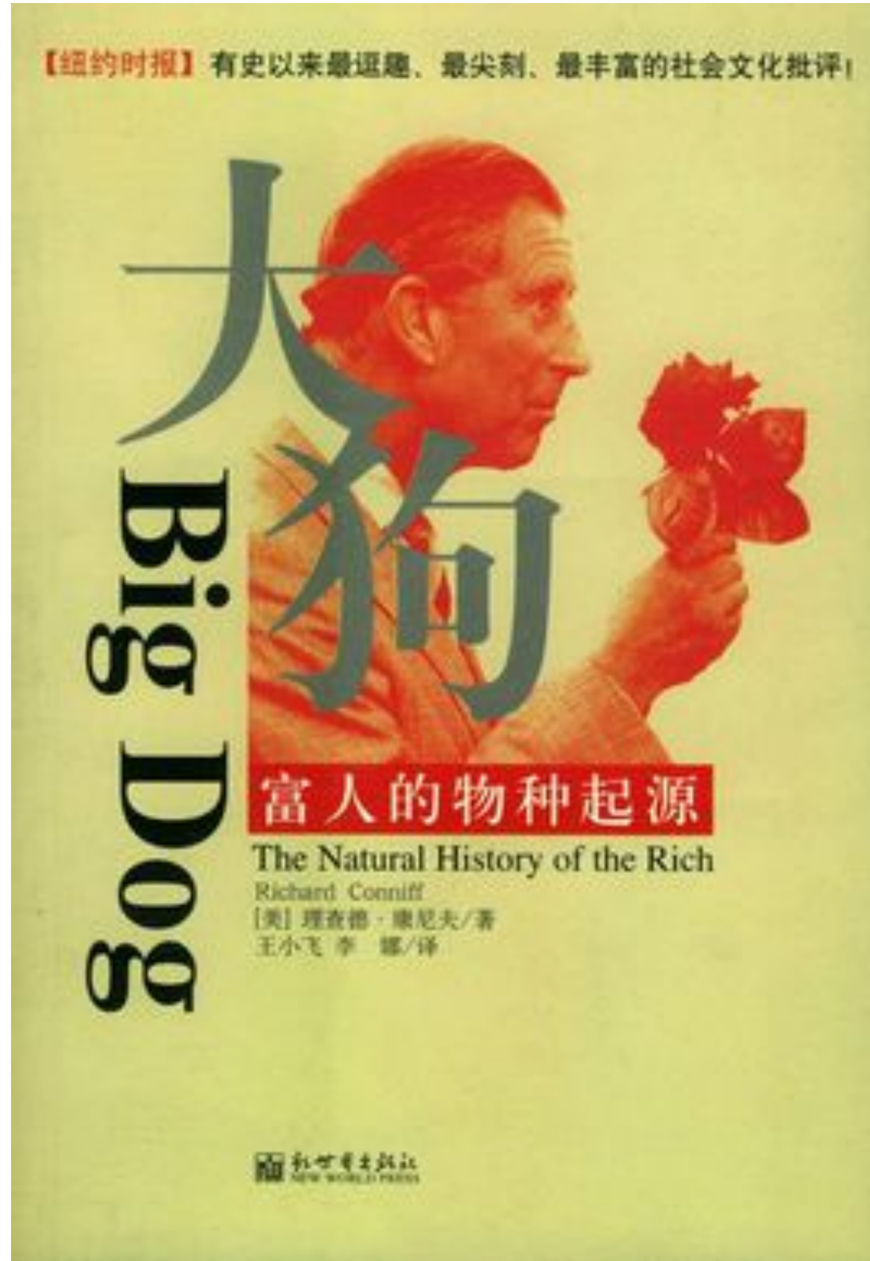
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Big Dog
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[美] 理查德·康尼夫/著
王小飞 李 娜/译