

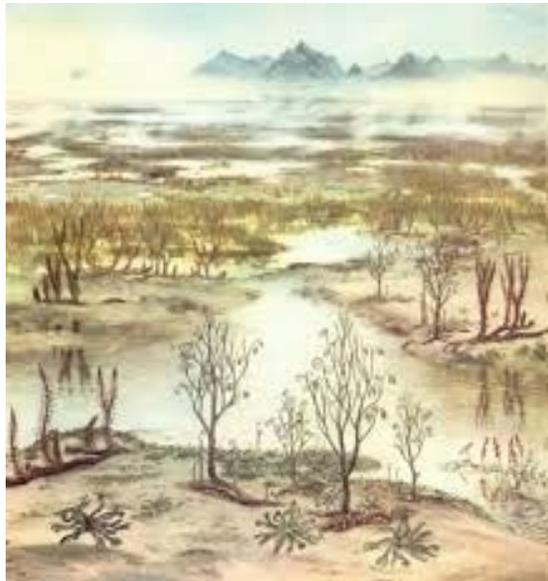
古生物学  
Palaeontology

# 蚩蜉撼大树——昆虫与生态系统

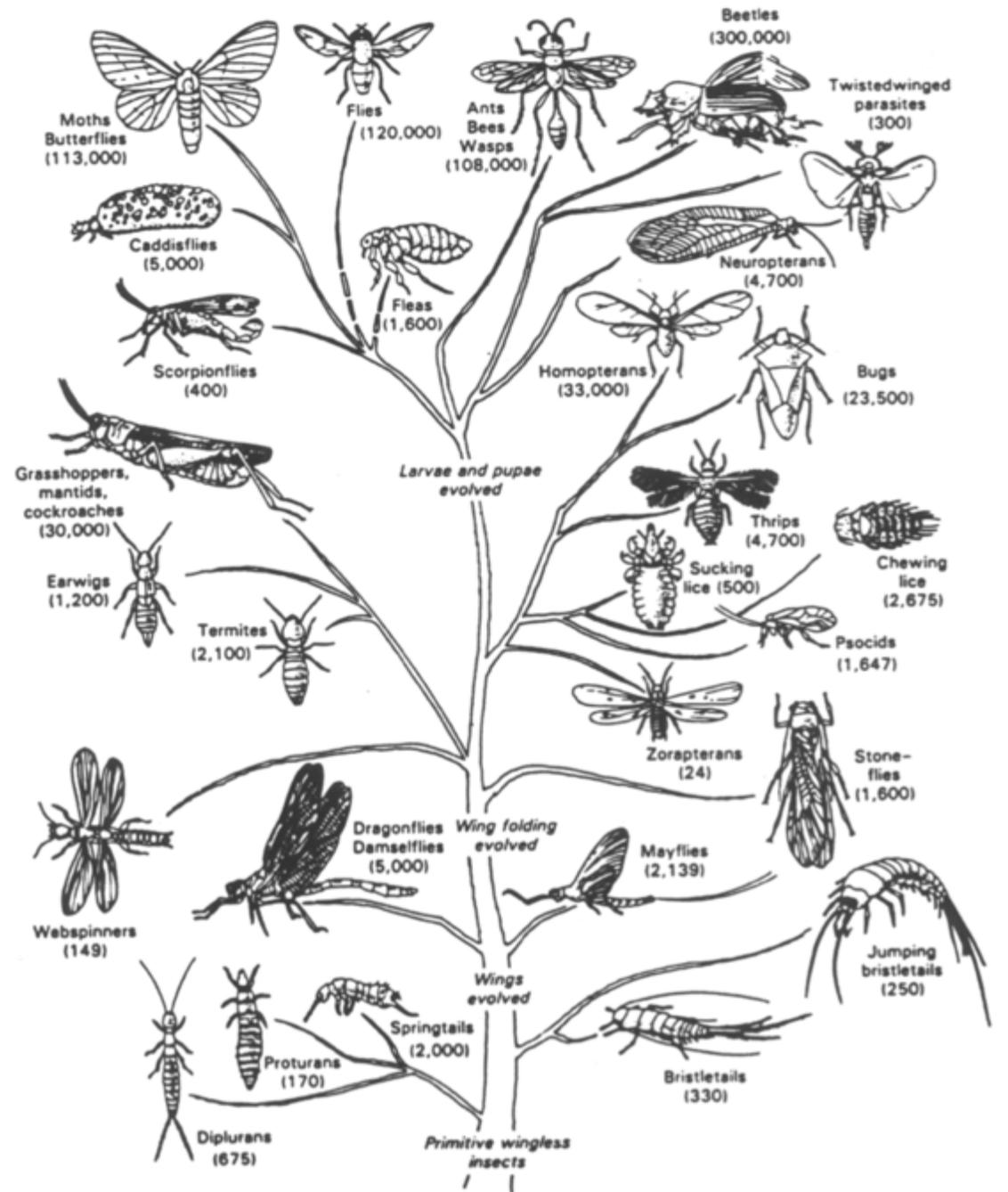


# 很久很久以前

- 据分子生物学推断，昆虫祖先最迟于志留纪中晚期已经登陆
- 同时期登陆的还有蛛形纲祖先（是什么？）
- “开心吃土”



Euthycarinoidea  
Є-T

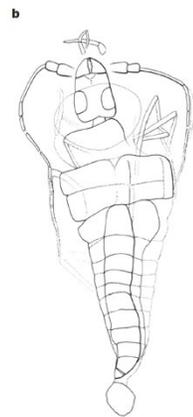
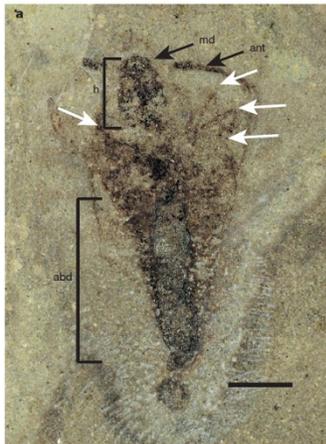


# 主角登场



多足动物  
身体-  
口器+

螯肢动物  
身体+  
口器-

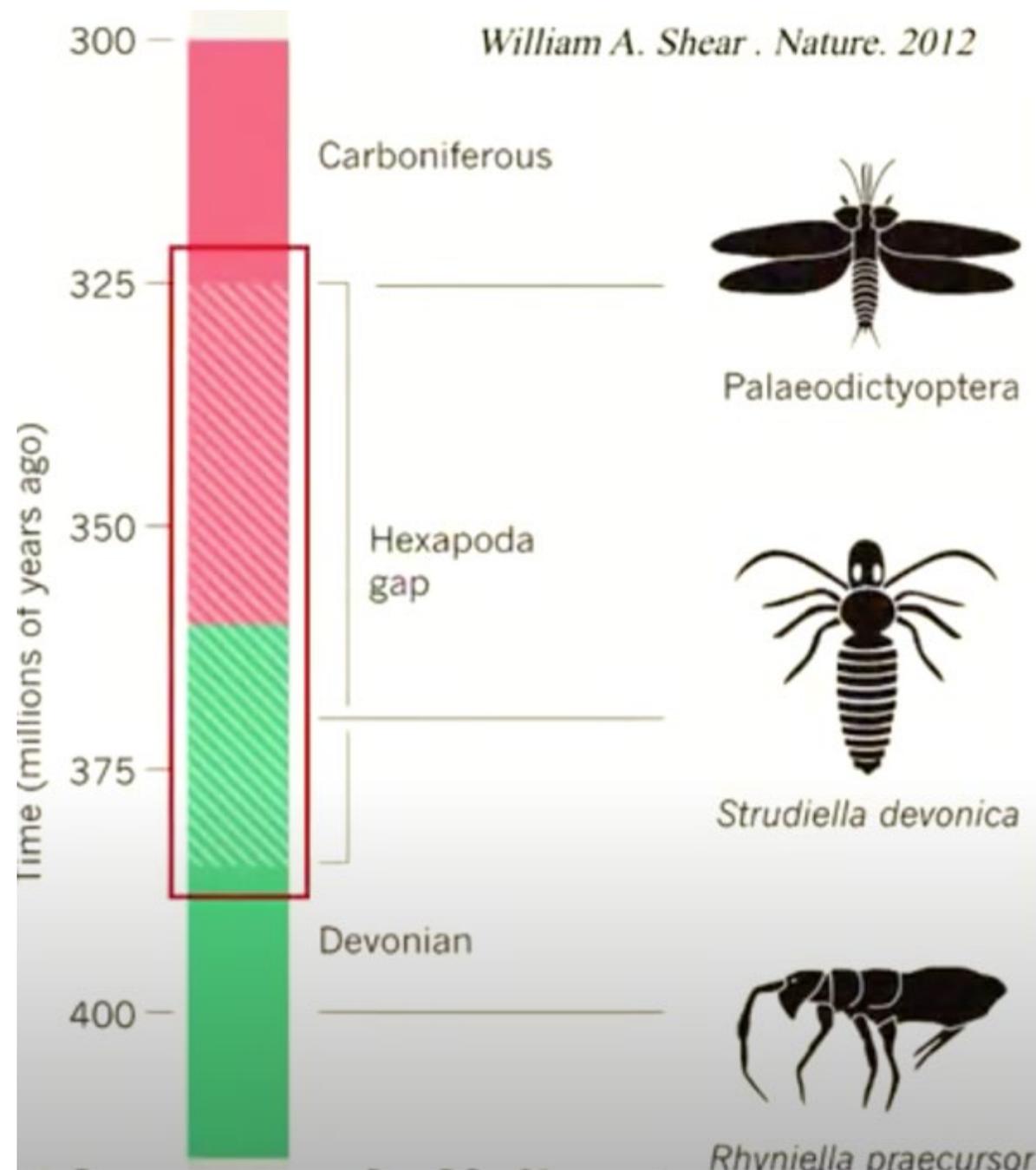


*Strudiella devonica*  
晚泥盆纪  
无翅

# Hexapoda gap 六足空缺

昆虫演化的“柔默空缺”

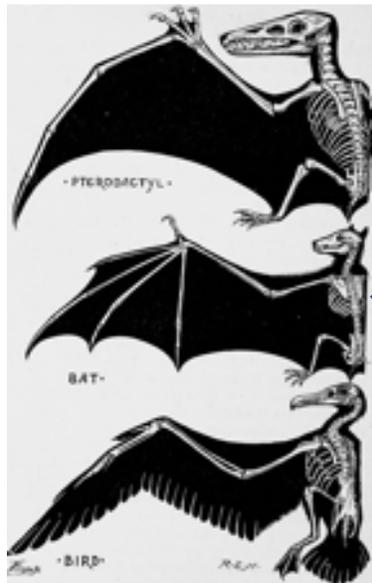
从“无翅”到“有翅”  
65Ma化石空缺



# 飞行能力



起飞



对比

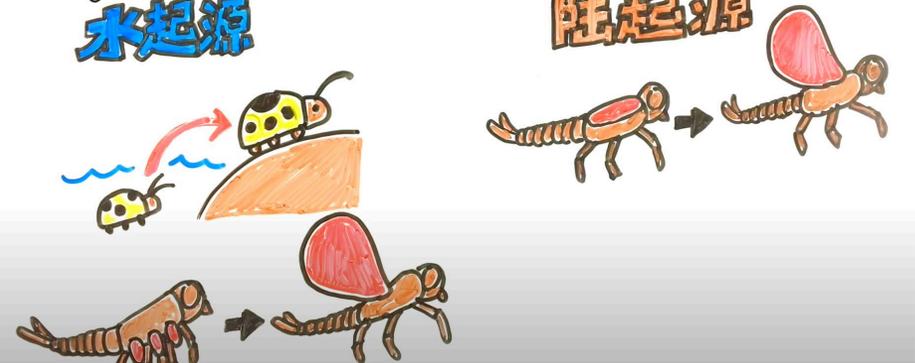


兔肉菌

水起源

20世纪上半叶

陆起源



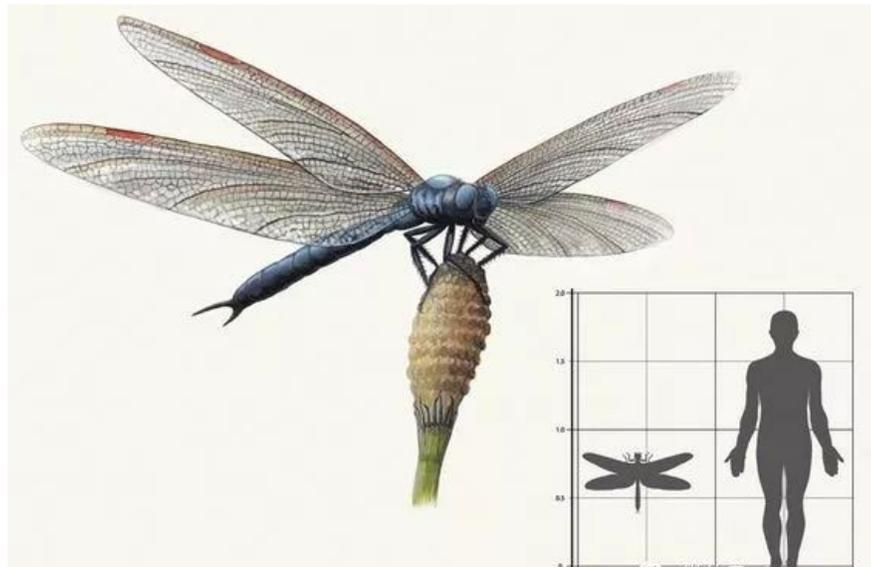
水起源：气管鳃

陆起源：背侧体壁扩张

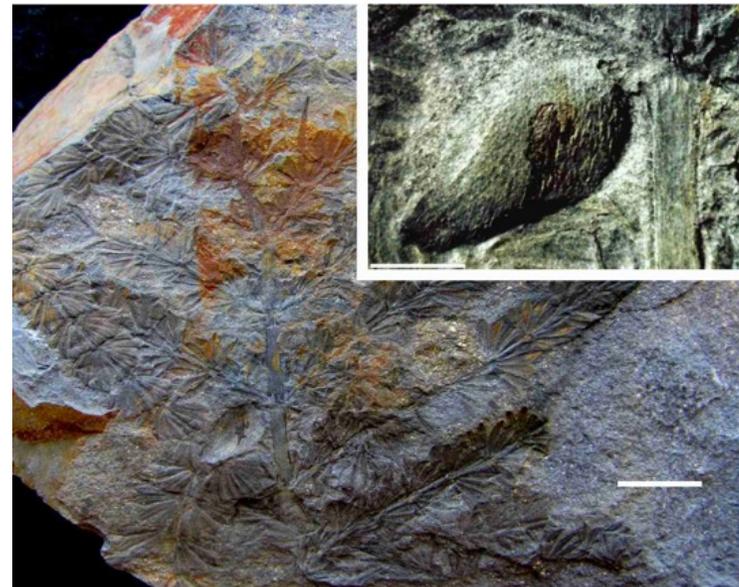
# 石炭纪的昆虫与森林



鳞木，封印木，芦木

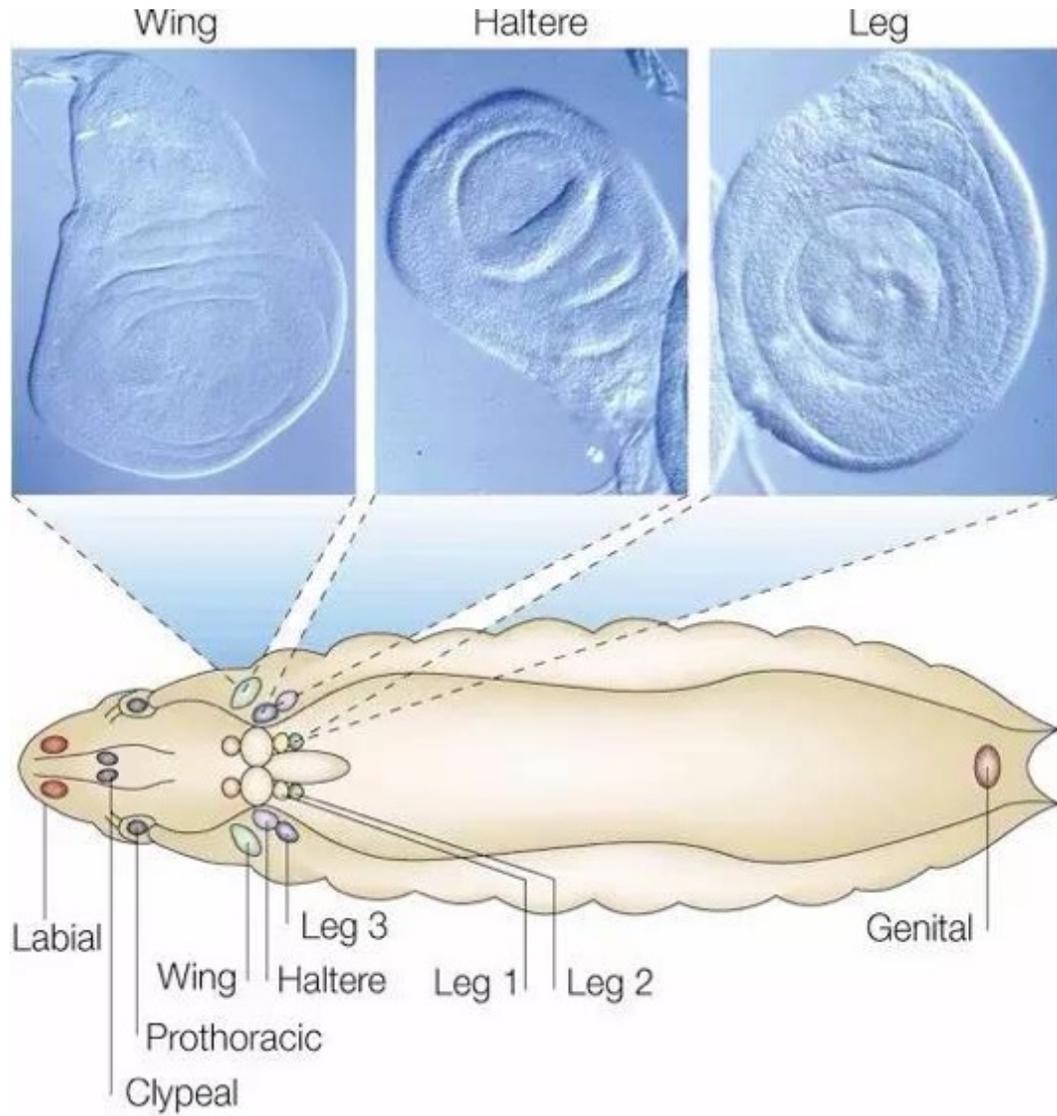


巨脉蜻蜓 *Meganeura* sp.

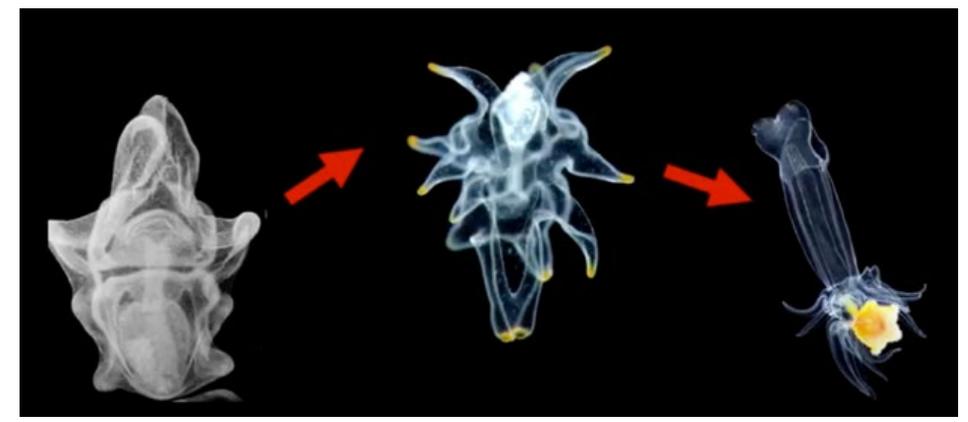
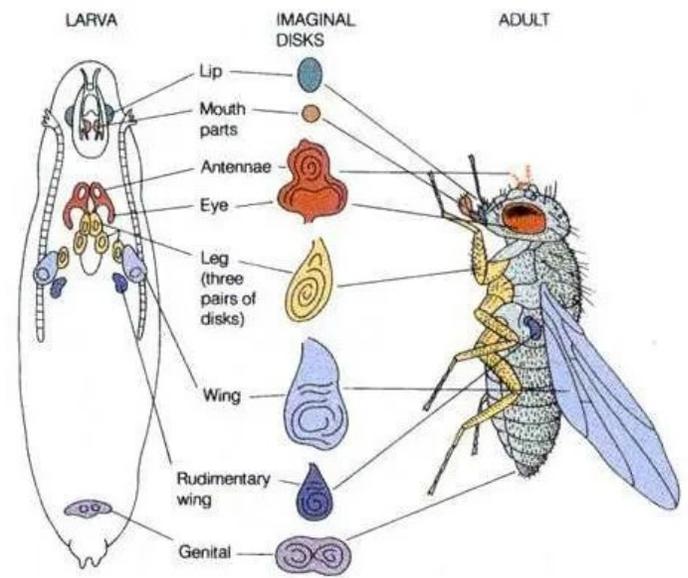


石炭纪虫瘿化石，树蕨

# 变态



# 成虫盘

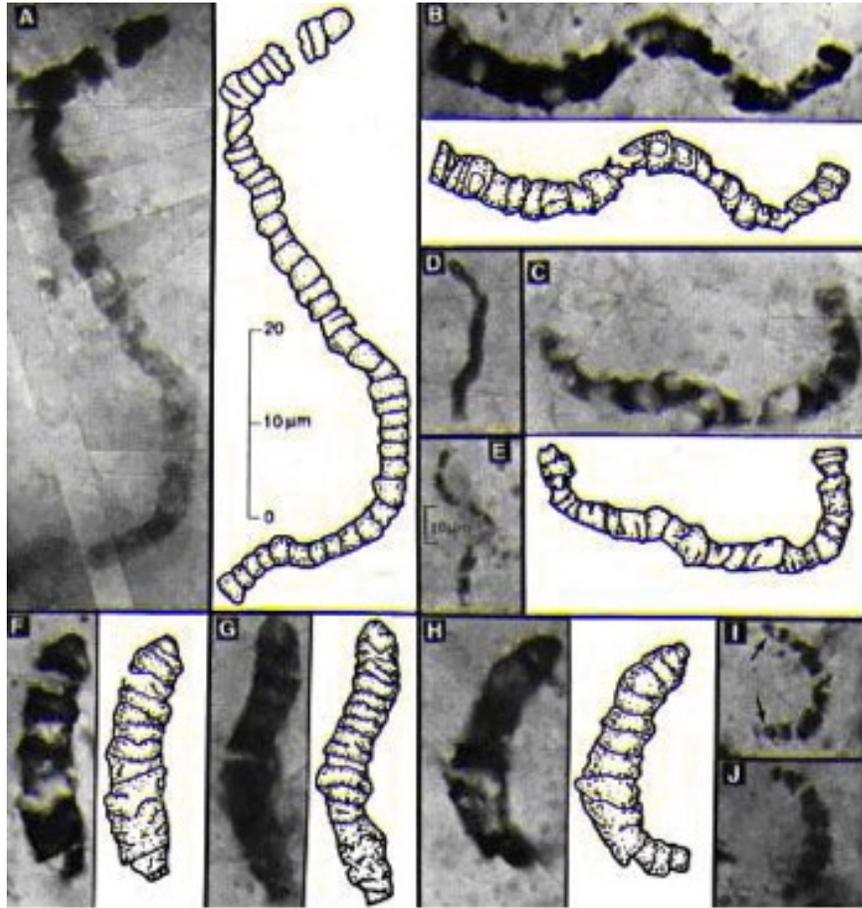


# 甲虫（鞘翅目）

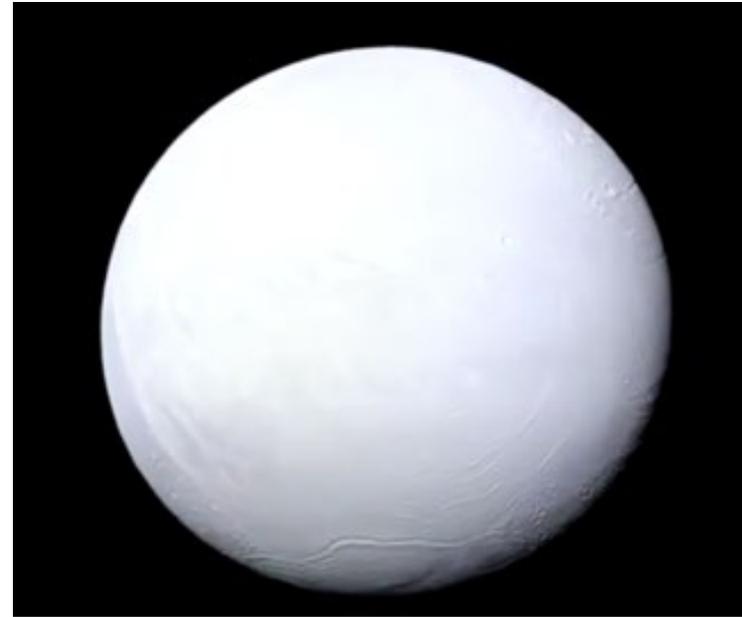


- 昆虫中最大的目，约182科，35万种
- 广泛分布
- 形态特征较其他类群易识别

# 真正影响世界的是“植物”

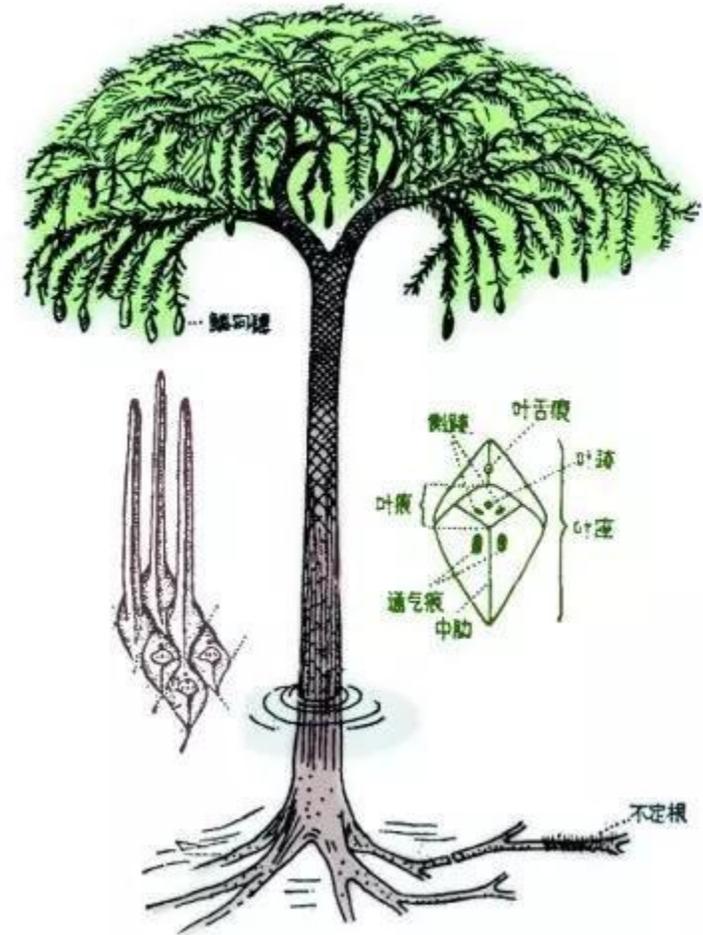


蓝菌



休伦冰期

# 真正影响世界的是“植物”



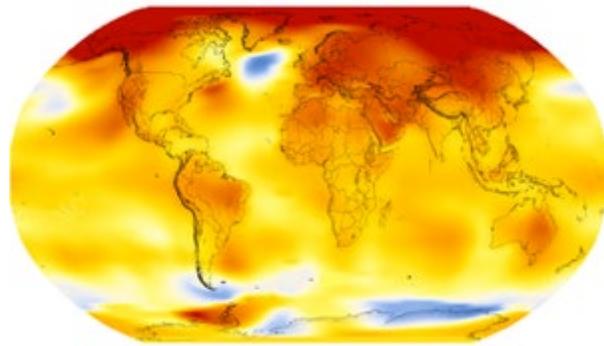
# 真正影响世界的是“植物”



植物疯长



森林崩溃 “石炭纪雨林崩溃事件”



温度异常 (°C)



全球变暖

泥盆纪灭绝事件



全球变冷

# 昆虫活动与碳循环



## 碳循环



## 中国主要气候目标



2025年前  
继续降低碳排放强度



2030年前  
二氧化碳排放达峰



2060年前  
实现碳中和

# 昆虫与中生代古生态变化

- 中生代 (~ 251–66 Ma): 全球植被变化关键时期
- 被子植物在白垩纪迅速辐射 (~ 125 Ma)
- 达尔文的“讨厌之谜”， 1879

Forests dominated by gymnosperms



Forests dominated by angiosperms



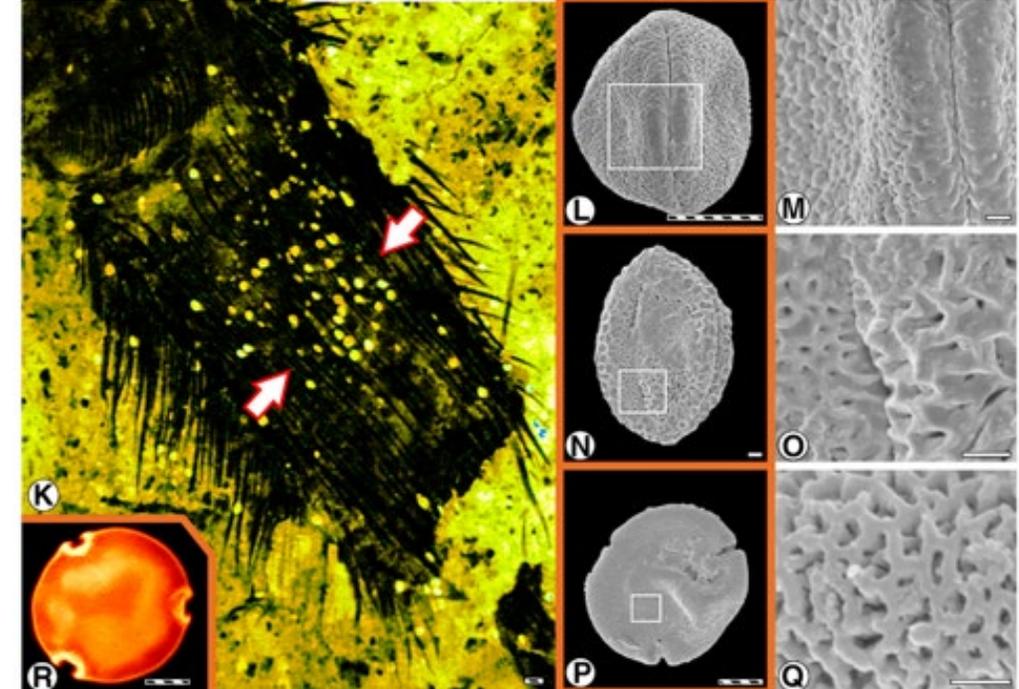
# 提出解释假说

## 假说

- 昆虫传粉加速了被子植物的辐射和多样性提高
- 被子植物的发展同样影响了昆虫的多样性

## 缺陷

- 无同一传粉类群昆虫的连续化石记录
- 无昆虫传粉的直接证据



# 花蚤科



Photo: Pocketmacro



Photo: Berglinde2

Family: Mordellidae Latreille, 1802

四个亚科

Mordellinae

Ctenidiinae

Praemordellinae †

Apotomourinae †

通俗名称

Tumbling flower beetles (花蚤)

Pintail beetles (针尾甲?)

食性偏好

取食花朵 (部分) 和花粉 → 传粉

# 侏罗纪的花蚤类群 (Coleoptera: Tenebrionoidea)



*Wuhua peregrine* Bao, 2019

中侏罗纪 (~ 168–152 Ma)

- 身体较扁平
- 后足不发达
- 臀锥未发育



*Praemordella martynovi*  
Scegoleva-Barovskaja, 1929

晚侏罗纪 (~ 158–152 Ma)



Photo: NickyBay

# 白垩纪的花蚤类群 (Apotomourinae)



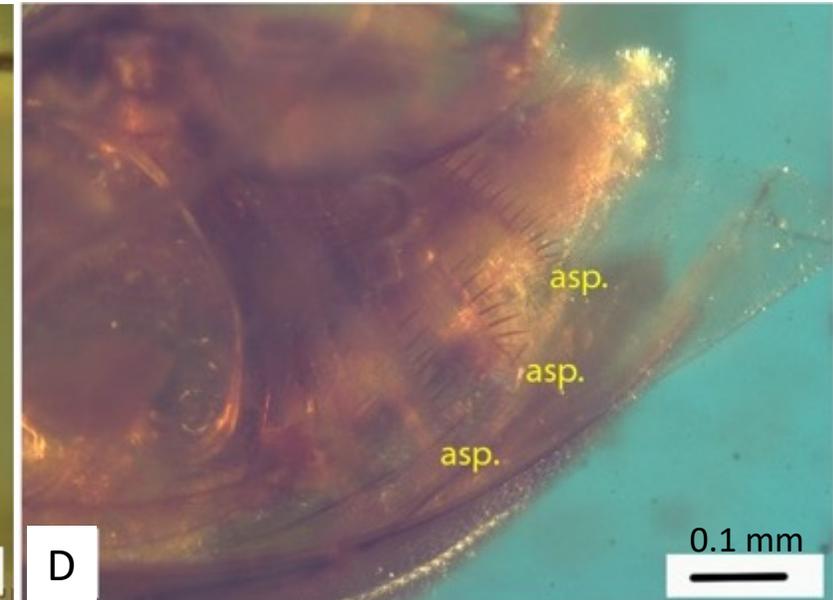
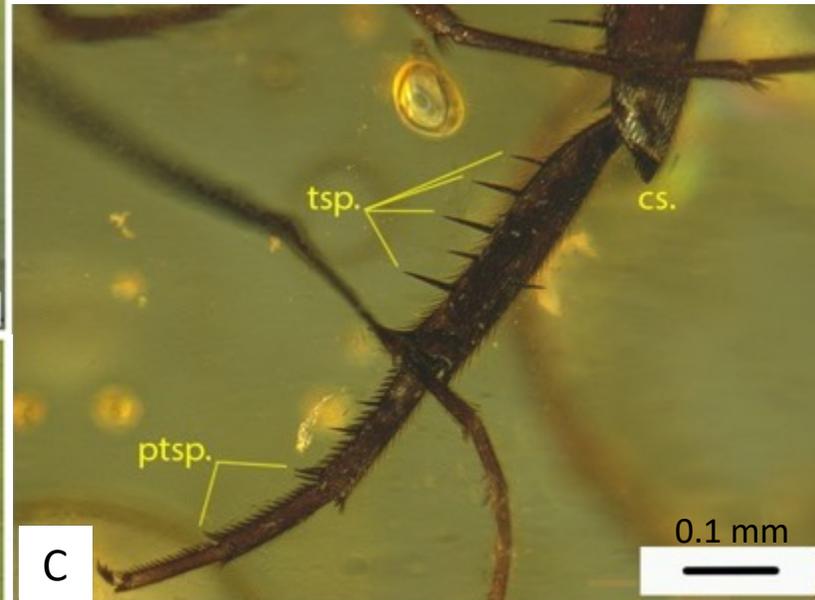
*Multispinus multispinosus* Bao, 2018

白垩纪中期，森诺曼期 (~ 99 Ma)



*Apotomoura fortiscrura* Bao, 2018

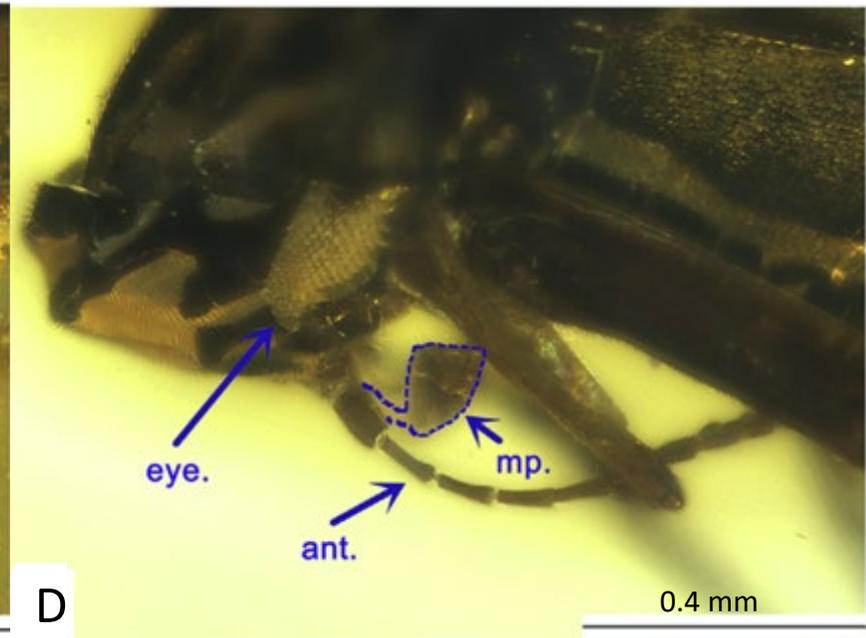
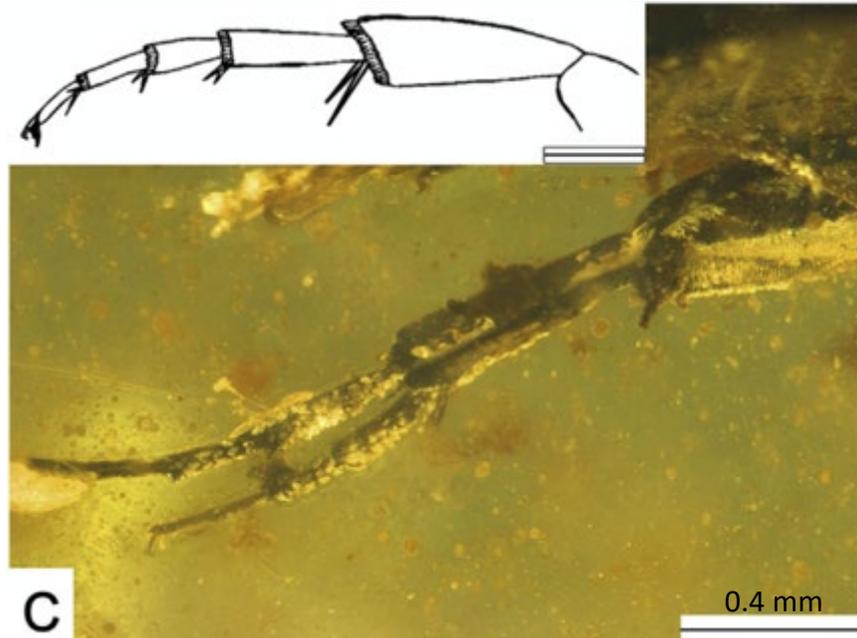
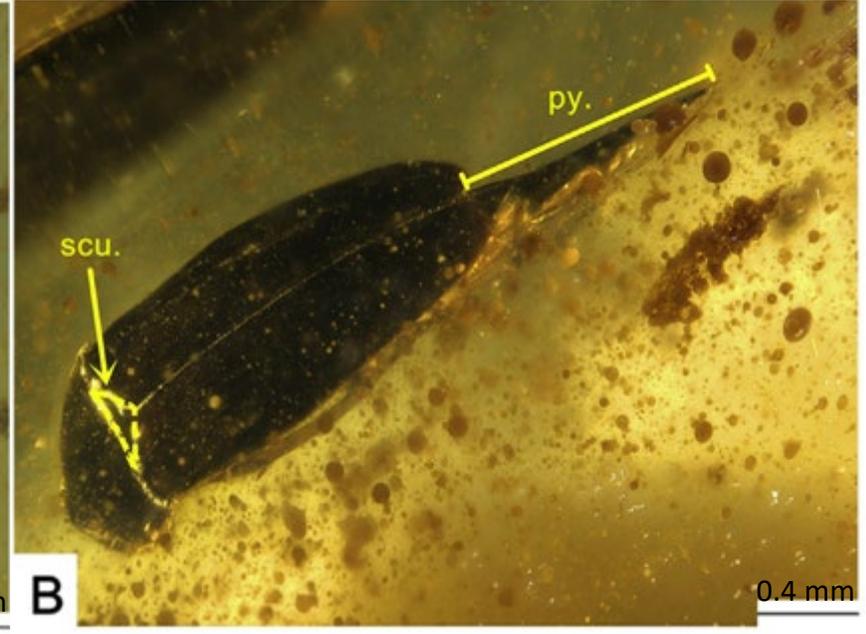
白垩纪中期，森诺曼期 (~ 99 Ma)



# 白垩纪的花蚤类群 (Mordellinae)

*Primaevomordellida burmitina*  
Bao, 2018

白垩纪中期，森诺曼期 (~ 99 Ma)



# 新生代的花蚤类群 (Mordellinae)



*Tomoxia succinea*  
Bao, 2018

波罗的海琥珀，始新世 (~44 Ma)

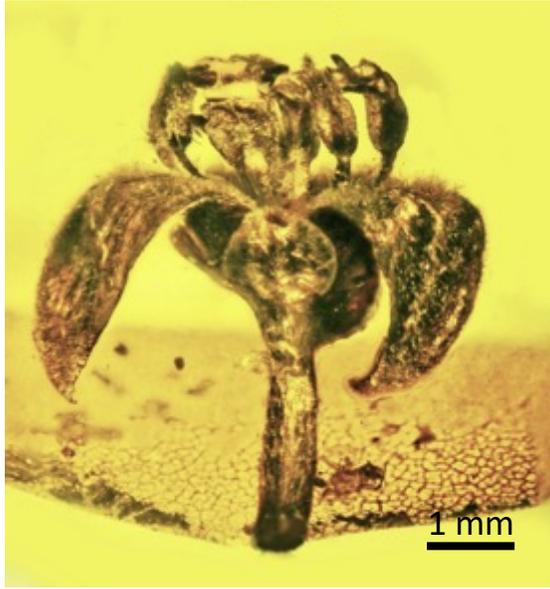


Photo: Josef Dvořák

*Tomoxia bucephala*  
Costa, 1854

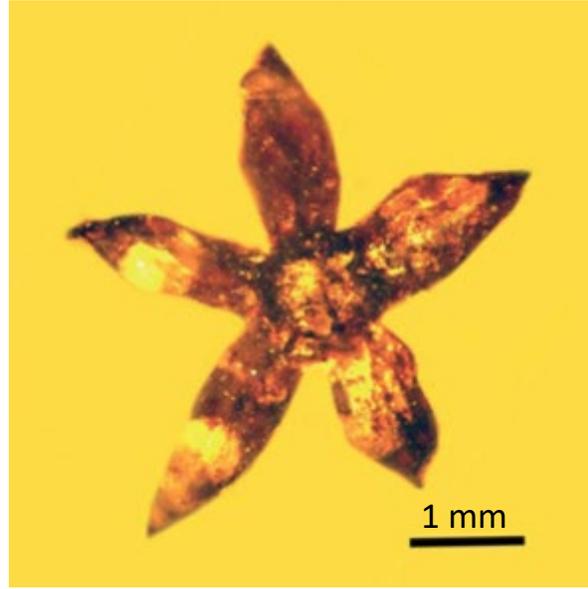
现生欧洲物种

# 白垩纪缅甸琥珀中的花朵内含物



Poinar, 2017

**Lauraceae species**



Poinar and Chambers, 2017

**Cunoniaceae species**



Photo: Didier Descouens

***Laurus sp.* 伞状花序**

白垩纪中期，森诺曼期 (~ 99 Ma)

现生

# 被子植物传粉授粉的最早证据

*Angimordella burmitina*  
Bao, 2019

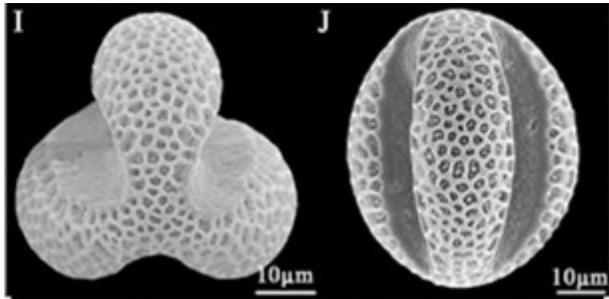
白垩纪中期，森诺曼期 (~ 99 Ma)

三沟花粉 (真双子叶植物)

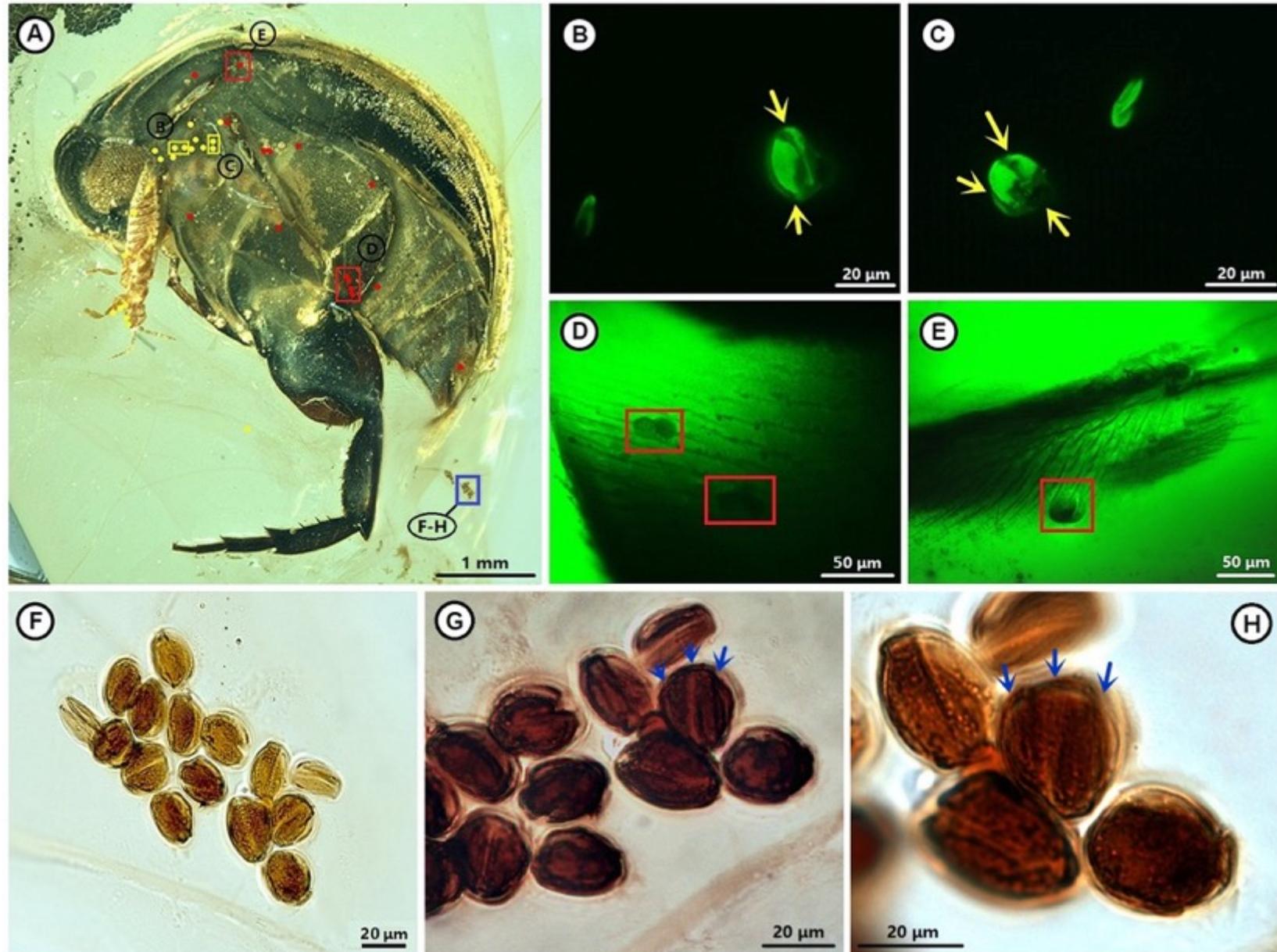
虫媒传粉花粉:

- 尺寸 ~30  $\mu\text{m}$
- 表面纹饰
- 集结

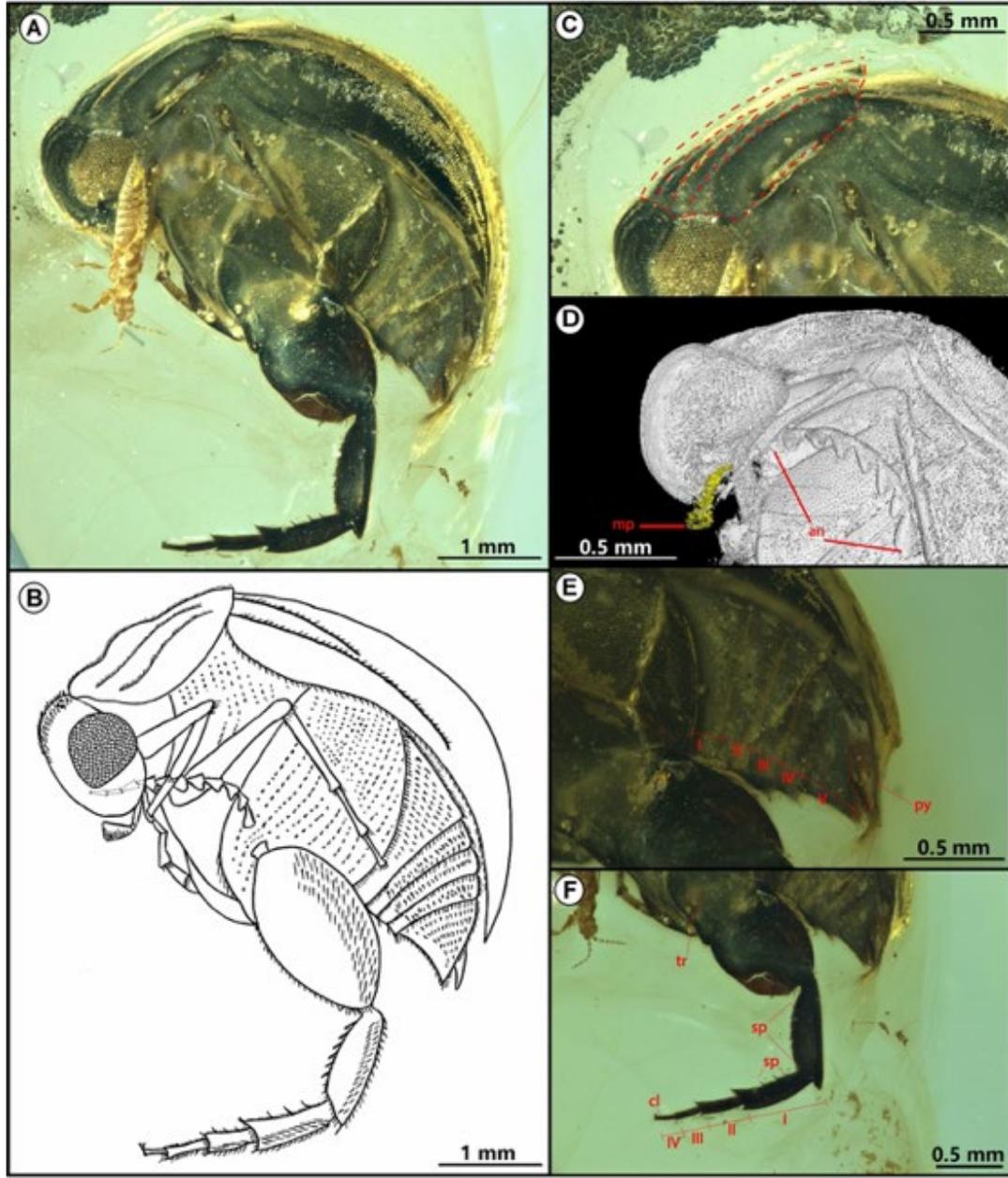
Pollen grains of extant eudicots



Jiang et al., 2019

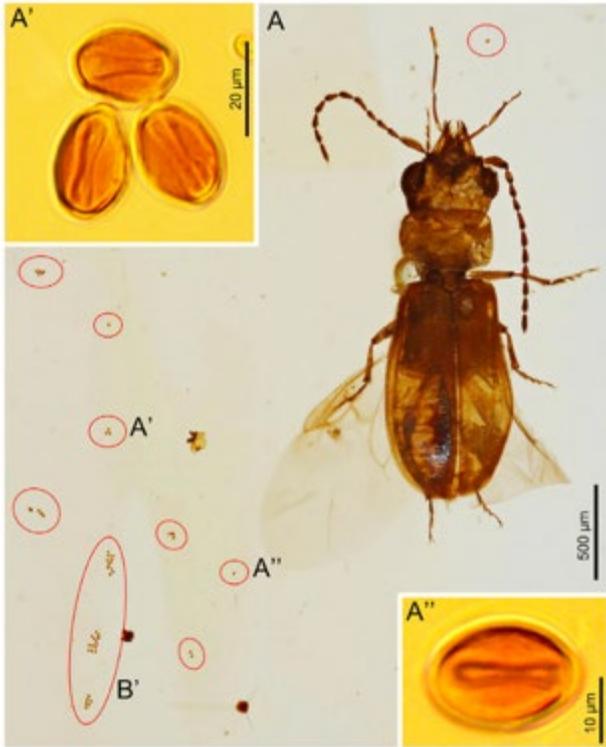


# 被子植物传粉授粉的最早证据



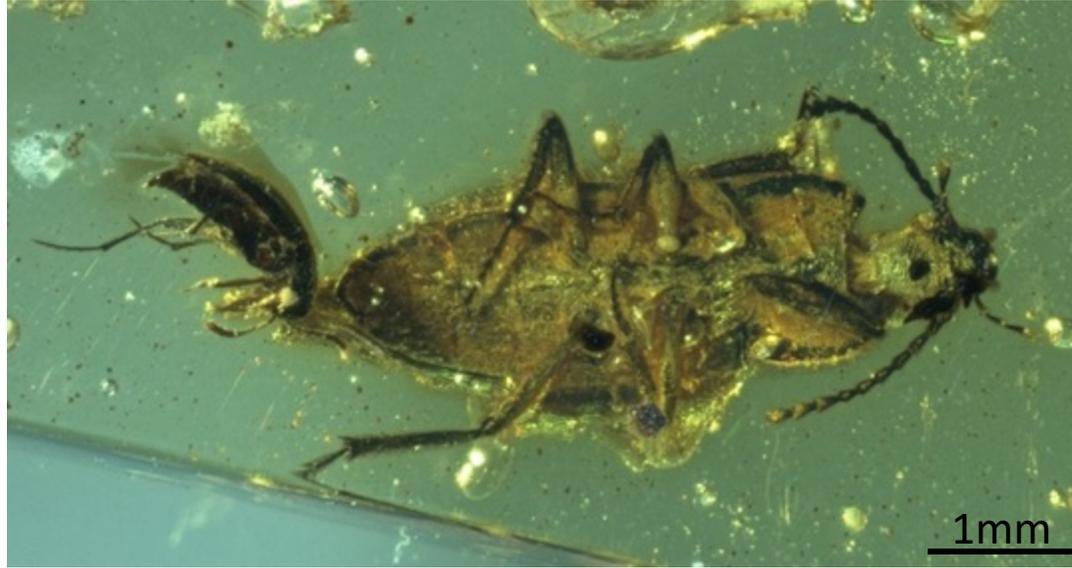
Cretaceous flowers based on *Lijinganthus revoluta* Wang, 2018  
Art work: Dinghua Yang

# 白垩纪琥珀中甲虫类群古生态多样性



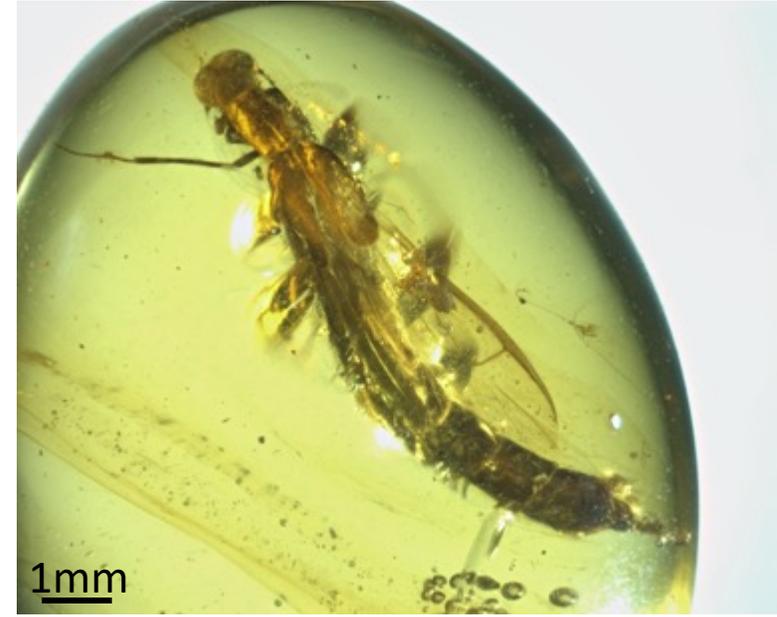
Cai et al., 2018

**Cycad environment**  
**Boganiidae**



**Fern environment**  
**Tenebrionidae**

**Scavenger**  
**Leiodidae**



**Wood-borer**  
**Lymexylidae**

# 思考：

从白垩纪缅甸琥珀森林生态系统可以看出，一亿年前已基本形成了现代昆虫-植物关系的雏形，体现了那种演化理论？



Pollination of Cretaceous flowers by *Angimordella burmitina*, art work: Dinghua Yang



Pollination of extant flowers by Mordellidae, photo: Radoslav Valkov