



演化的争论： 生物与环境之间的关系探讨

浙江大学生命演化研究中心

刘虹均 李心
郑霖轩 谢宇龙

Relationship between organism and environment



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Standard Evolutionary Theory (SET)

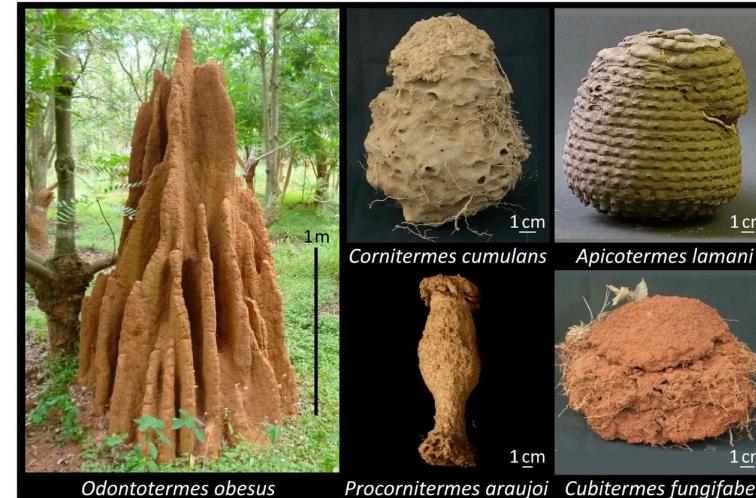
Environment: ‘background condition’ which may trigger or modify selection, but is **not itself part of the evolutionary process.**



Versus

Extended Evolutionary Synthesis (EES)

Niche construction: like developmental bias, means that organisms **co-direct their own evolution** by systematically changing environments and thereby biasing selection.

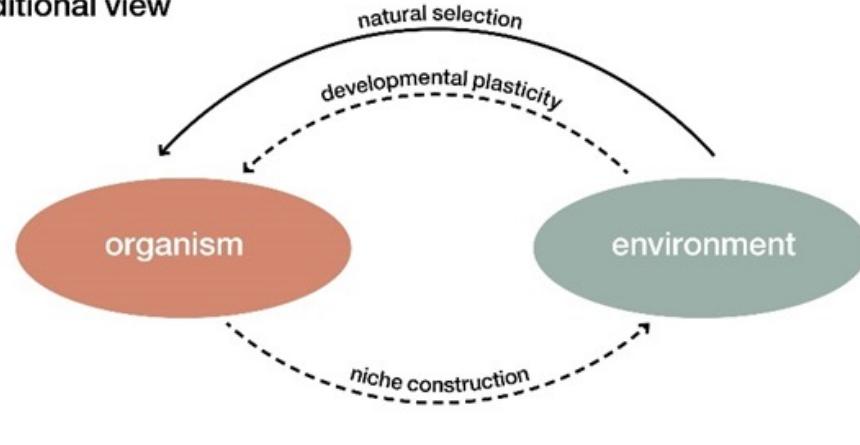


SET: Environmental states modified by organisms are not systematically different from environments that change through processes independent of organismal activity

Reciprocal causation



Traditional view

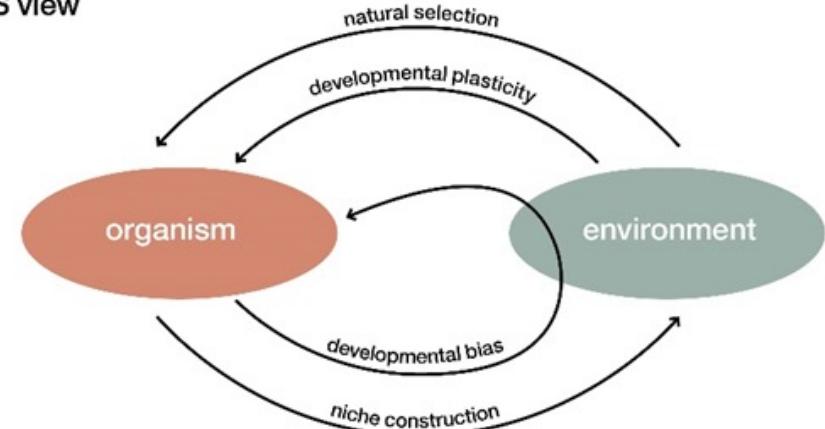


→ recognized evolutionary causes
- - - → effects of these causes

SET: Natural selection from the environment is the **only cause** of biological evolution. The response to the environment (developmental plasticity) and the change to the environment (niche construction) are regarded as a continuous cycle of response processes under the action of natural selection

Versus

EES view



→ recognized evolutionary causes

EES: All are the reasons for driving biological evolution, and have the same important status as natural selection. Thus, developing organisms are not only products of evolution, but also causes of evolution.

Guidelines for explaining evolution



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Standard Evolutionary Theory (SET)

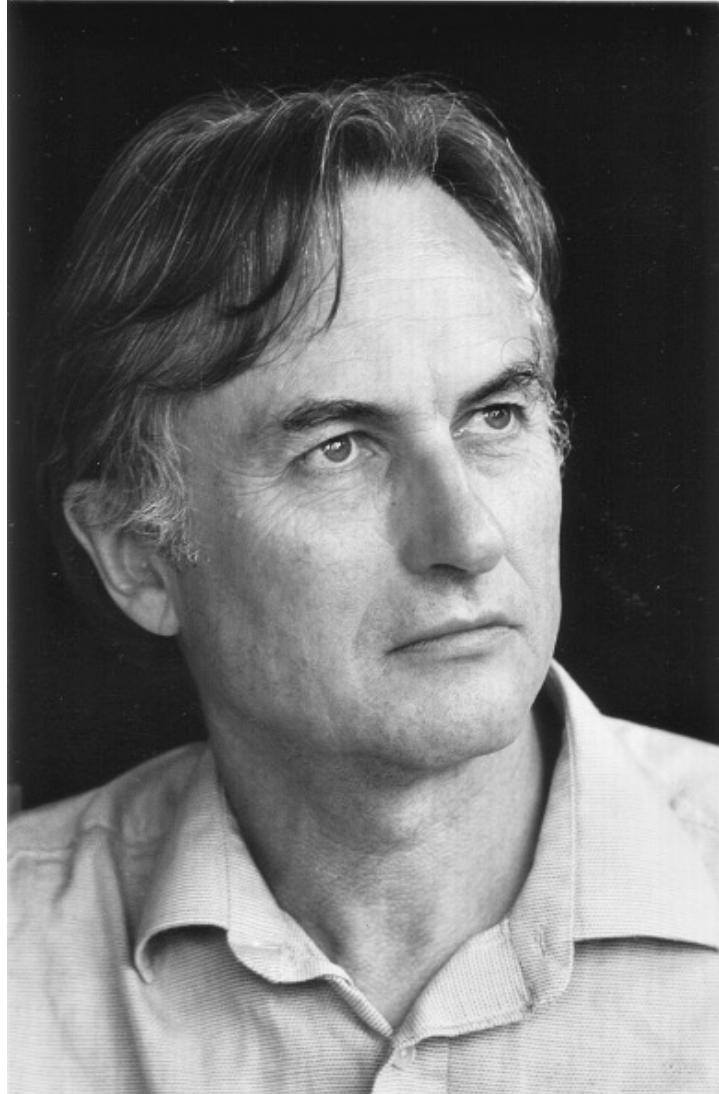
有机体的基因 → 产生表型 → 环境对表型进行筛选 → 种群基因频率改变 → 有机体演化发生

Extended Evolutionary Synthesis (EES)

有机体的基因 ? → 产生表型 → 表型与环境相互影响 → 环境改变
种群基因频率改变 → 有机体与生态演化发生



SET观点的延伸



Richard Dawkins (26 March 1941 -)

1976, The Selfish Gene

1982, The Extended Phenotype

- Gene-centered view of evolution
- An animal's behaviour tends to maximize the survival of the genes **"for"** that behaviour, whether or not those genes happen to be in the body of the particular animal performing it

“扩展表型” (Extended Phenotype)



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道金斯提出了扩展表型的三种形式：

- 用建筑等 “工程” 手段适应更严酷的环境
- 操纵别的生物 (物理接触或分子信号等手段，直接调控)
- 操纵别的生物 (远距离)





EES理论体系

立场

- 不是以寻找最简单的或普遍的解释为出发点（疯狂暗示这是SET），而是以寻找最能解释生物学主要问题的方法组合为出发点
- 主流EES应当排除那些煽动者和极端分子，并被视为改良派

诉求

- EES的支持者希望自己所研究的子领域，比如可塑性、生态演化、演化发育、表观遗传学以及文化演化等，不仅得到承认，而且被纳入生物学的经典——以得到更广泛的传播和重视

——来自《卫报》评论

【被指责忽视了SET的自我改良】



破除SET使用的一些最经典的案例带来的一系列思维惯性

环境是稳定的“背景”

生物的表型差异归根到底都是基因序列差异，因此只要研究基因层次的问题

.....

把其他学科揭示的其他层级的规律和更丰富的案例纳入进来，使我们看问题的视角更全面

生态学

发育生物学

表观遗传学

.....



Eco-Evo-Devo

生态学 演化生物学 发育生物学



Eco-Evo-Devo

生态学 演化生物学 发育生物学



E Extended Evolutionary Synthesis

An integrative research program

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Dr John Odling-Smee

University of Oxford

Contact

Email: [John Odling-Smee](#)

Phone: +44 1865 270999

Biosketch

John Odling-Smee is Emeritus Research Fellow, Mansfield College at the University of Oxford. Prior to retirement, he lectured in Biological Anthropology at Oxford.

Niche Construction

THE NEGLECTED PROCESS IN EVOLUTION

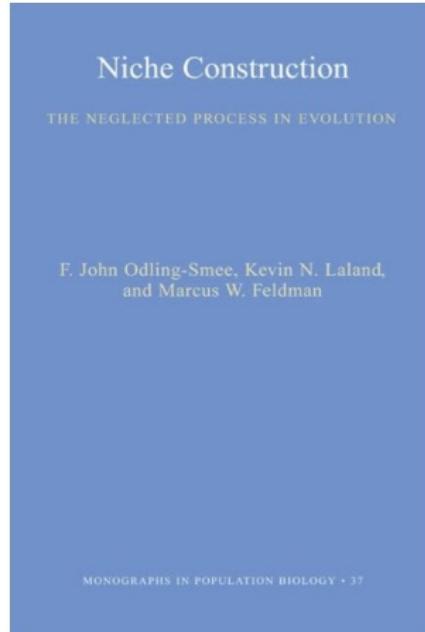
F. John Odling-Smee, Kevin N. Laland,
and Marcus W. Feldman

MONOGRAPHS IN POPULATION BIOLOGY • 37

“生态位构建” (Niche Construction)



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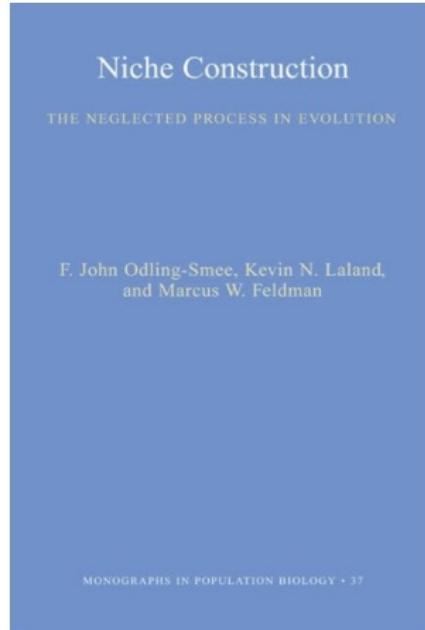


定义：造成与有机体互作的环境发生改变的生命活动

- 命名为生态位构建，是想强调互作环境改变的结果是“生态位”改变。这个语境中的生态位被称为“演化生态位”。
- 作者认为它等价于生态学中“生态位”的演化效应，利用它可以实现生态学和演化的整合。

演化生态位：一个种群受到的演化压力的总和

(传统) 生态位：允许某个种群持续存在的生物和非生物环境因素的总和



定义：造成与有机体互作的环境发生改变的生命活动

识别了两类生态位构建的过程：

1. 扰动型

有机体对环境造成变化。除了鸟筑巢，河狸建水坝，珊瑚虫造礁等经典案例，还有平时的生理、行为，甚至死亡后分解的影响，几乎无所不包。

2. 位移型

通过移动等改变和自身互作的环境，如鸟迁徙。

后人补充：

3. 发育等

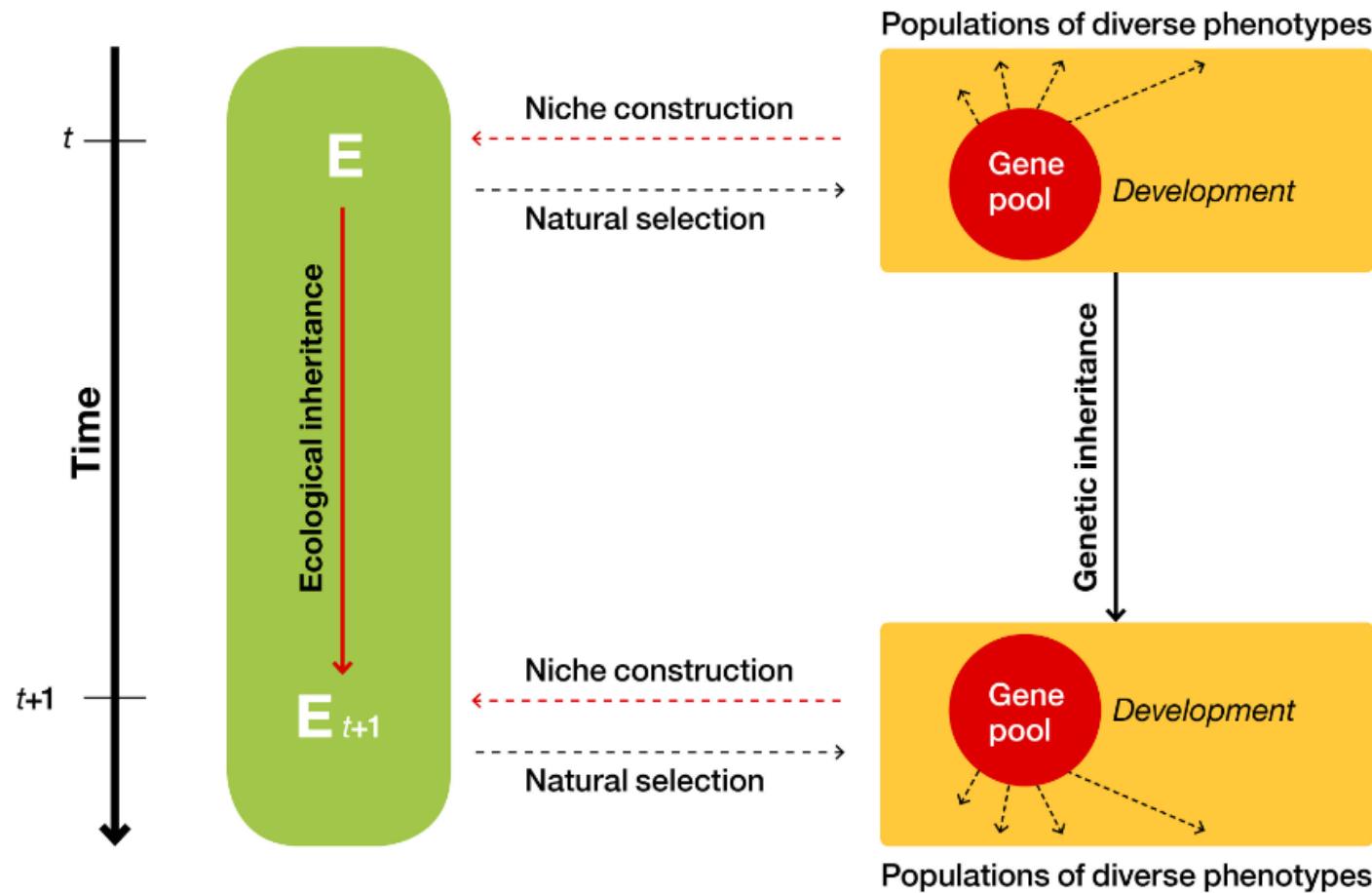
什么算构建；演化生态位是否等价于生态位的演化视角；有没有意义… 争议不断

“扩展表型” 对 “生态位构建” 的态度：

- 太过广义，等于什么都没说。道金斯建议将生态位构建分为"适应性生态位构建"（基本等于他自己的“扩展表型”）和"副产品"。

“生态位构建” 对 “扩展表型” 的态度：

- 欲抑先扬，肯定了“扩展表型”对理解“生态位构建”现象是如何演化产生的有积极意义，但对理解“生态位构建”对演化的影响并无帮助。
- 定义多广不是评价有没有用的标准（发育，自然选择，环境等）；关键在于**定义的目的**。概念上，不能遗漏潜在的重要过程；具体研究中，大多数生命过程造成的影响可以忽略。
- 扩展表型本身存在一些概念不清的情况，解释力不足。





相同问题，不同视角

In October 1881, just six months before he died, Charles Darwin published his final book. *'The Formation of Vegetable Mould, Through the Actions of Worms'*: earthworms are adapted to thrive in an environment that they modify through their own activities.

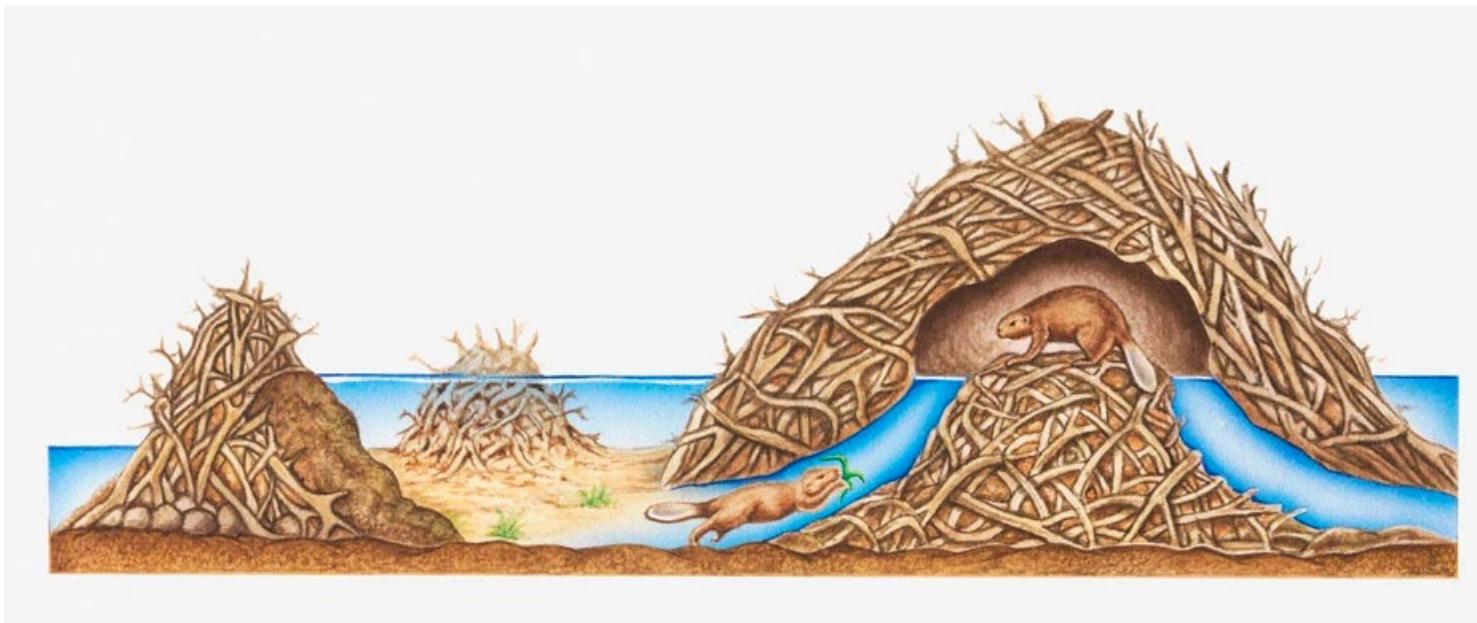
Feedback between organisms and the environment have been studying for well over a century.



Beaver



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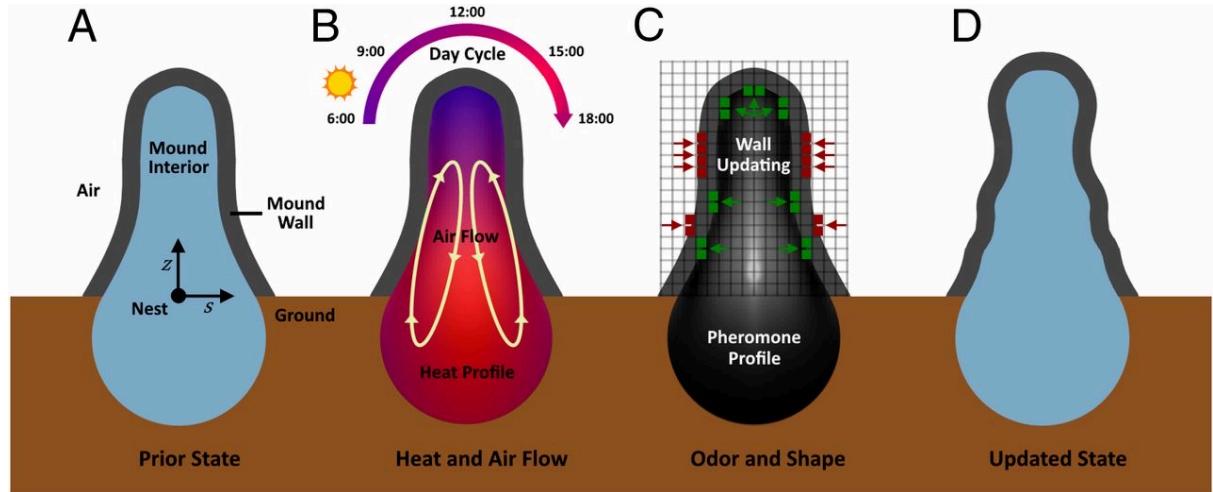
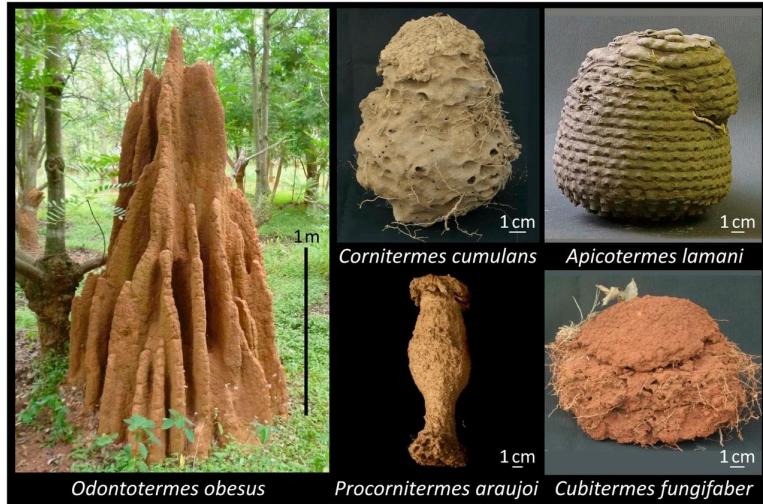


A beaver dam (L) and lodge (R) © Getty

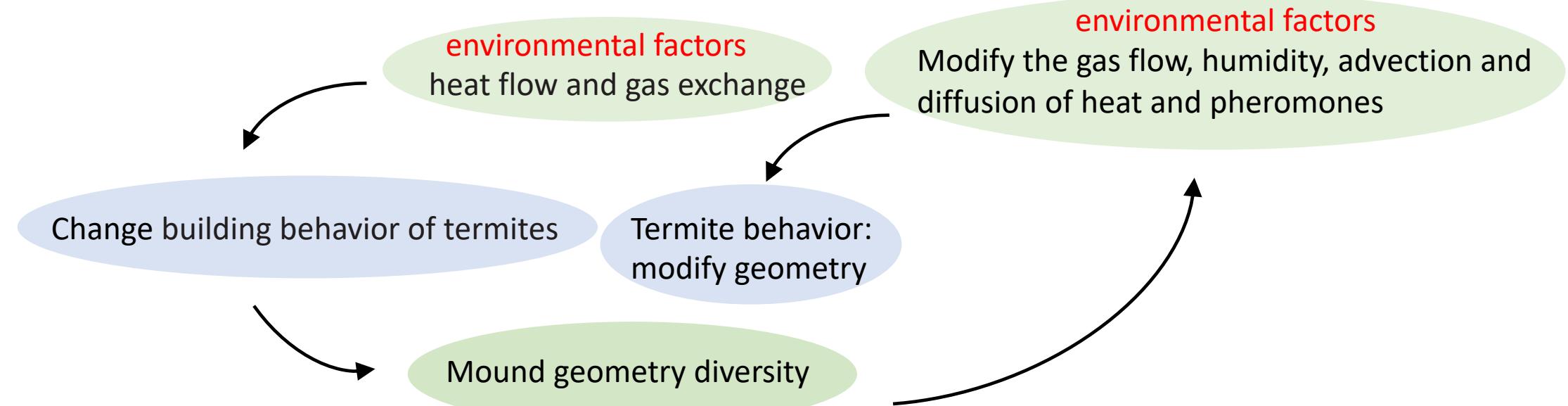
Termite mounds



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Ocko SA et al. Morphogenesis of termite mounds. Proc Natl Acad Sci U S A. 2019





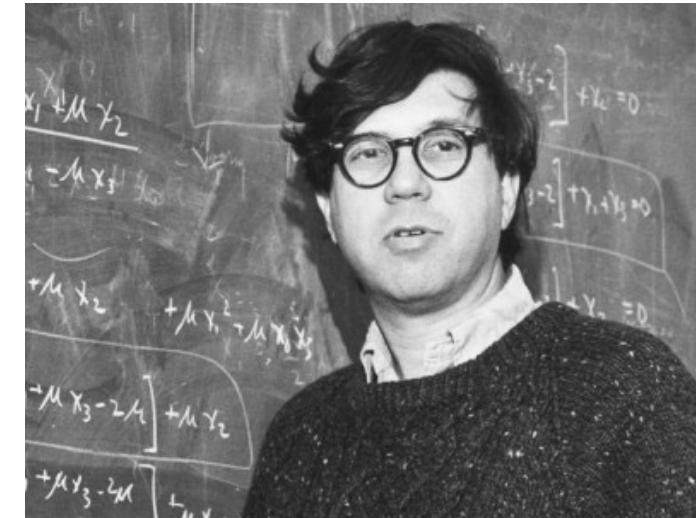
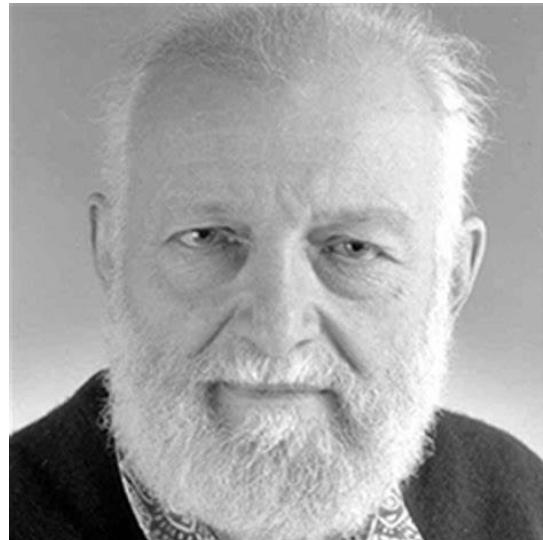
对EES的发散讨论

Natural selection was thought to sculpt organisms over millennia to become adapted to their ecological niches, with no steer from the goals or purposes of organisms. But it is controversial among evolutionary biologists.

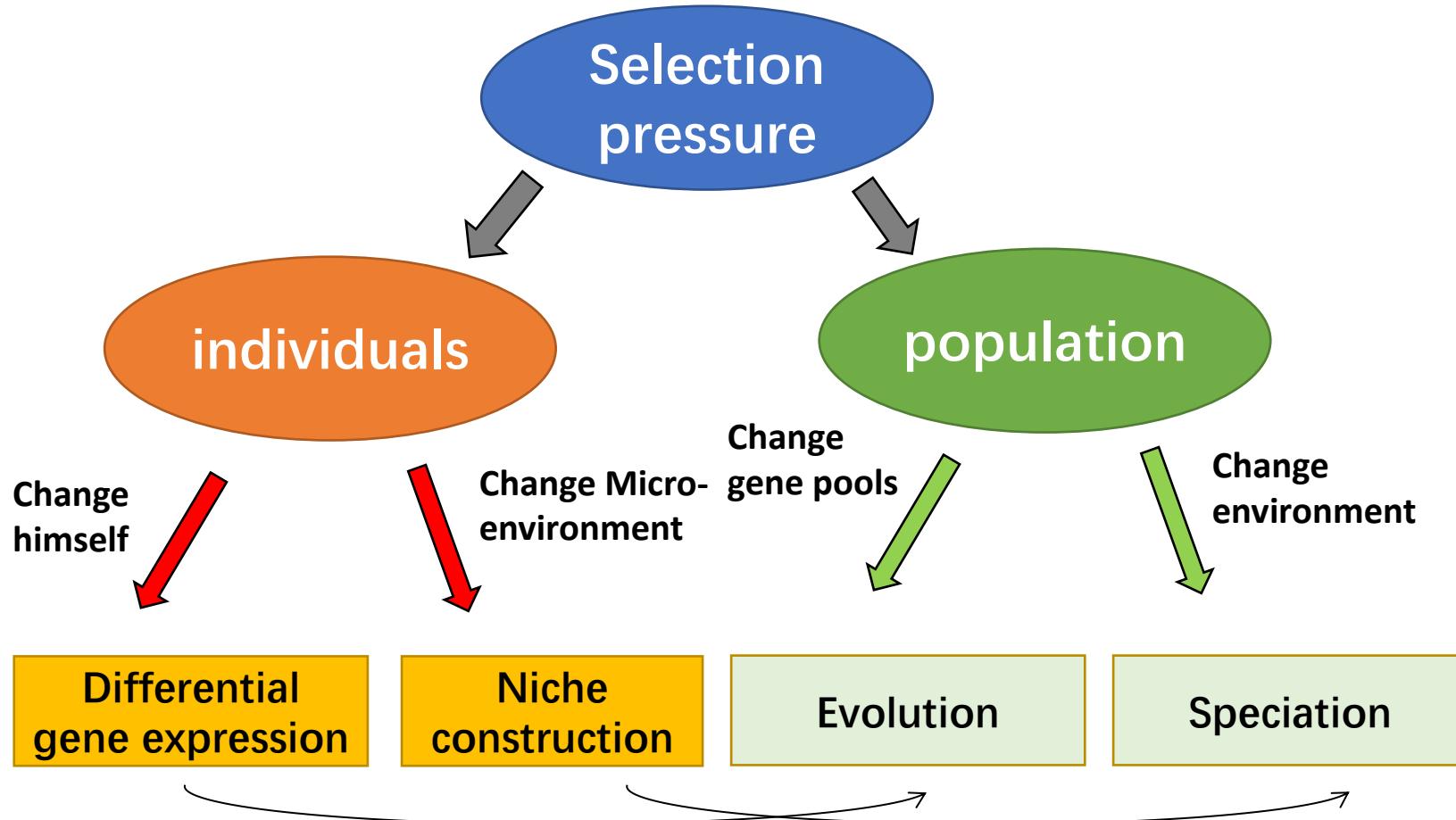
Ecological inheritance means that organisms does not evolve in response of static adaptive landscape, but instead mould that landscape to alleviate or intensify the particular selective pressures it places upon us.

“The organism influences its own evolution, by being both the object of natural selection and the creator of the conditions of that selection,”

——Richard Levins and Richard Lewontin



Strategies of facing selection pressure



Change the environment



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The body structure of earthworm does not adapt well to land life.



身体柔软

分泌稀释尿液

But he can create a tiny wet environment to live —— the cave.



The way earthworm changes the environment to reduce the natural selection pressure is what EES had pointed as “niche constructing”.

Change the environment



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changes



influence

More organisms

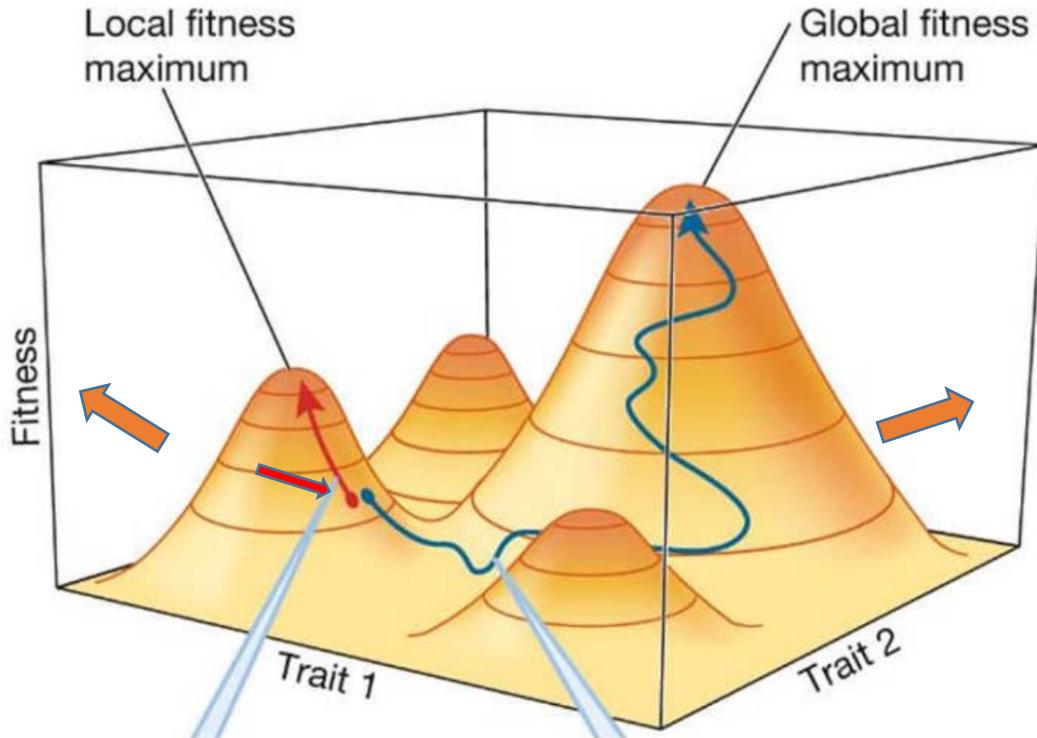
因此我们指出，认为生物体改变自然环境的行为仅仅是对自然选择的响应，自然选择是唯一影响生物进化的理论是不全面的。生物体也可以通过改变自然选择条件的方式影响自己和其他物种的进化命运。

Evolution from generation to generation



The progeny corals inherited the carbonic acid crust of their ancestors and formed a new born ecosystem.

Co-evolution between environment and organisms



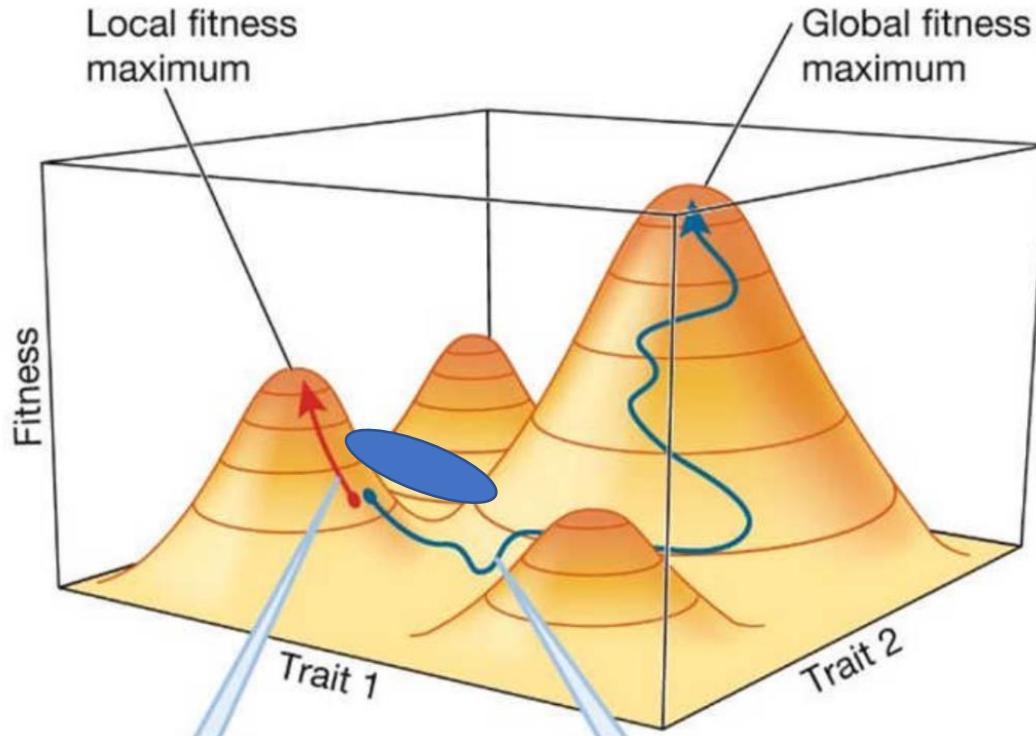
The point not always running after the mountain top, but also has a "gravity" on it.

- The fitness constructed with each factor as the coordinate axis is a curved surface.
- The characteristics of high fitness form mountains, organisms is the point on the curved surface, and the mountain of fitness is constantly moving.
- In the process of formation of the relationship between organisms and the environment can be understood as the rapid movement of the mountain and the species on the mountainside, while the relationship between the balanced living things and the environment can be understood as the slow movement and relatively static of the mountain top and species.

Co-evolution between environment and organisms



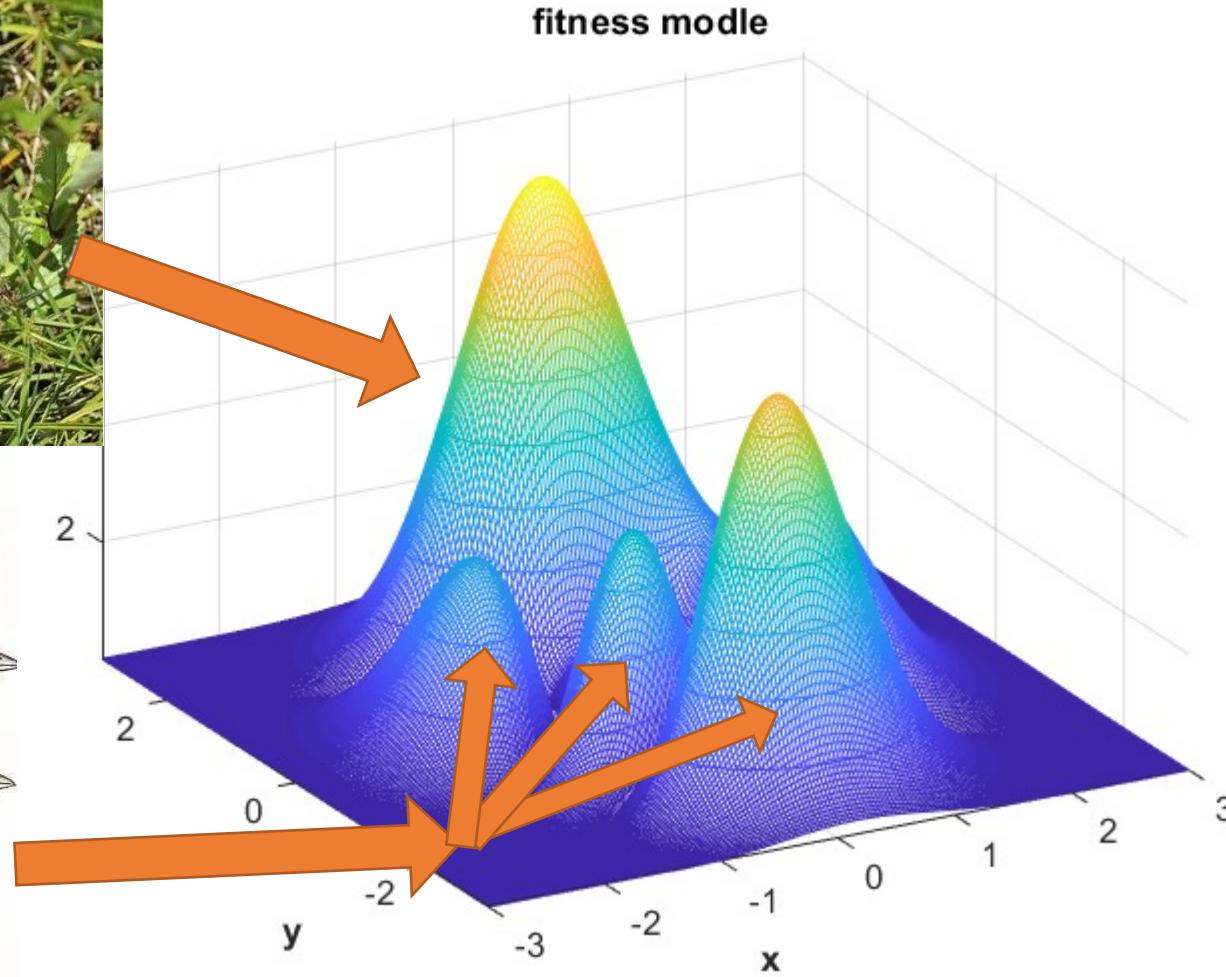
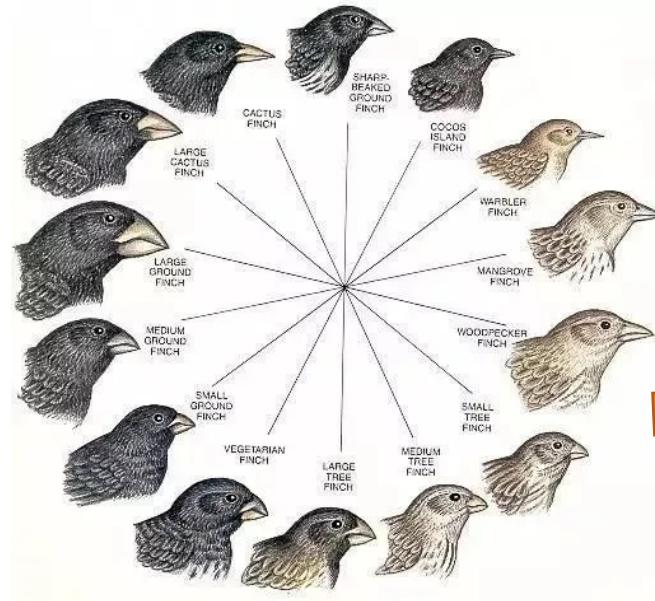
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The blindness of biological evolution makes organisms evolve to adapt to the current environment

The price to reach global fitness maximum is too expansive so that individuals could hardly reach this way once they have reached local fitness maximum.

Some examples



方向性：有利？

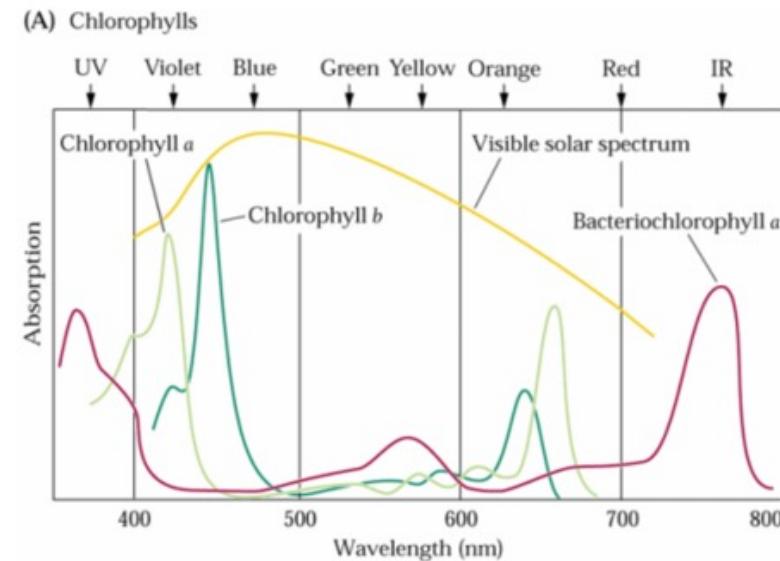


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“紫色地球”假说（35~24亿年前）

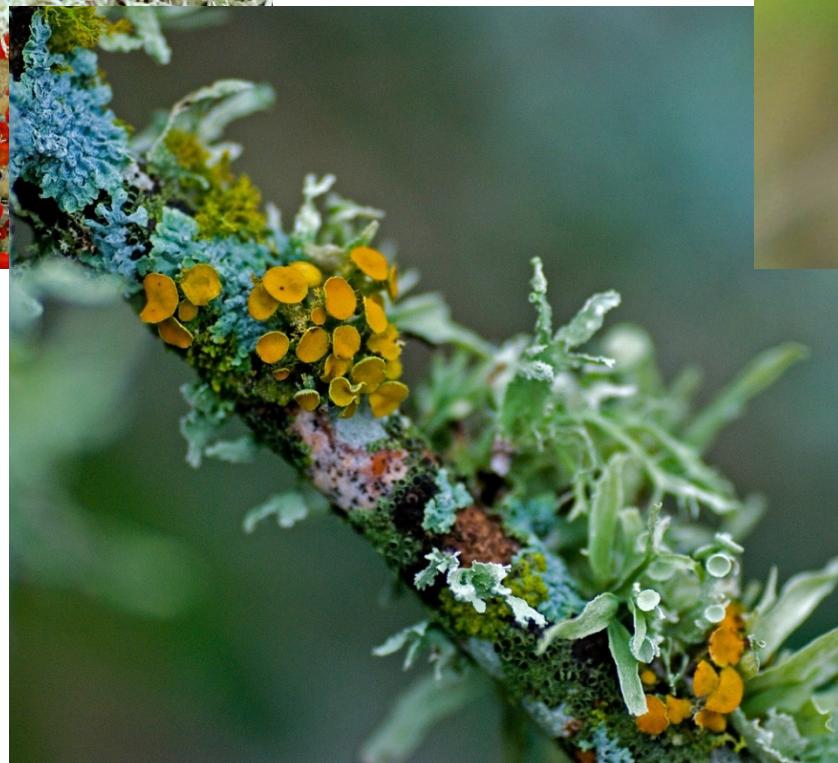
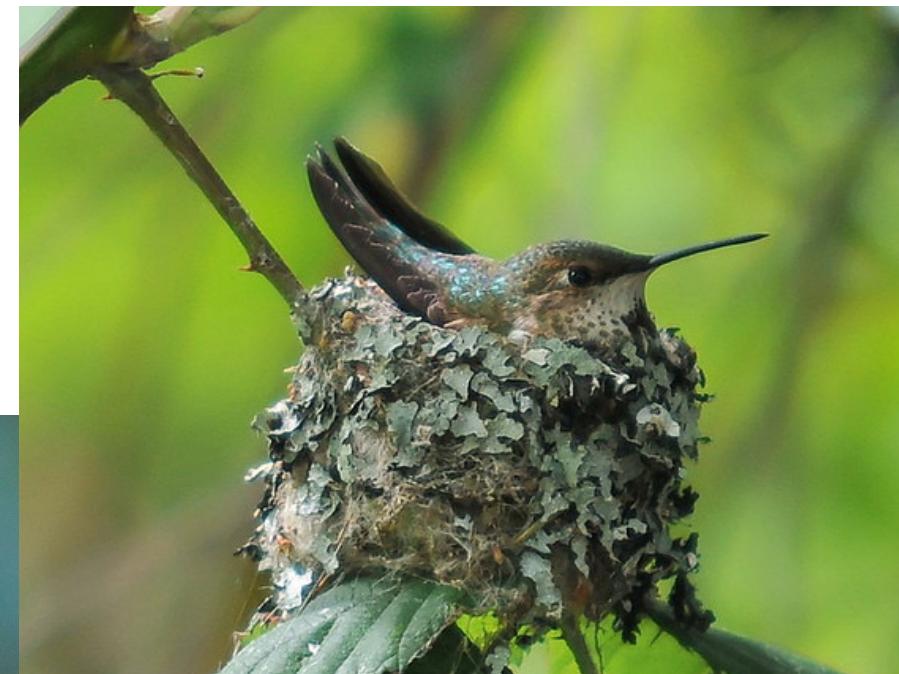
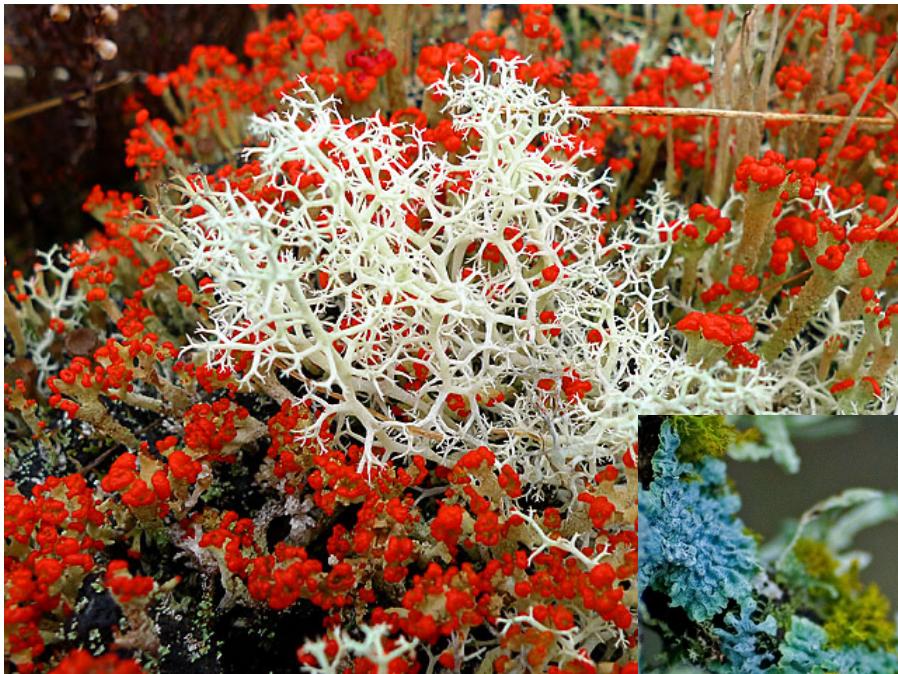
利用视黄醛类色素进行光合作用的厌氧古菌，在大氧化事件后进入边缘生态位。氧气的出现，以及随后的休伦冰期，或许造成了第一轮重大灭绝事件，对生物演化轨迹产生深远影响



方向性：有利？



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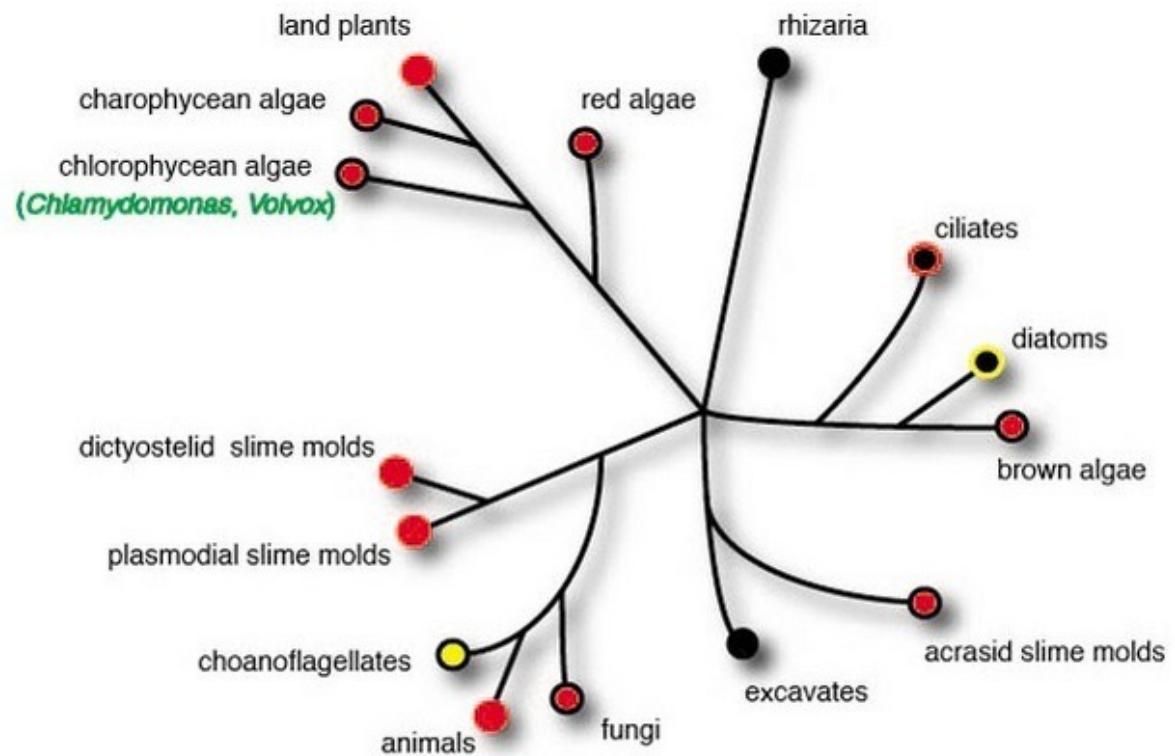


Always advantageous?

系统和功能主义视角



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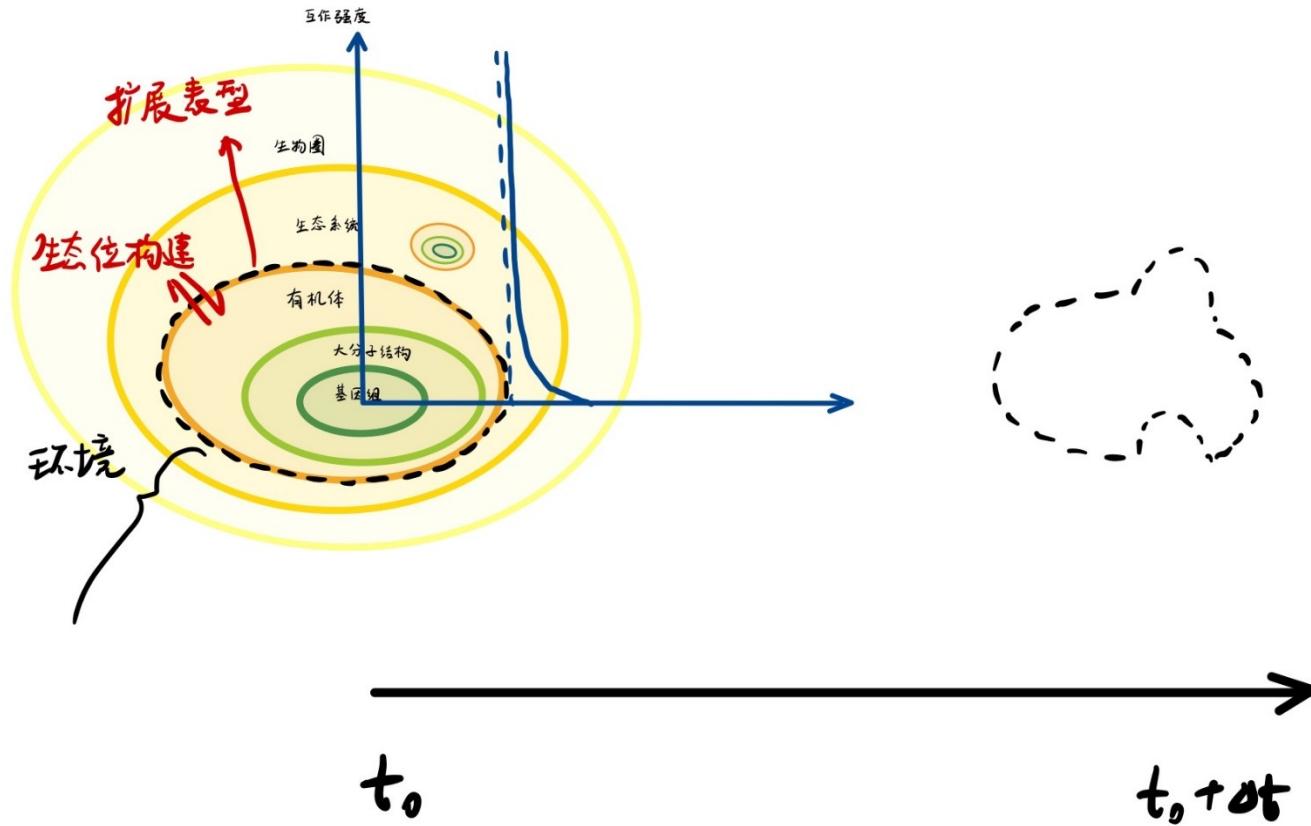
- all members multicellular
- some members multicellular, some unicellular
- most members unicellular, rare multicellular species
- all members unicellular or colonial
- most members unicellular, rare colonial species
- all members unicellular



系统和功能主义视角



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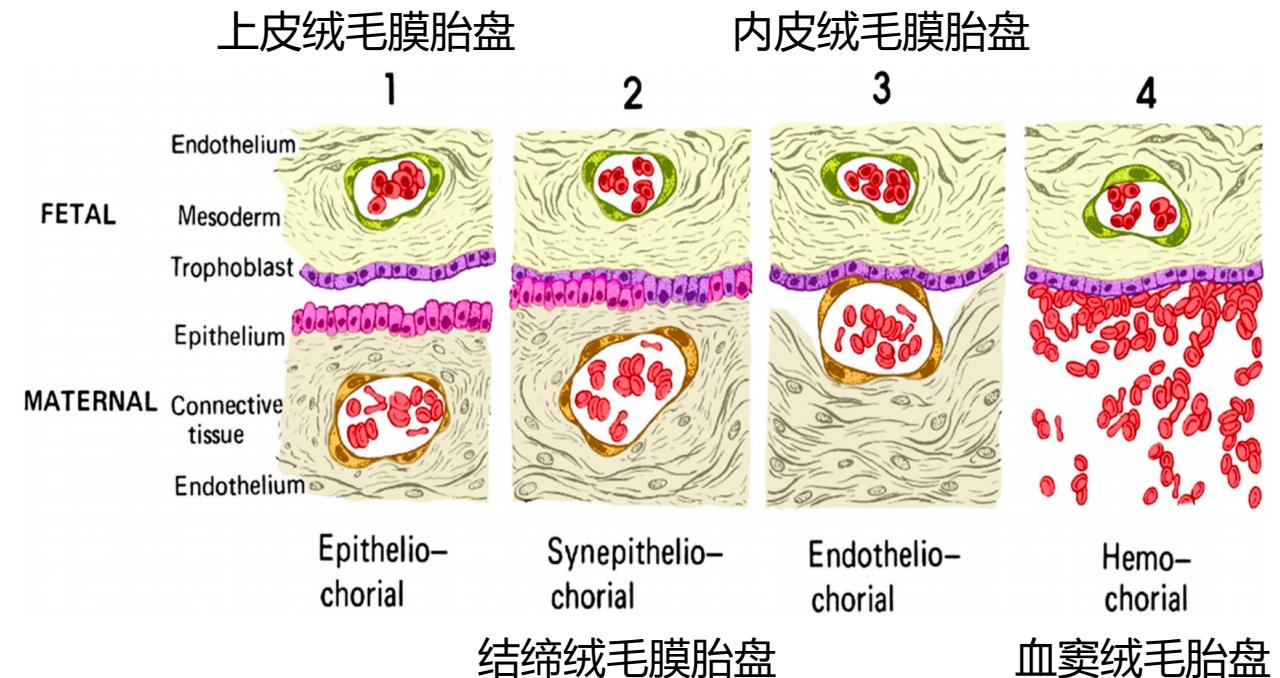
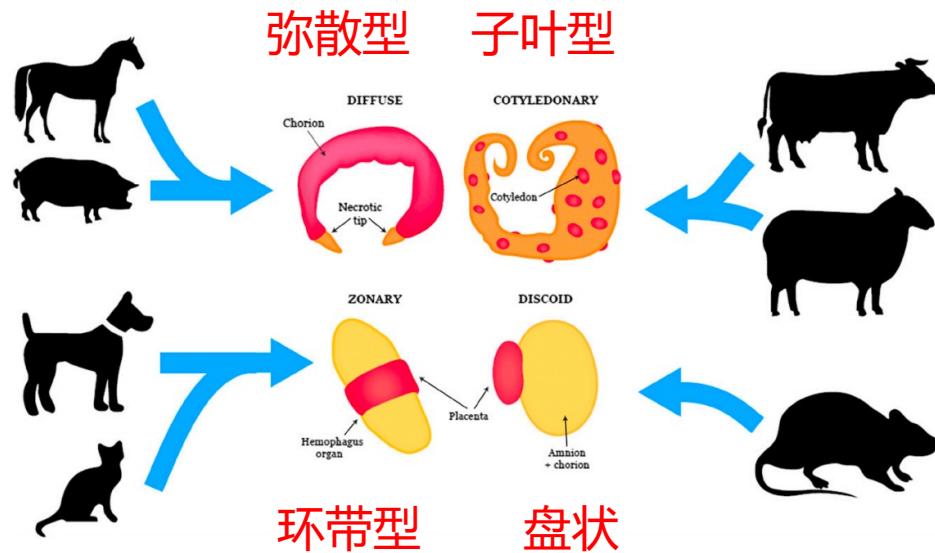




思考与讨论

Phenotype diversity

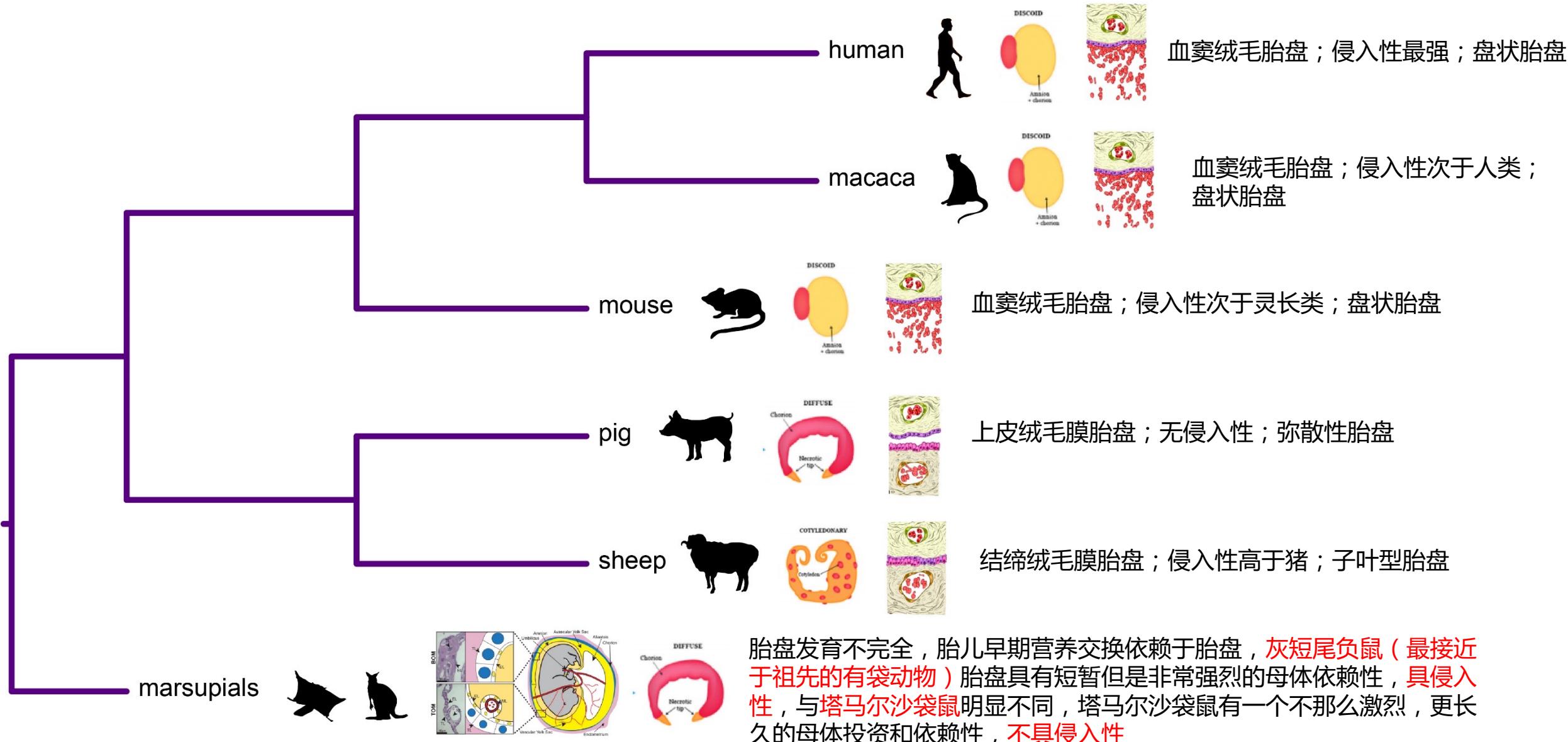
Different degree of invasion with different placenta type



Roberts RM, Green JA, Schulz LC. The evolution of the placenta. *Reproduction*. 2016

Epitheliochorial placenta is not only a derived form that has evolved from a more invasive placental type, but has arisen independently in three distinct mammalian lineages, including primates

Hypothesis of placental evolution



SET or EES?



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why is the epitheliochorial placenta evolved multiple times from a more invasive placental type?

