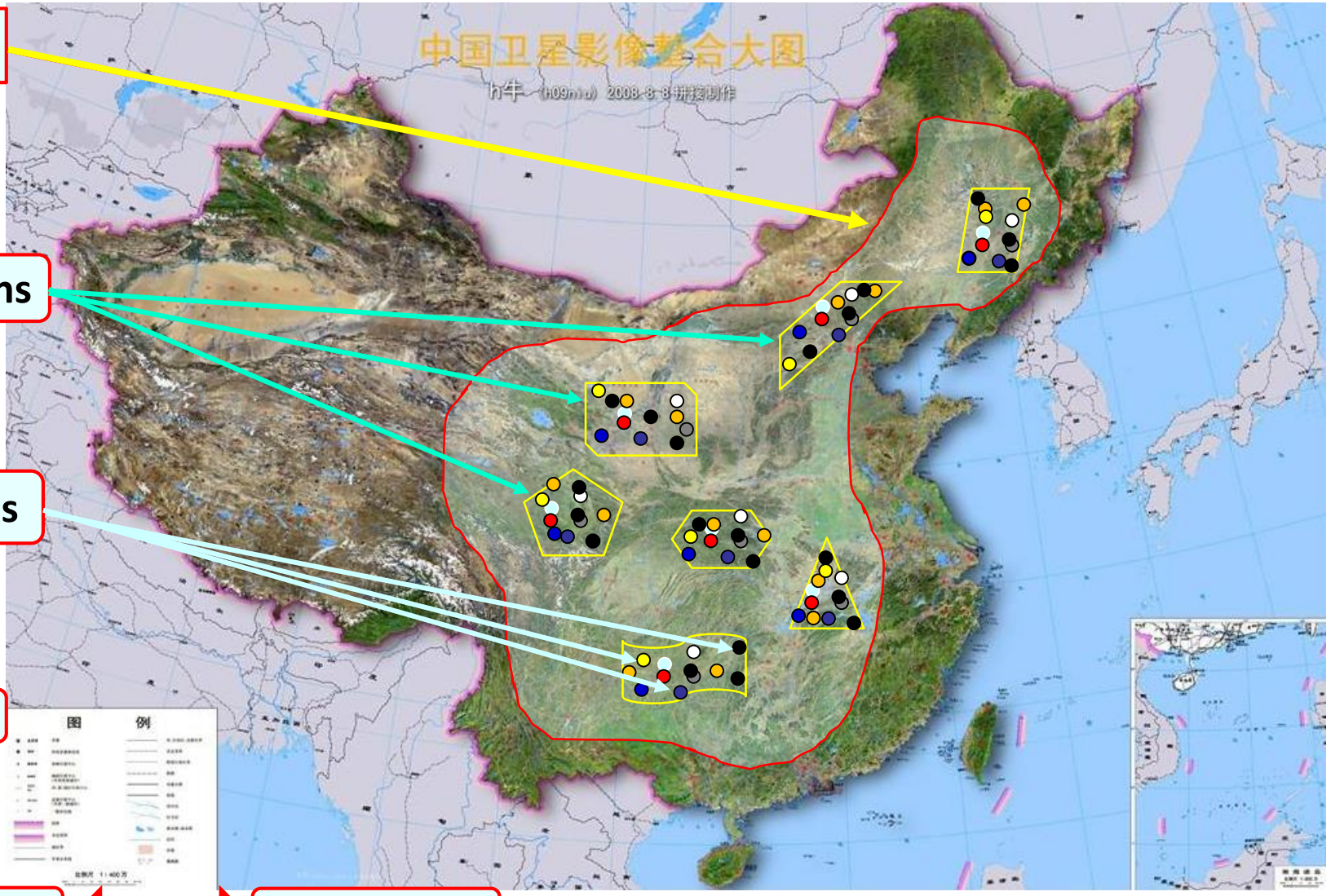
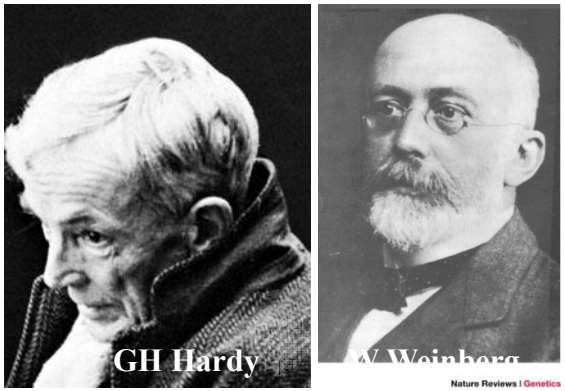
The "hierarchical" structure of a species



Hardy-Weinberg Equilibrium

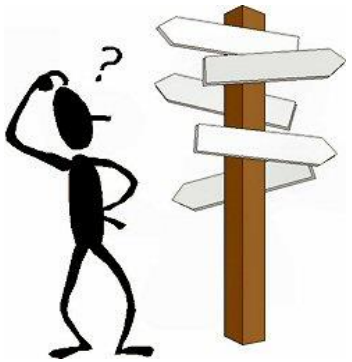


Godfrey H. Hardy (English mathematician) and **Wilhelm Weinberg** (German physiologist) independently enunciated in 1908 what is now known as the Hardy-Weinberg equilibrium.

Hard-Weinberg equilibrium ------- The gene and genotype frequencies do not change in a large Mendelian population with random mating and no mutation, selection, or gene flow. Considering a locus with two alleles *A* and *a* with frequencies *p* and *q* The relationship between the allele and genotype frequencies can be expressed as following:

$$(p + q)^2 = p^2 + 2pq + q^2 = 1$$

★在一个无限大、随机交配的居群中，如果没有突变、迁移和选择因素的影响，居群的基因频率和基因型频率在世代间保持不变。



What does Hardy-Weinberg equilibrium mean?

Hardy-Weinberg Equilibrium is defined as the situation in which no evolution is occurring.

No Evolution !!

Five Agents of Microevolution

1. Finite population size

Genetic drift = random changes in allele frequency

Bottleneck

Founder effect

Inbreeding ➡ inbreeding depression

2. **Nonrandom mating** within a population

3. **Gene flow** can change a gene pool due to the movement of genes into or out of a population

e.g. migration

4. **Mutation** changes alleles

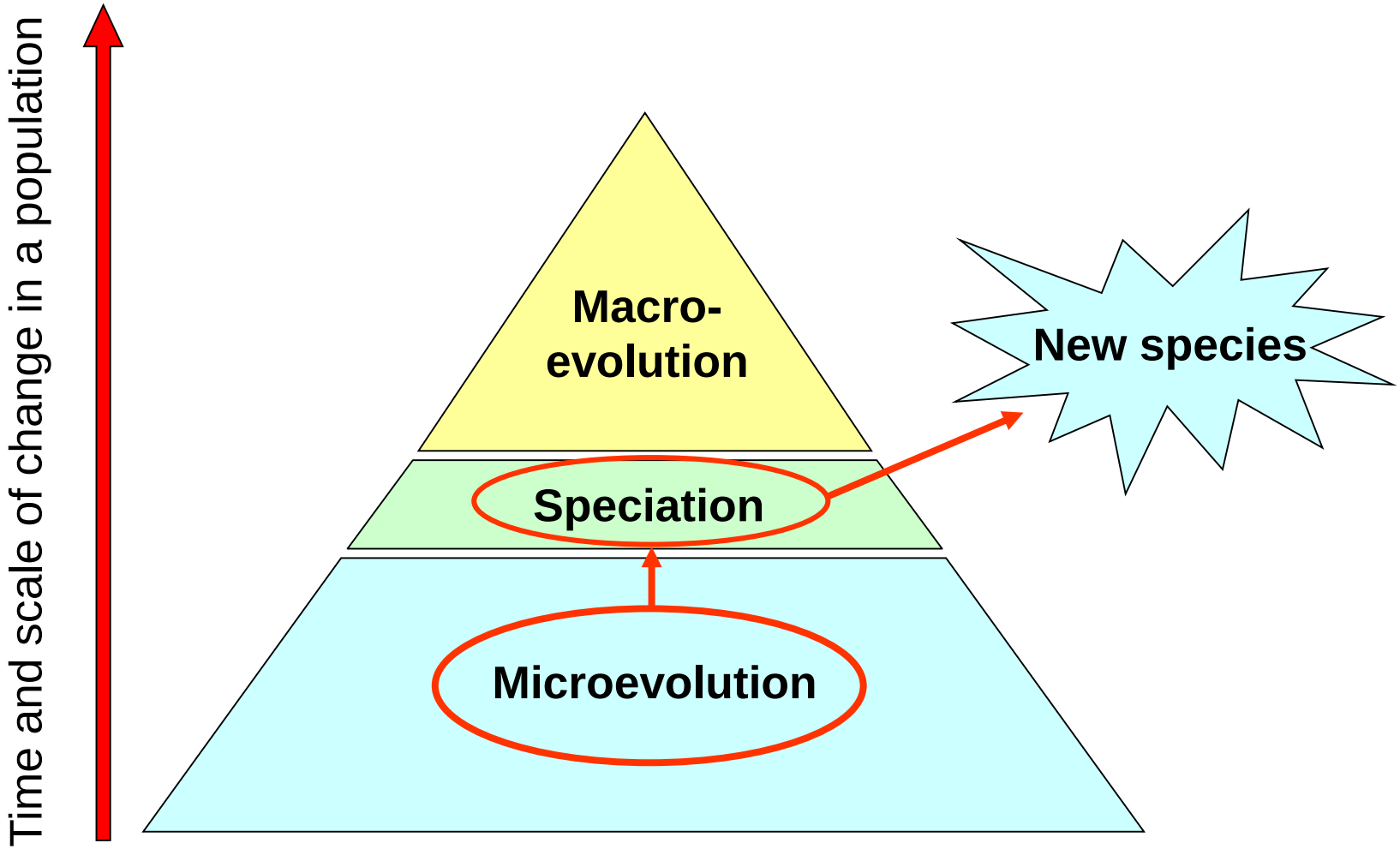
5. **Natural selection** leads to differential reproductive success

§5.4 Population Differentiation and Speciation

植物的居群分化与物种形成

- **Differentiation of populations**
  植物居群的分化
- **Species and Speciation**
  物种与物种形成
- **Modes of Speciation**
  物种形成的方式

Evolution – change through time



Species

- Species form the link between *Microevolution* and *Macroevolution*

- Species, to some extent, is the end product of *microevolution* as well as the start point of *macroevolution*

What is a Species?

☞ How we define a “species”

1. A number of definitions have been suggested

2. Certain definitions work better for certain taxa

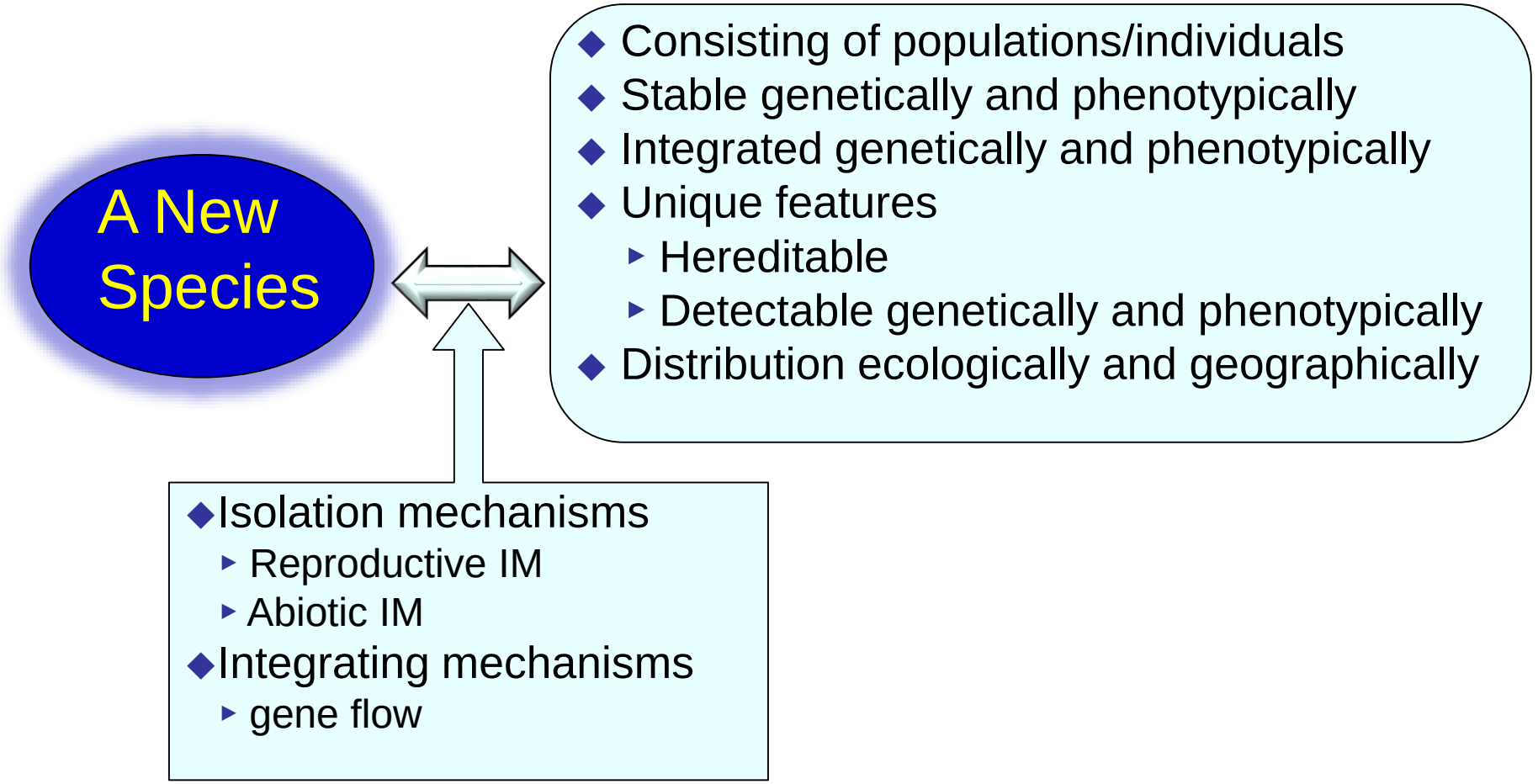
3. No one species definition will fit all types of species

☞ Speciation is a process by which new species arise, and also the keystone process in the origination of biodiversity.

1. The end product of the speciation is a species

2. Different processes lead to different types of species

The Continuity of Evolution Makes Species Hard to Define but Easier to Characterize a Species



Species Concepts

- There are over 50 recognized species concepts. Each seeks to define groups that cannot (or do not) 'talk to each other' genetically
- We'll limit our discussion to 5 basic ideas of species delineation
  - Morphological species/形态学/分类学种
  - Paleontological species/古生物学种
  - Phylogenetic species/谱系生物学种
  - Ecological species/生态学种
  - Biological species/生物学种

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Phylogenetic Species

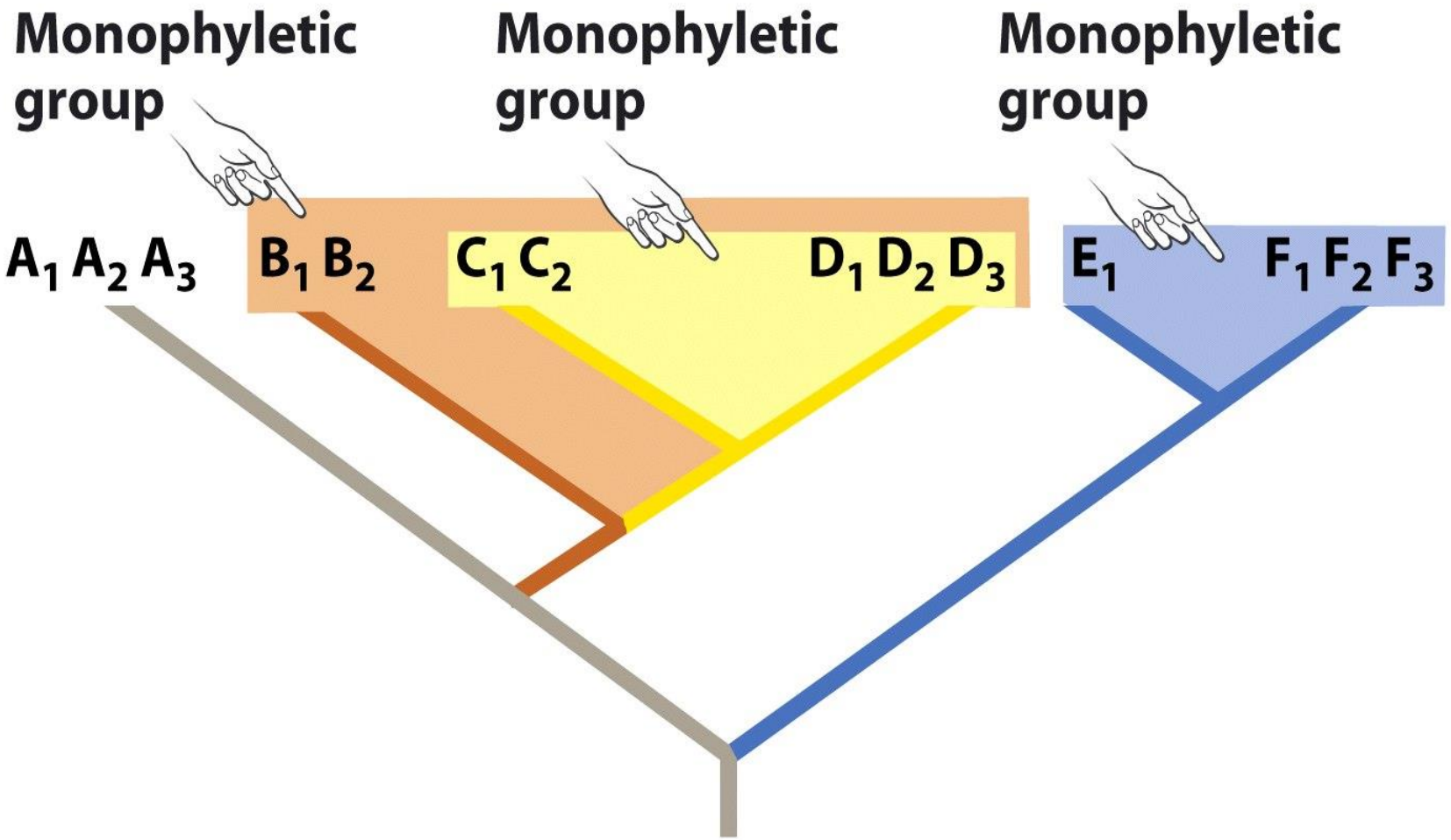
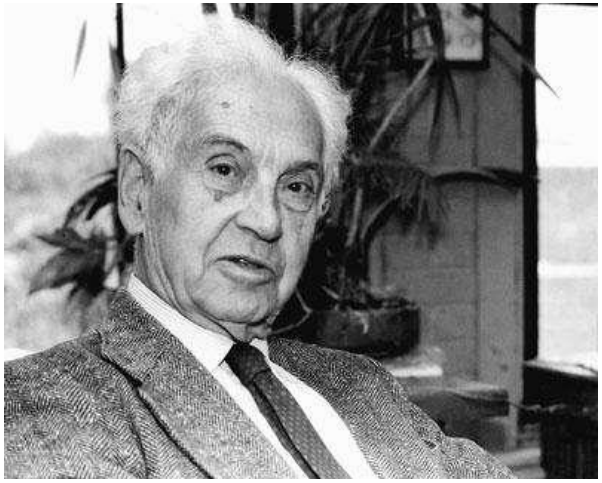


Figure 25-3 Biological Science, 2/e

Biological Species Concept



- **Proposed by Ernst Mayr (1942)**
- **Definition:**

☞ Species are groups of actually or potentially interbreeding natural populations that are reproductively isolated from other such groups

- Definition is based upon interbreeding/互交能育

☞ Most important part of definition is reproductive isolation. That implies that if individuals from two separate populations cannot produce fertile offspring they are said to be two different species

Advantages of BSC

Reproductive isolation provides taxonomists a criterion for identifying species

- Reproductive isolation is a complete lack of gene flow
- Species integrity is maintained by gene flow within species and lack of gene flow between species
- Opportunity for large amounts of genetic divergence to occur between reproductively isolated populations

Major difficulties of BSC in Practice

- Asexual organisms?
- Geographically separated groups?
- What is “potentially interbreeding”?

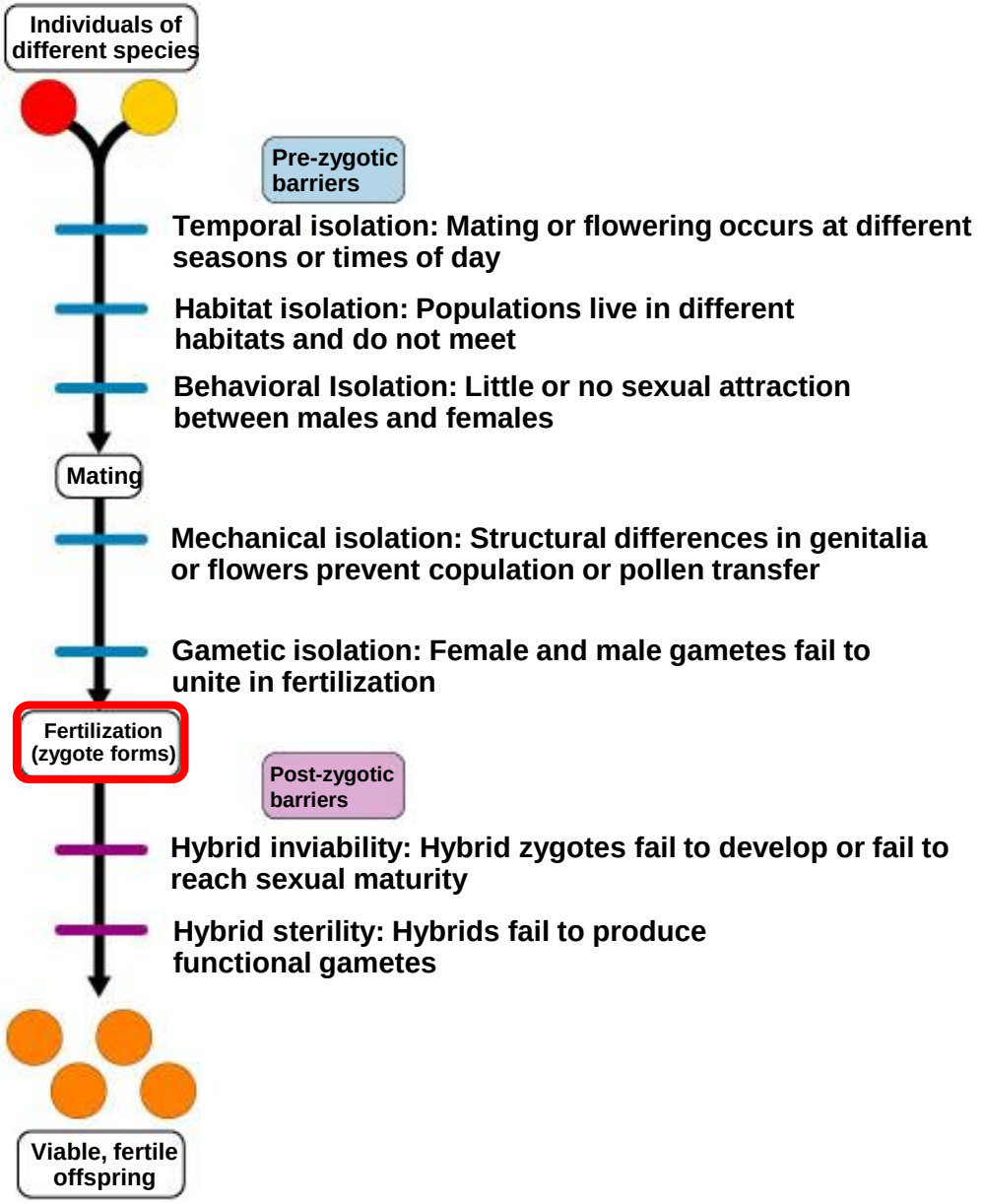
Reproductive Isolation Mechanism (RIM):
2 Major Categories

- Prezygotic RIM/合子前的生殖隔离 – prevents the formation of hybrid zygotes

- Postzygotic RIM/合子后的生殖隔离 – reduced fitness of hybrid zygotes

Reproductive Barriers Between Species

- Pre-zygotic barriers impede mating between species or hinder fertilization of eggs
- Post-zygotic barriers prevent the hybrid zygote from developing into a viable, fertile offsprings



Isolating mechanisms: prezygotic

- **Prezygotic barriers that prevent mating**
  - habitat (spatial) isolation
  - temporal isolation
  - behavioral isolation
- **Prezygotic barriers that prevent fertilization**
  - mechanical: prevent copulation or pollen transfer, such mechanisms mainly occur in animals
  - gametic isolation, e.g. incompatibility barrier

Isolating mechanisms: postzygotic

★ **Postzygotic barriers are isolating mechanisms that take effect after fusion of gametes**

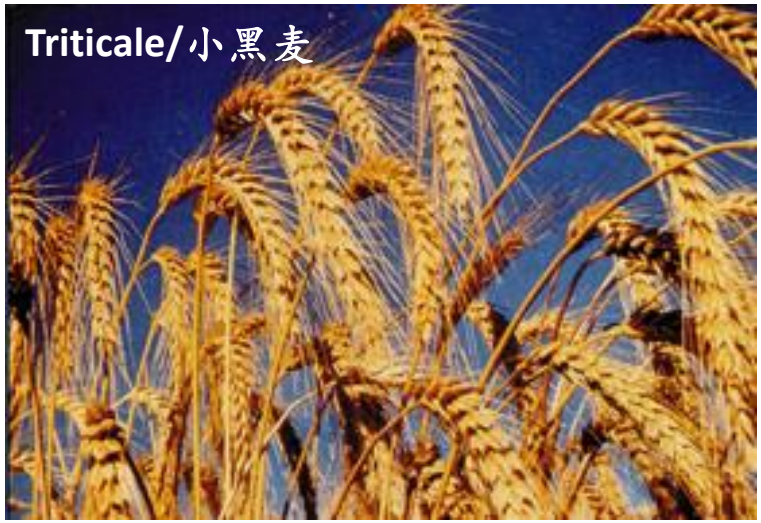
- decreased hybrid viability （杂种活力下降或无活力——杂种合子不能发育或不能发育到性成熟阶段）
- decreased hybrid fertility（杂种不育或生育力下降——杂种不能产生有功能的配子
- hybrid breakdown (offspring of hybrids have lowered viability or fertility/杂种衰败—— 杂种的适合度显著降低)

Postzygotic barriers - Hybrid problems

Triticum aestivum L. (2n = 6x = 42)

X

Secale cereale L. (2n = 2x = 14)



Triticum X *Secale* (2n = 8x = 56)

Evolution of Isolating Mechanisms

Selection generally favors prezygostic barriers for speciation to avoid the waste of energy on poor offspring!

Reproductive Barriers Between Species

- Pre-zygotic barriers impede mating between species or hinder fertilization of eggs
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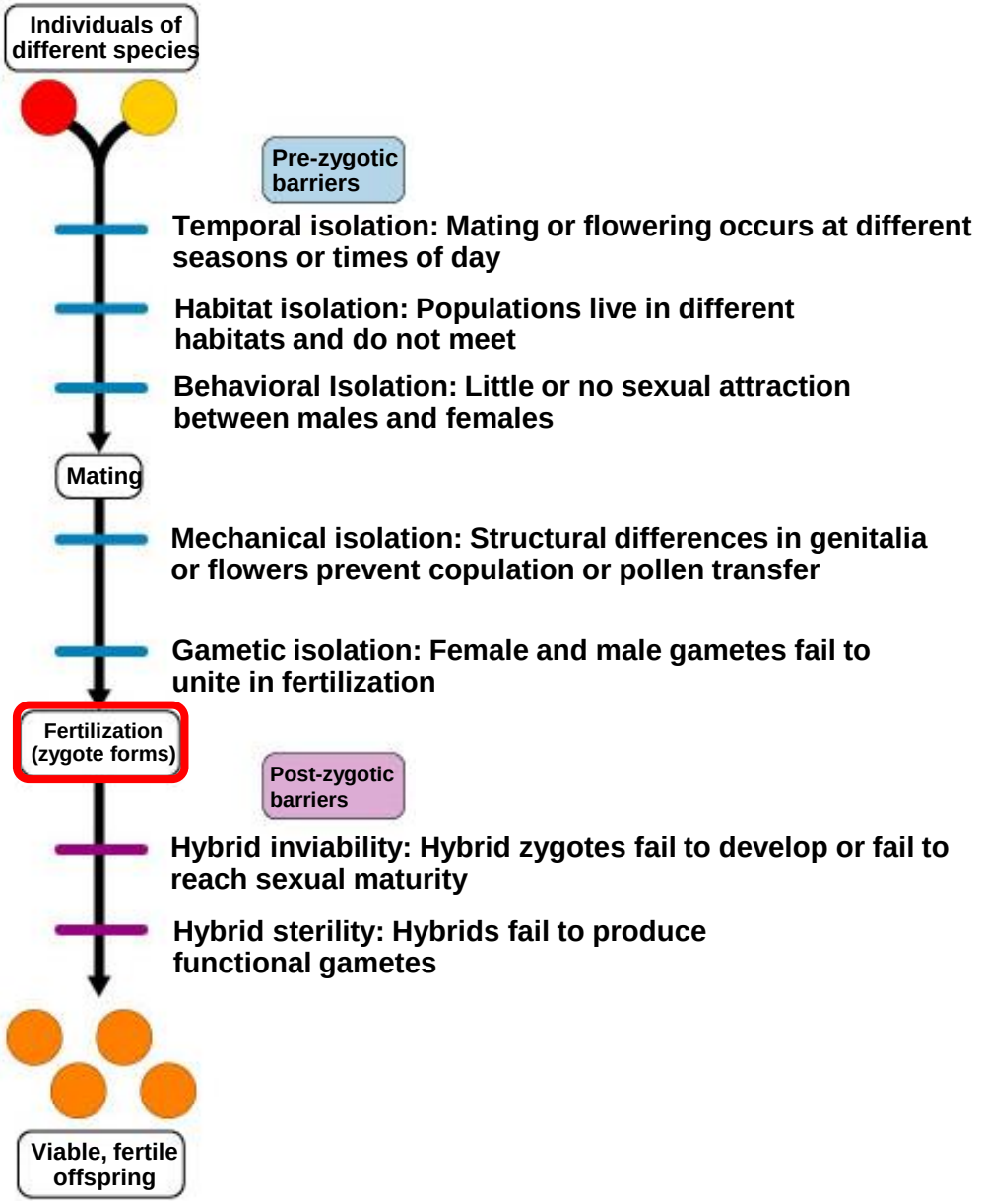
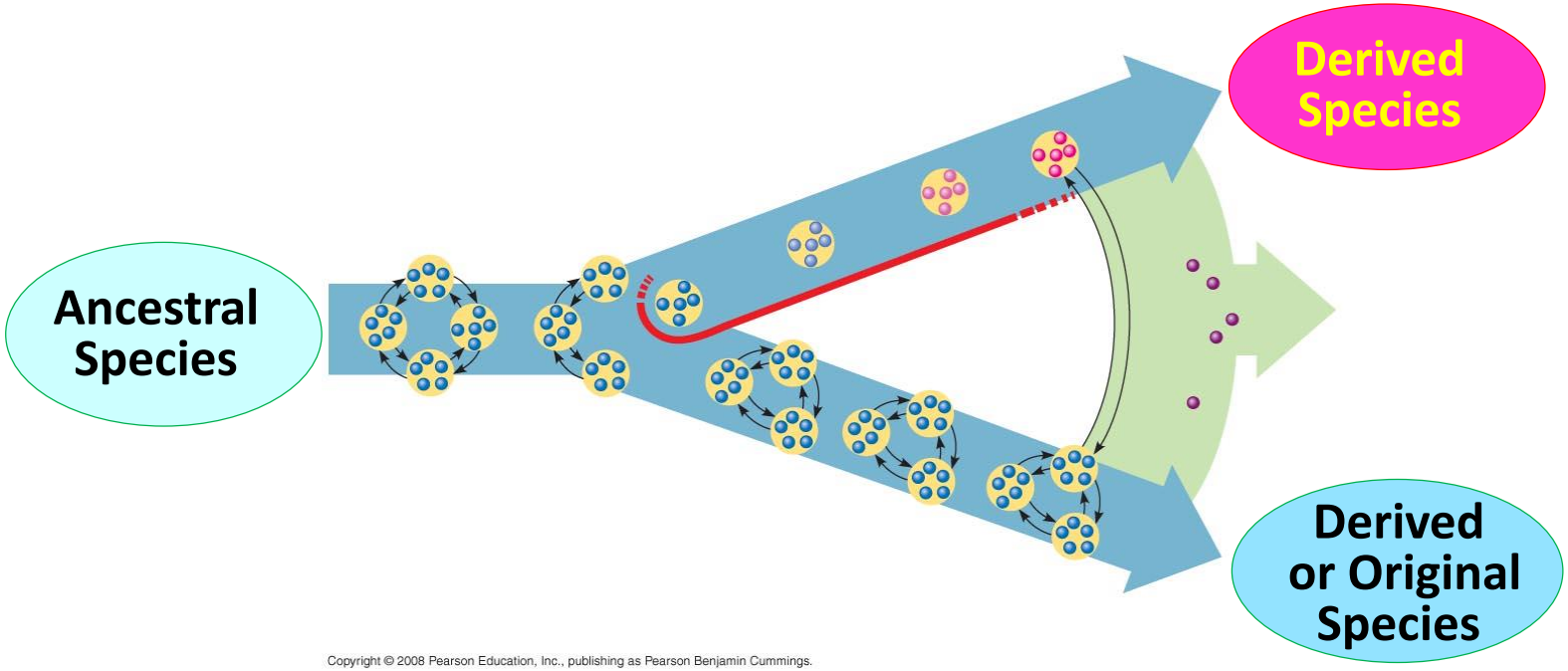


Five Agents of Microevolution



Modes of Speciation/物种形成的方式

By the consequence of speciation

根据物种形成的结果

- Cladogenic speciation (Cladogenesis) /分枝式的物种形成
- Phyletic speciation (Anagenesis) /线系式的物种形成

By the process and tempo of speciation

根据物种形成的过程和速度

- Gradual speciation/渐进式（连续式）的物种形成
- Quantum speciation/量子式（爆发式）的物种形成

By the spatial pattern of speciation

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- Allopatric speciation/异域的物种形成
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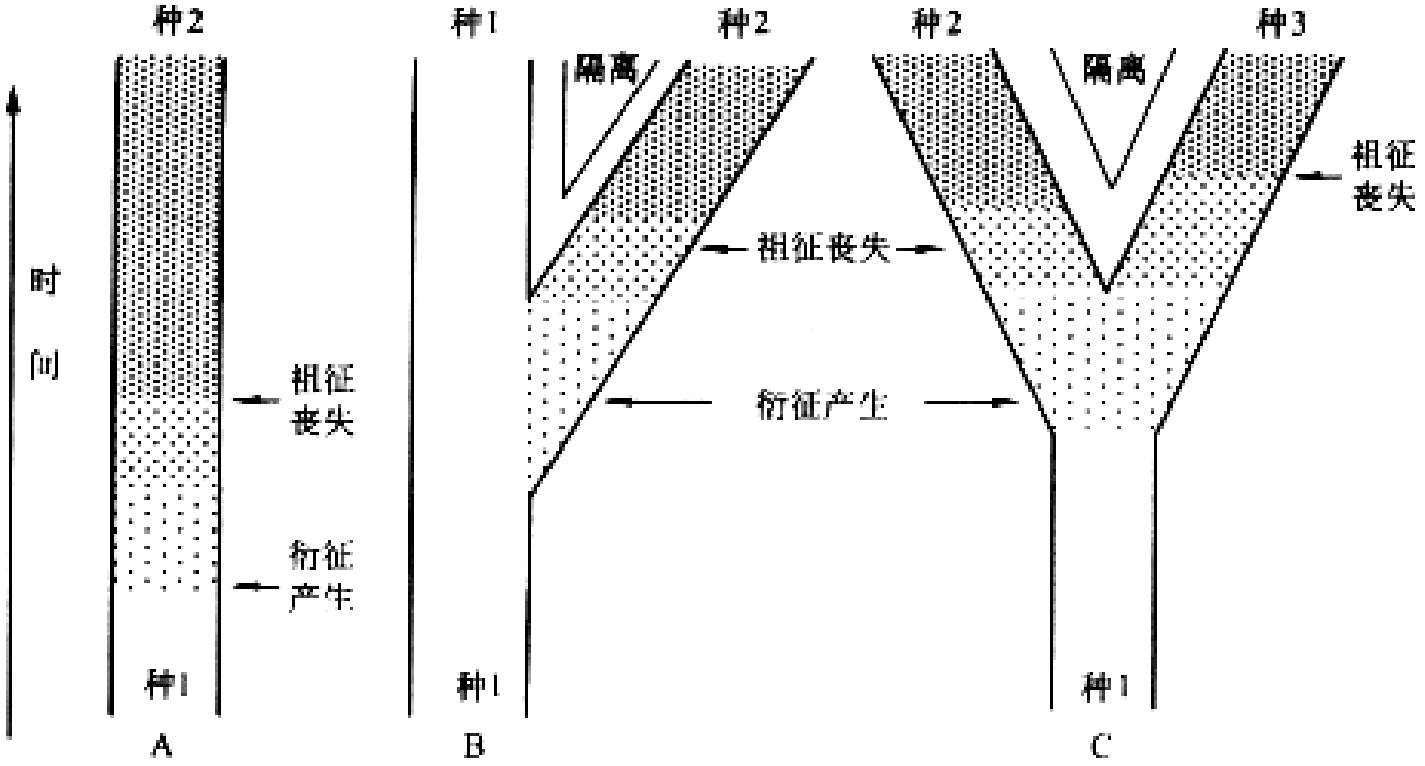
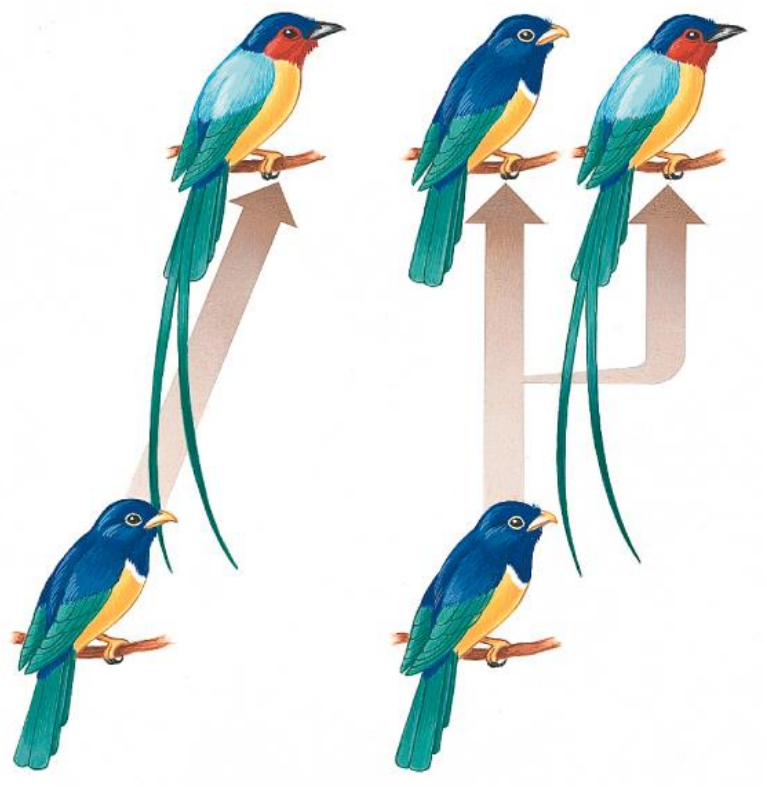
Phyletic/Anagentic and Cladogenetic Speciation

线系式和分枝式物种形成



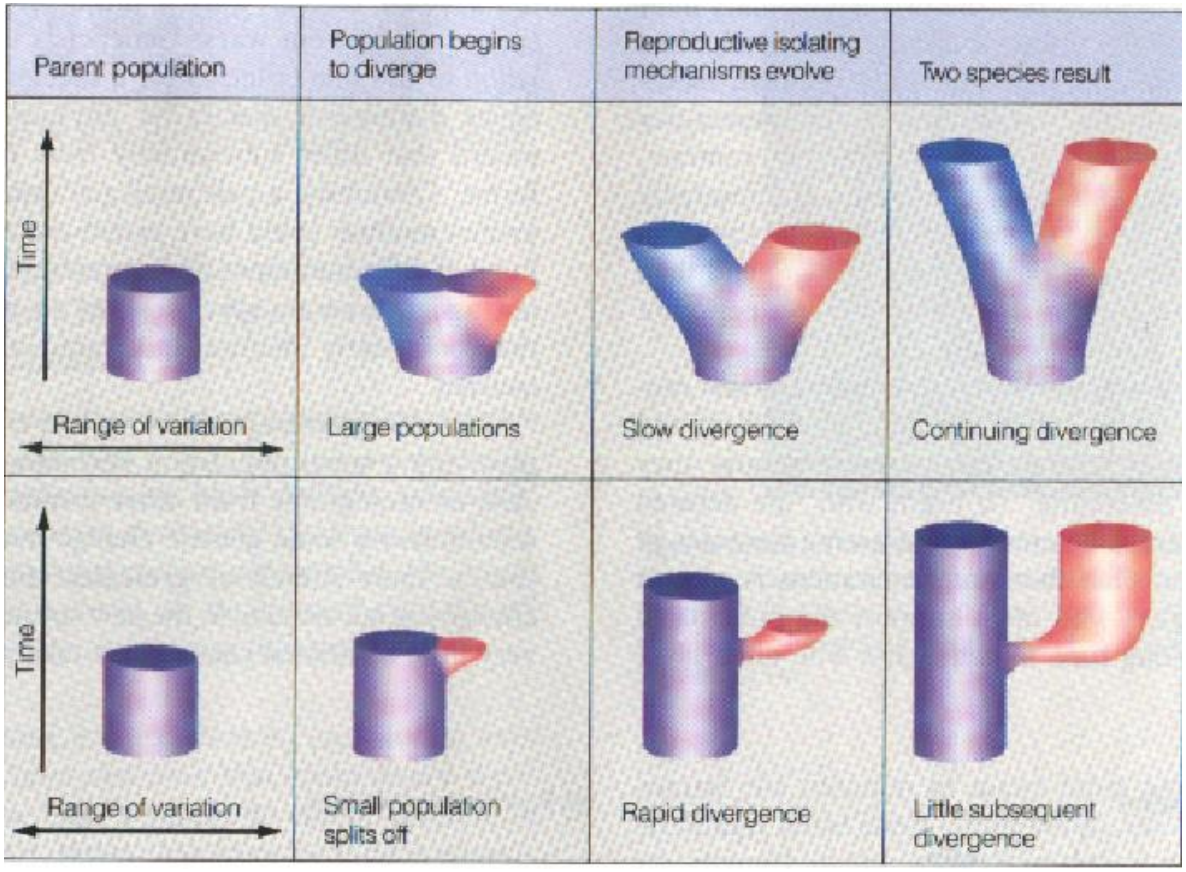
Anagenesis and cladogenesis

- Anagenesis: modification of a lineage over time (microevolution on a longer time scale)
- Cladogenesis: splitting of a lineage into two distinct lineages or clades



(a) Anagenesis (b) Cladogenesis

Cladogenetic Speciation
分枝式的物种形成



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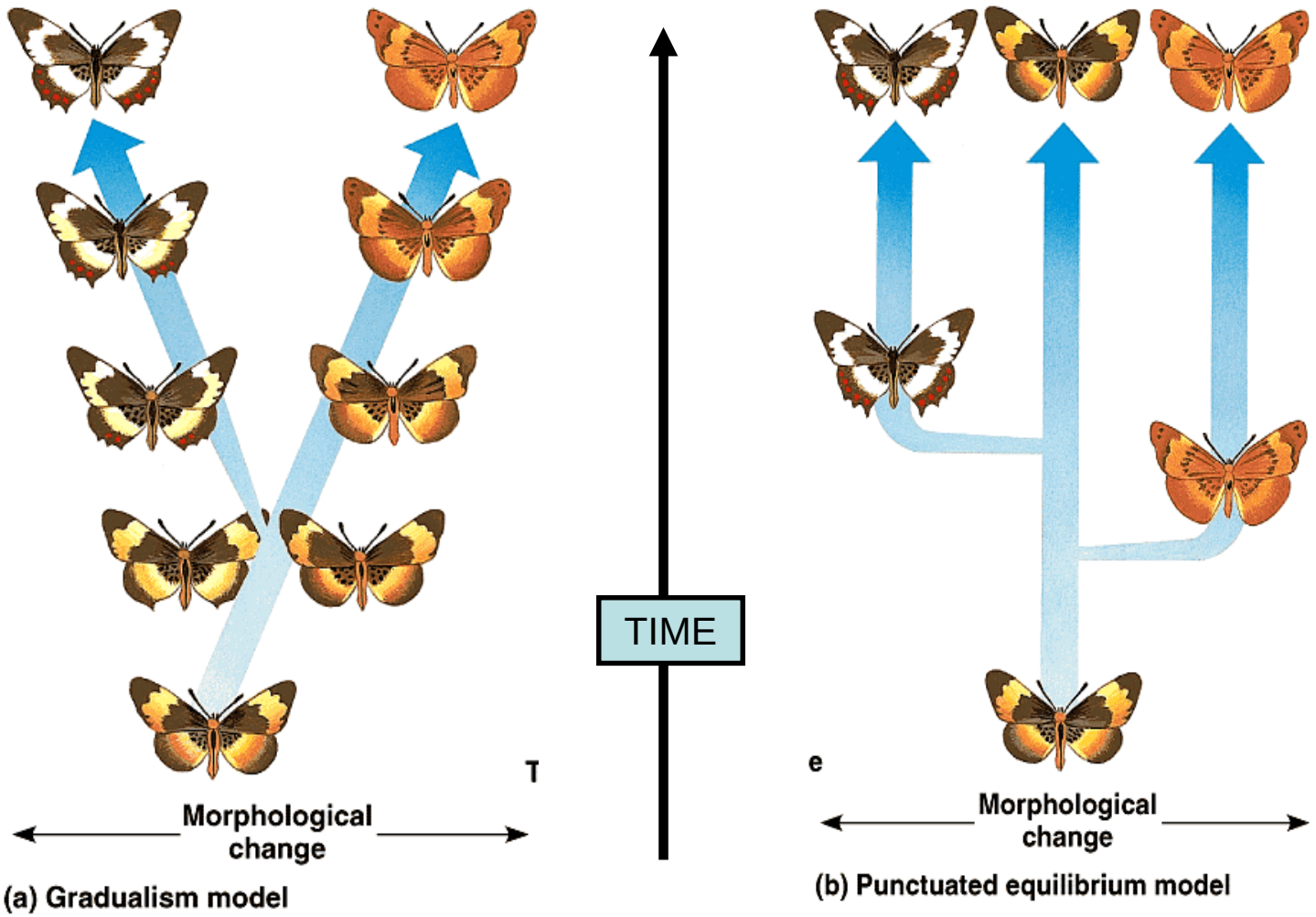
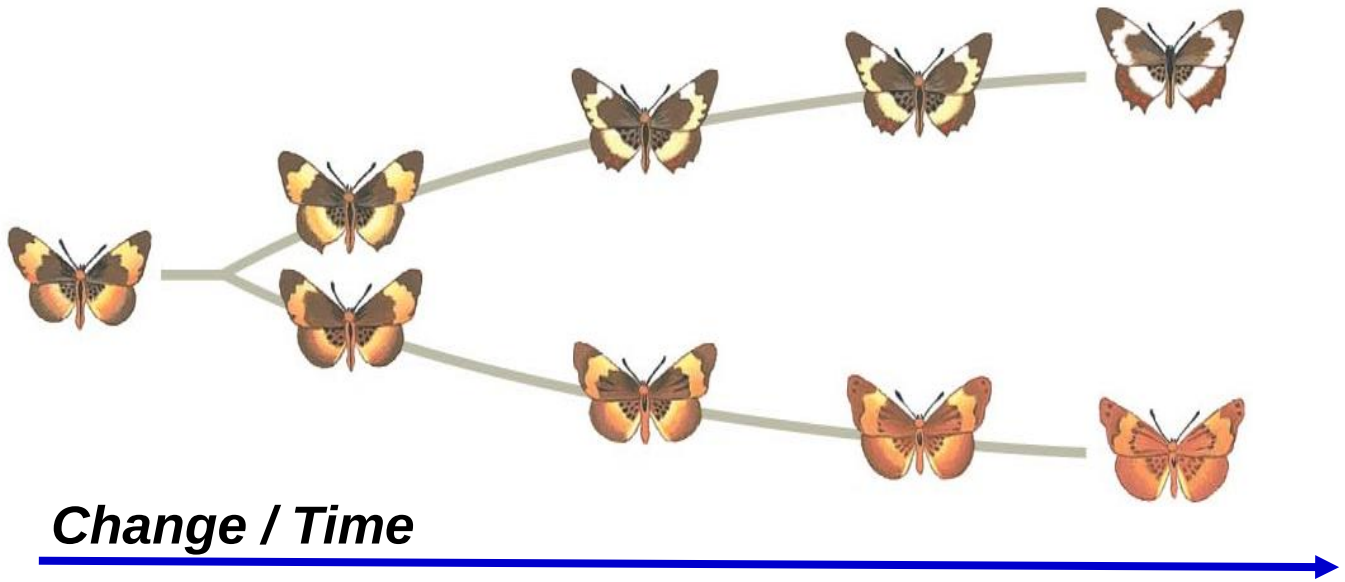
The Tempo of Speciation

- **Gradualism Model**
  - Gradual speciation
- **Punctuated Equilibrium Model**
  - Quantum speciation /punctual speciation


TIME
T
Morphological change
(a) Gradualism model
e
Morphological change
(b) Punctuated equilibrium model

Gradual Speciation may be viewed as a Three-Step Process

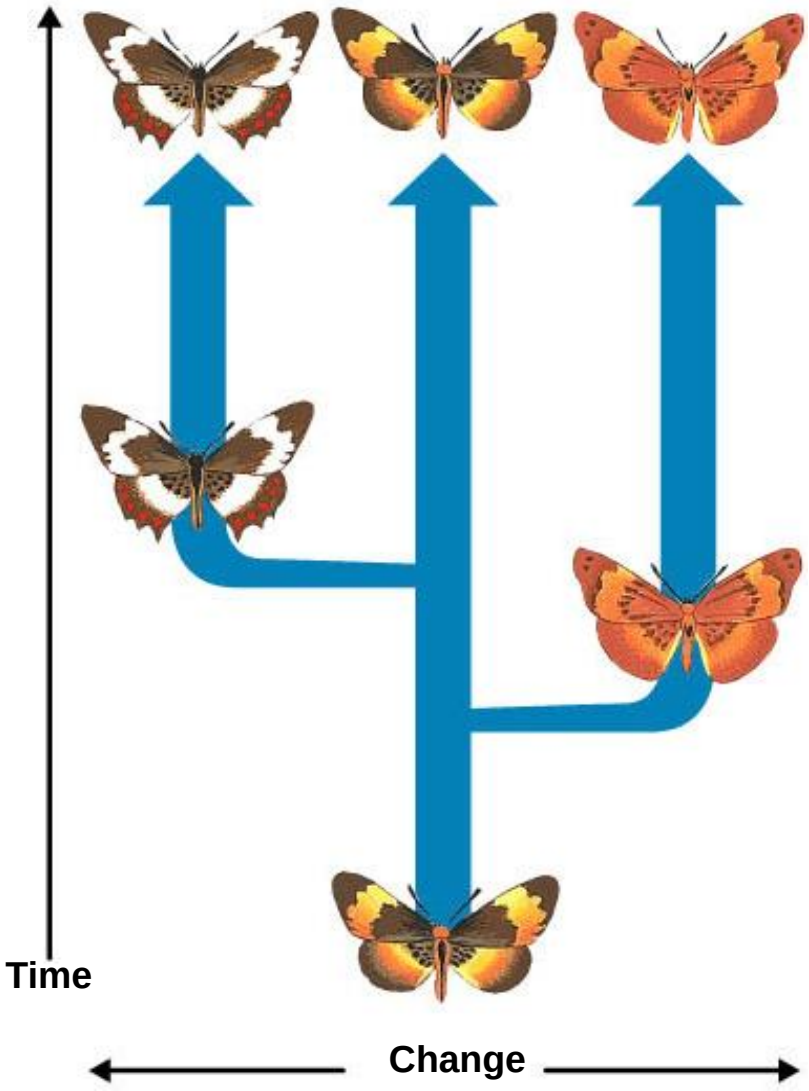


1. Population isolation
2. Divergence of phenotypes and genotypes
3. Reproductive isolation

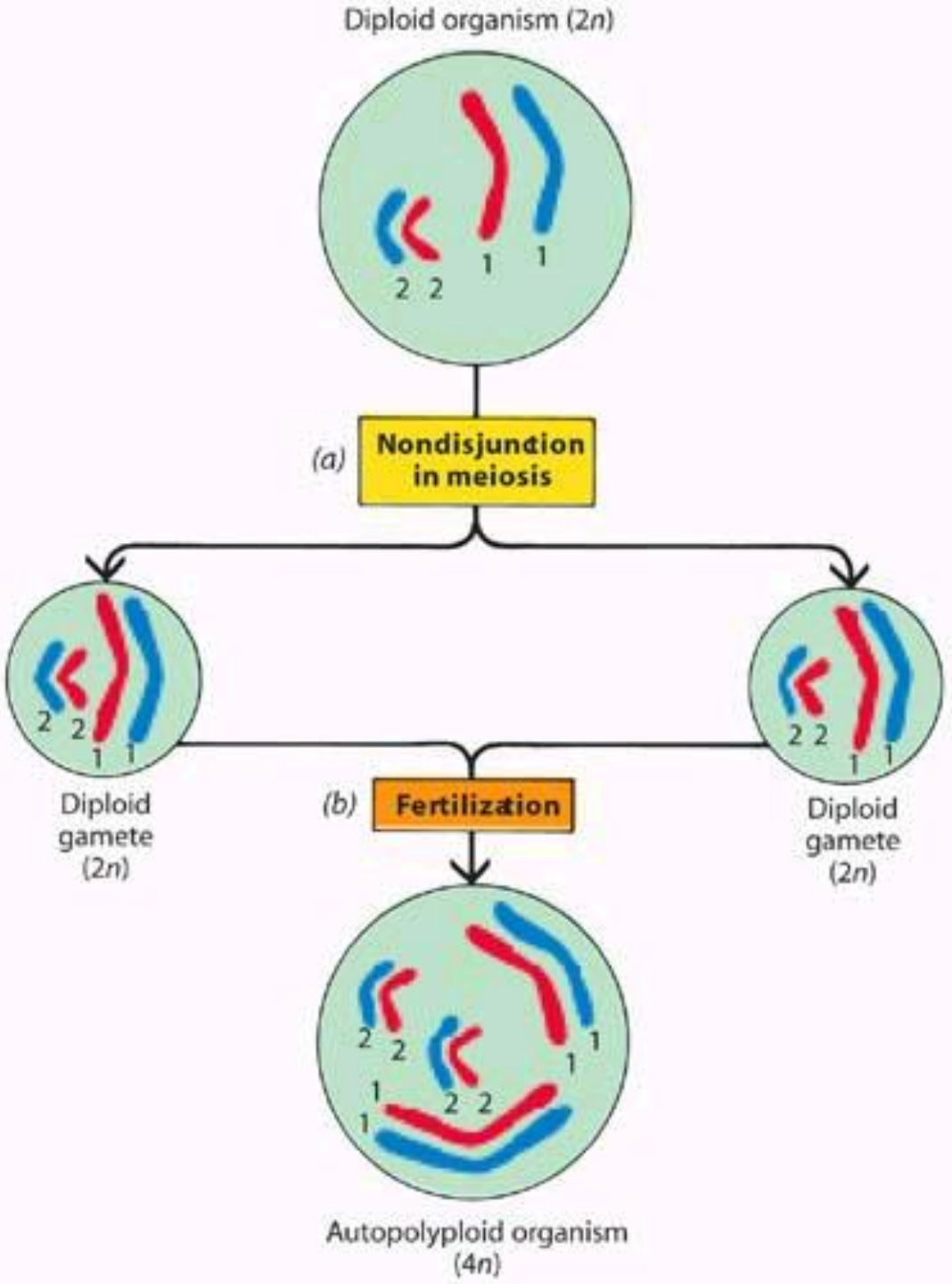
Punctuated Equilibrium

- **Niles Eldredge & Stephen Jay Gould (1972)** coined the term punctuated equilibria to describe periods of apparent stasis punctuated by sudden change
- Is a **contrasting model** of gradual evolution
- States that species most often **diverge in spurts** of relatively rapid change
- Accounts for the relative **rarity of transitional fossils**

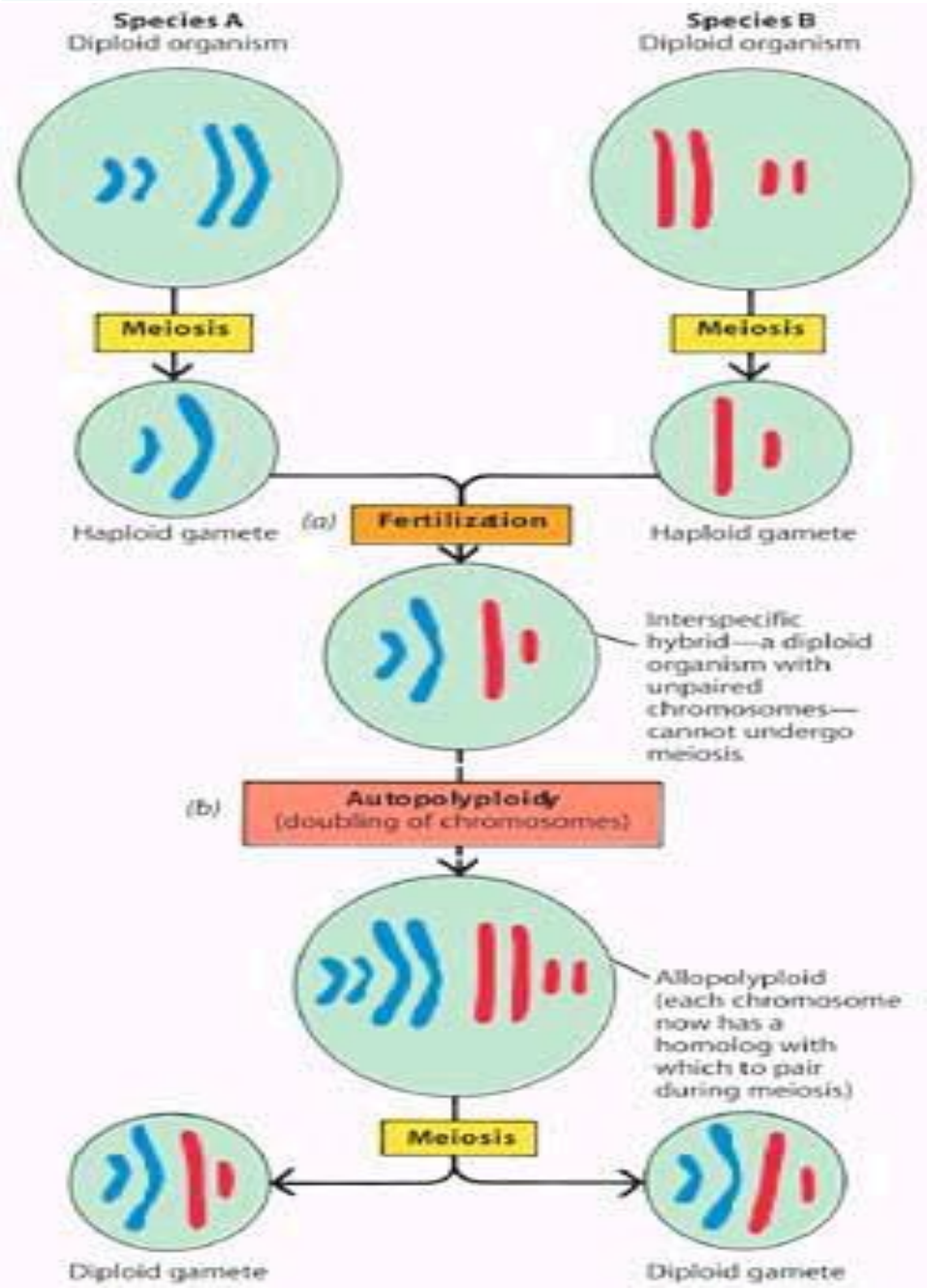
(b) Punctuated equilibrium model



量子式的物种形成——同源多倍化

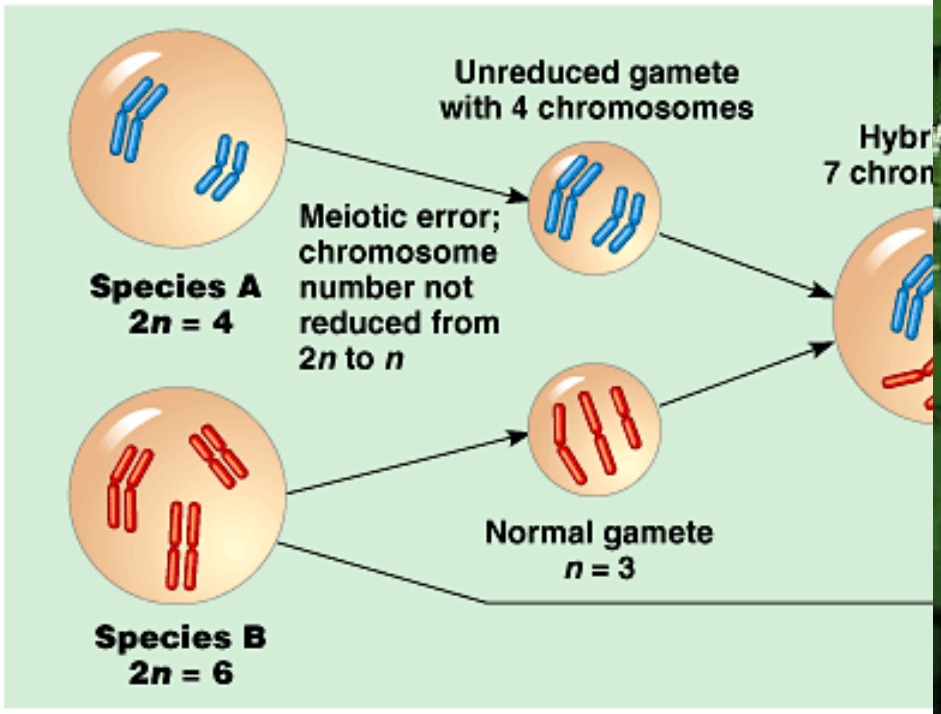


量子式的物种形成——杂交多倍化



Allopolyploidy
异源多倍化

Multiple-hybridization + Polyploidy



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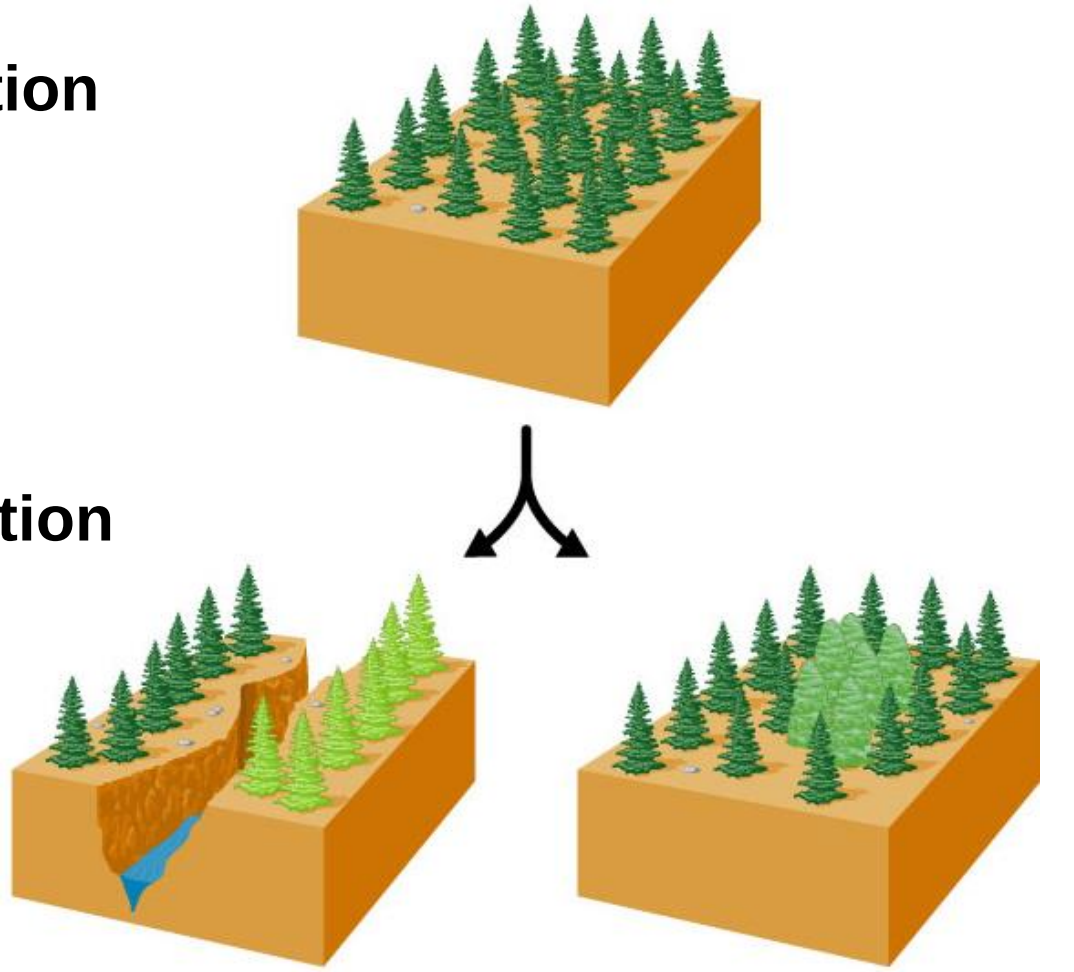
The Two Modes of Speciation

– **Allopatric speciation**

异域物种形成

– **Sympatric speciation**

同域物种形成

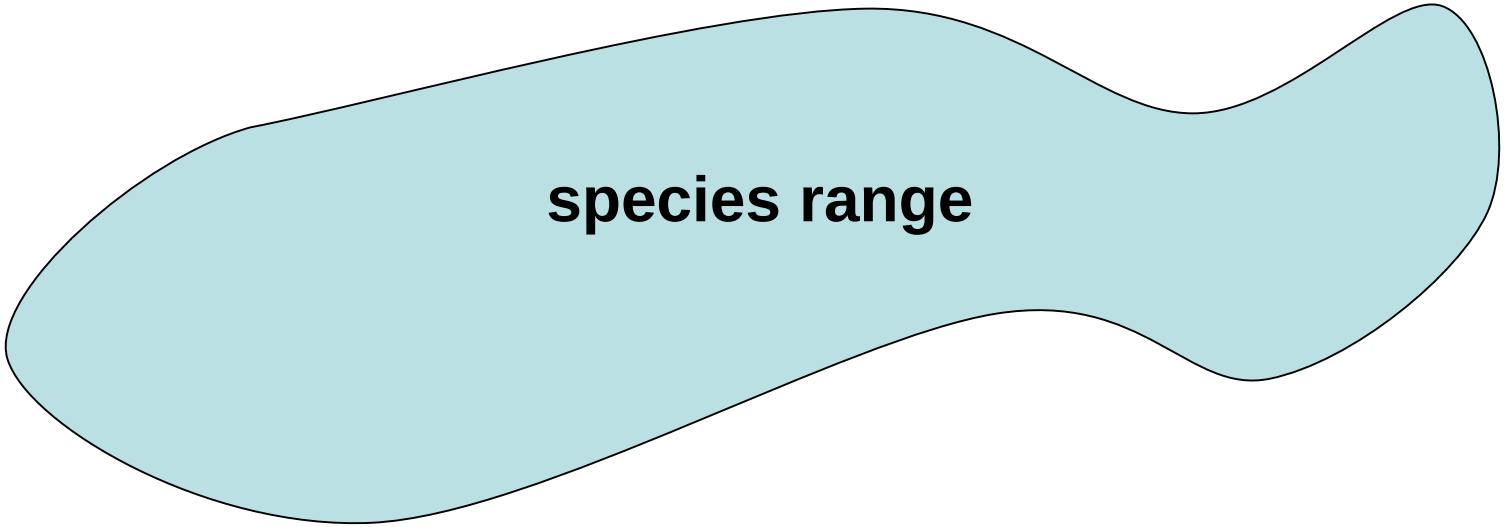


(a) Allopatric speciation (b) Sympatric speciation

Allopatric Speciation

Original hypothesis for how speciation occurs in allopatric populations

Three steps: 1) **isolation**
2) **divergence**
3) **reproductive isolation**



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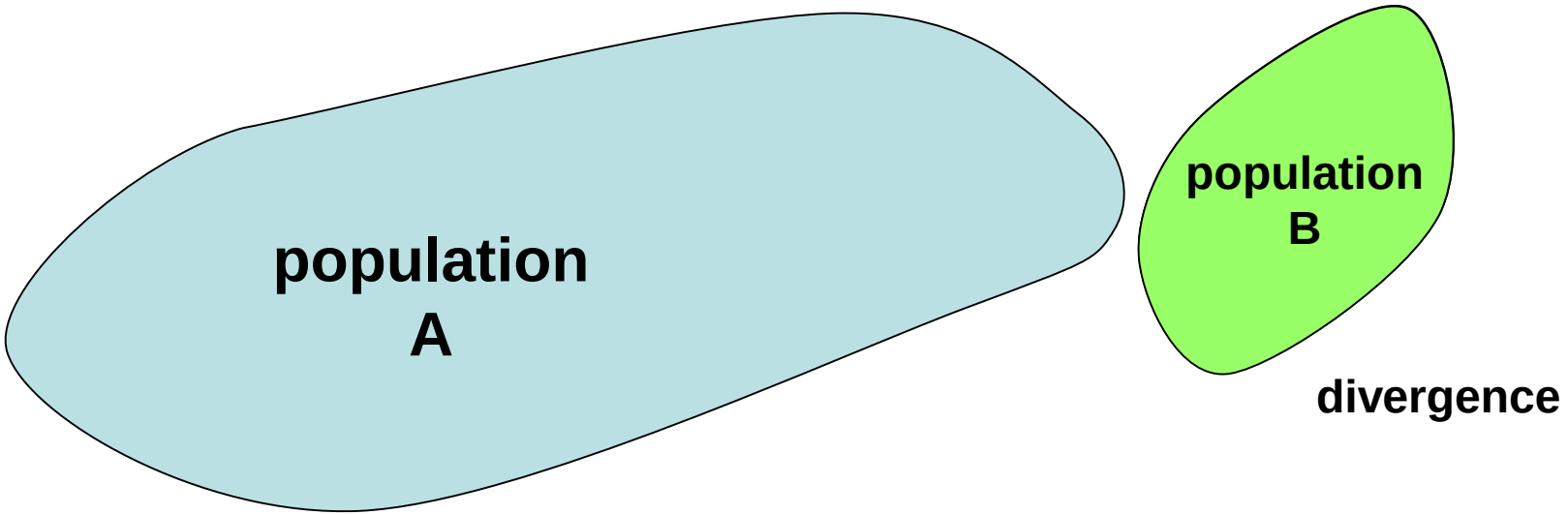
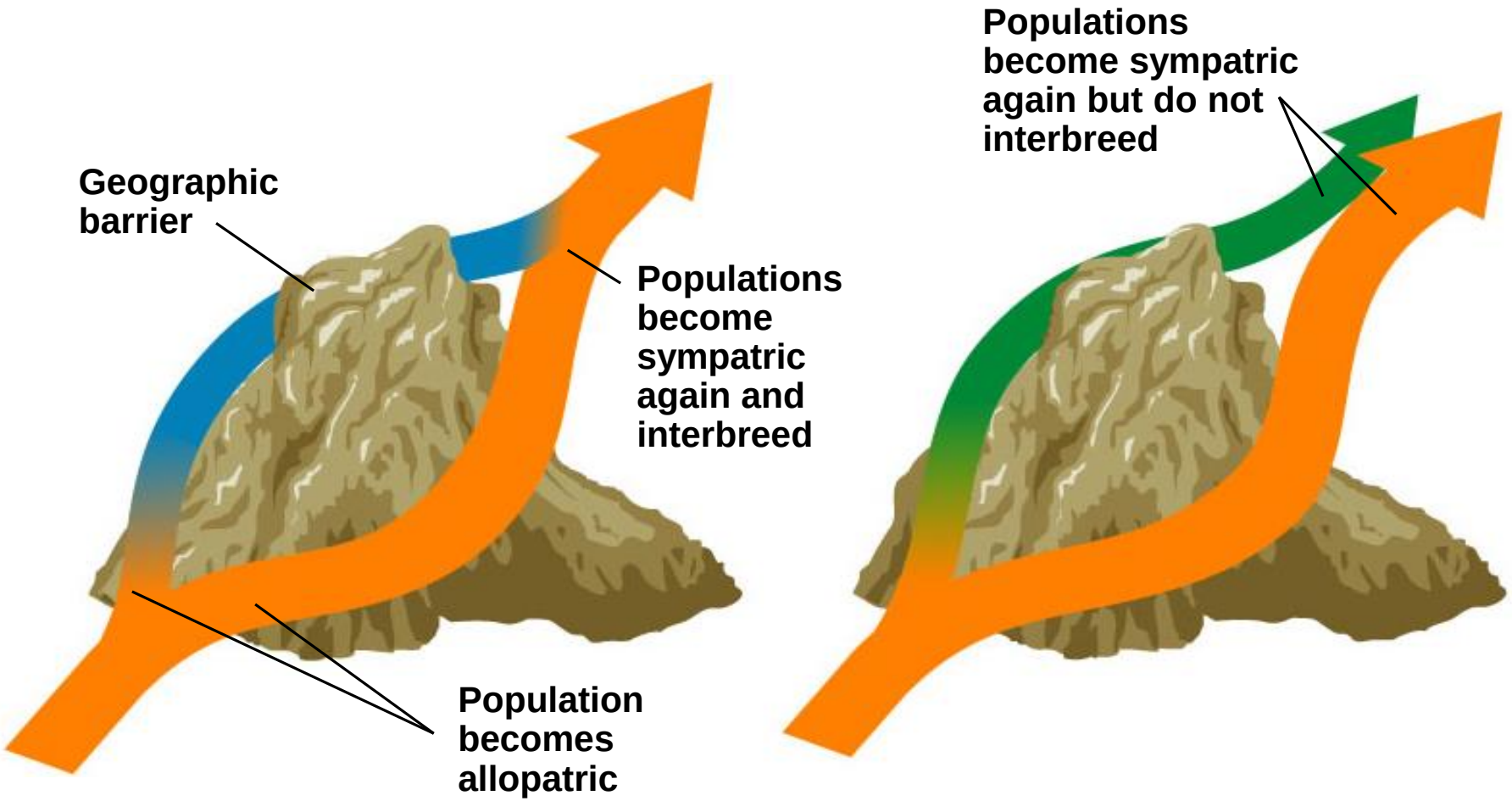


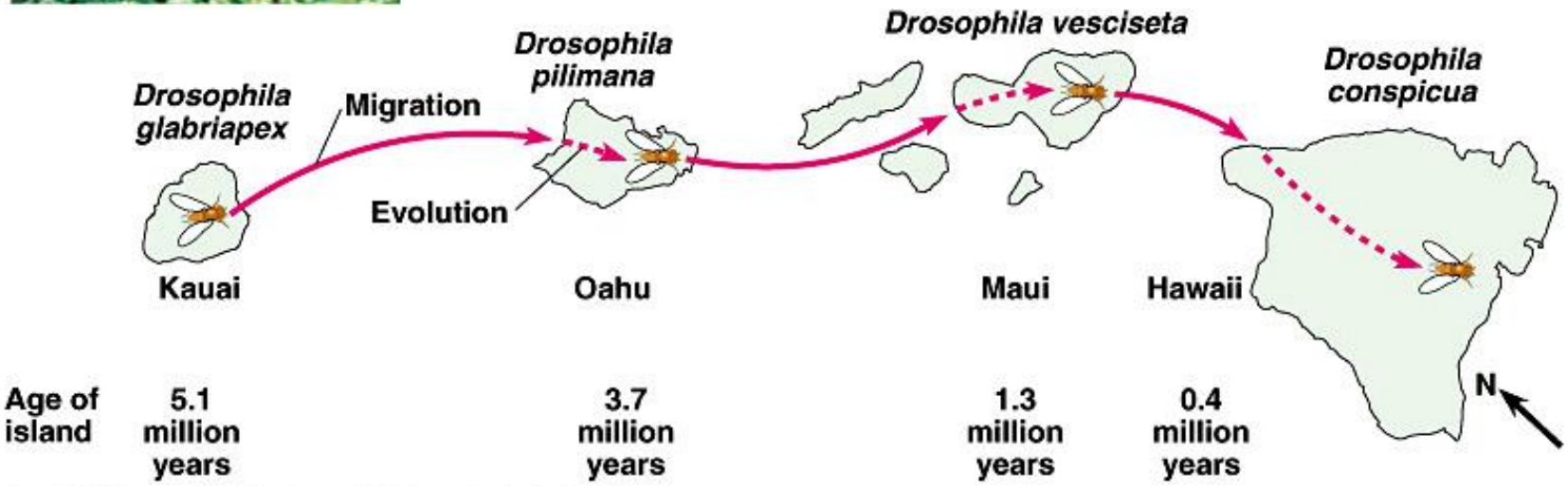


(a) Speciation has not occurred

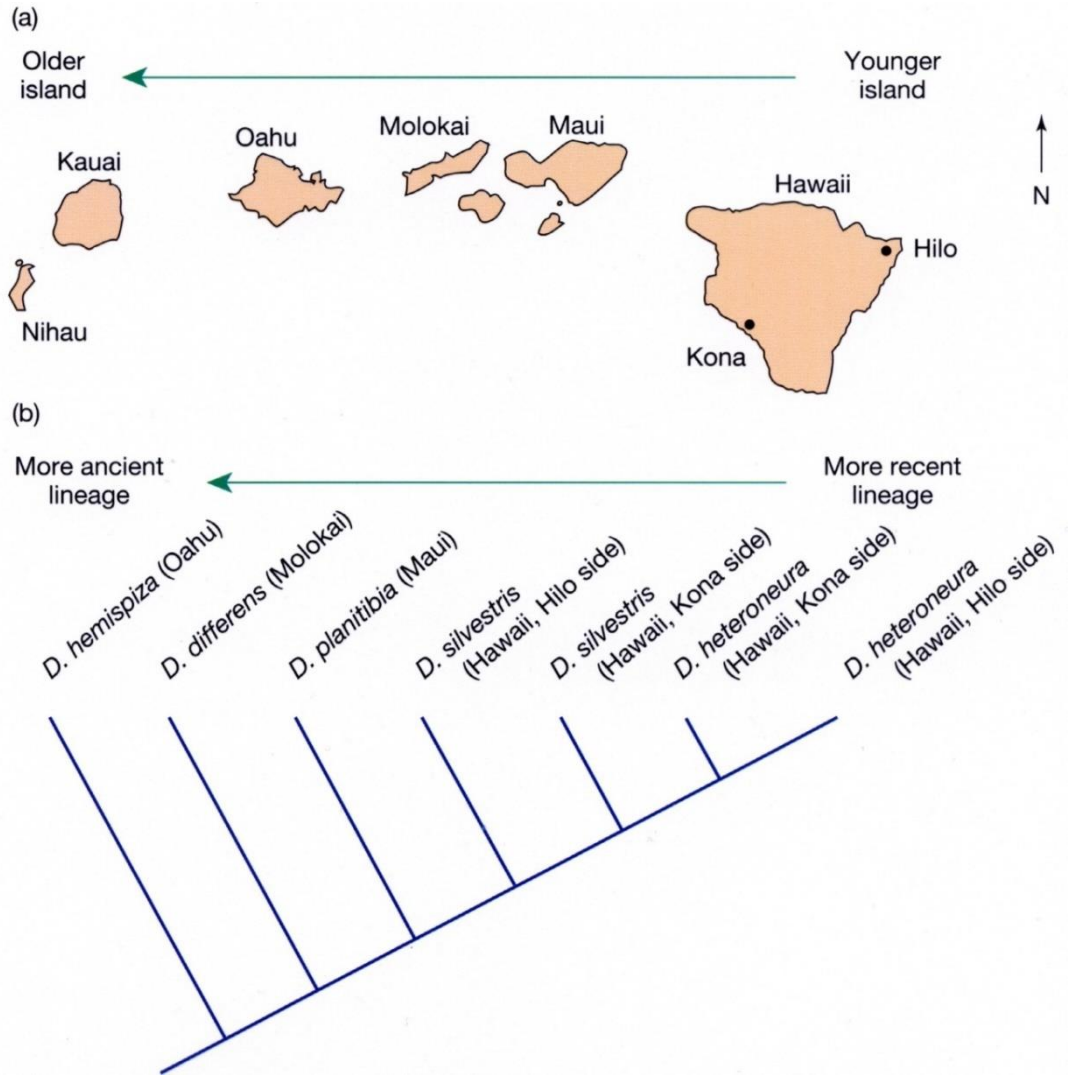
(b) Speciation has occurred

Allopatric Speciation —— Founder Effect

Fruit flies

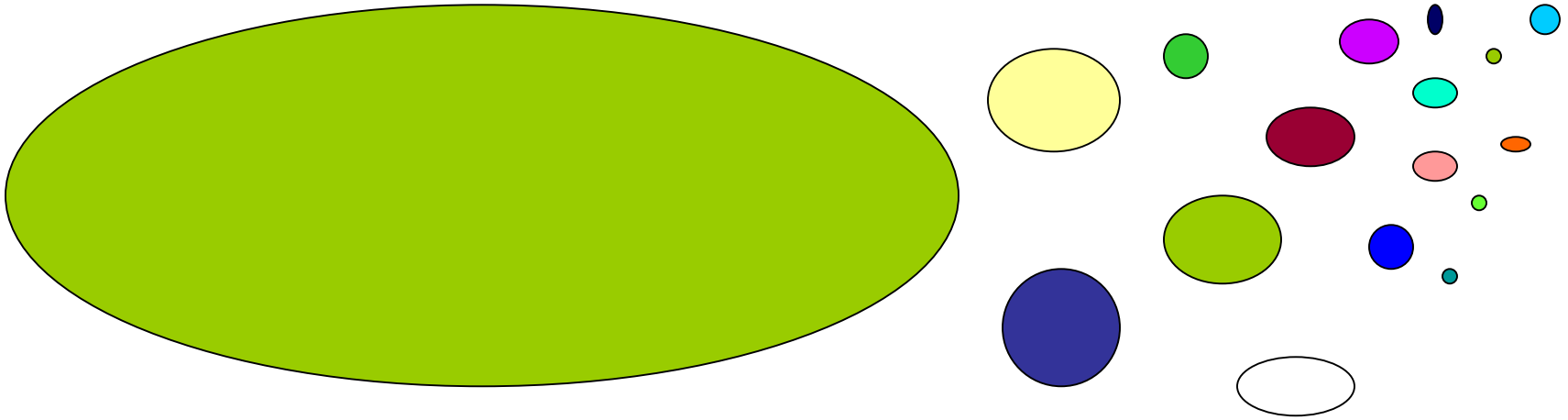


Evidence for Speciation by Dispersal and Colonization



If Small, Isolated Populations Persist

- Rapid evolution because of genetic drift and local adaptation
- If there is little immigration from other populations, the potential for speciation is high, if the population doesn't go extinct first (most do go extinct)



Allopatric Speciation

Factors driving allopatric speciation:

- Small populations (↑ drift)
- Environmental differences (divergent selection)
- Specialized requirements (more isolation)
- Different mutation rates among isolated populations
- more time

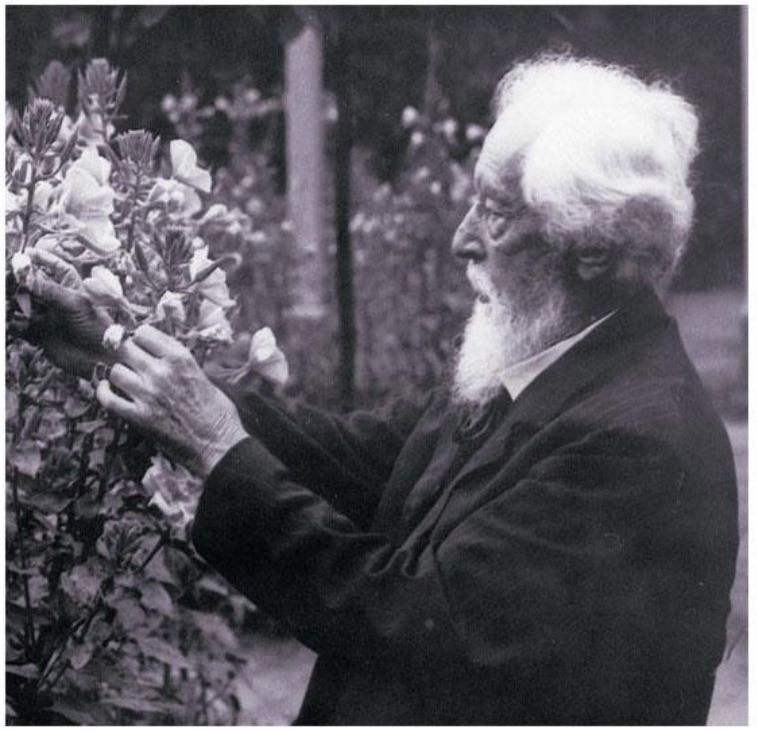
Sympatric Speciation

Sympatric speciation occurs if a genetic change produces a reproductive barrier between mutants and the parent population

– Polyploidy, a mechanism of sympatric speciation, was first observed by Hugo de Vries

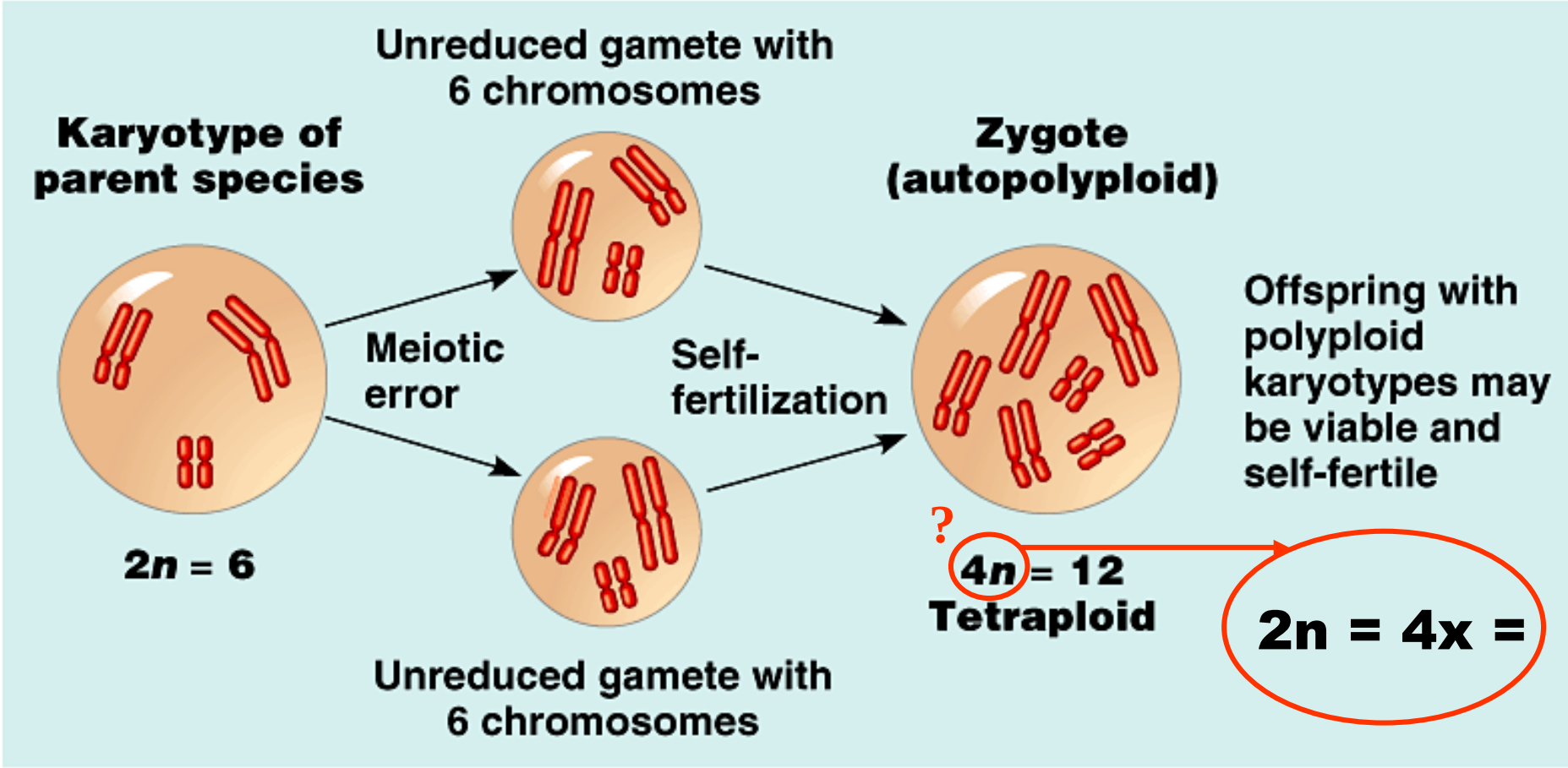
O. lamarckiana

O. gigas



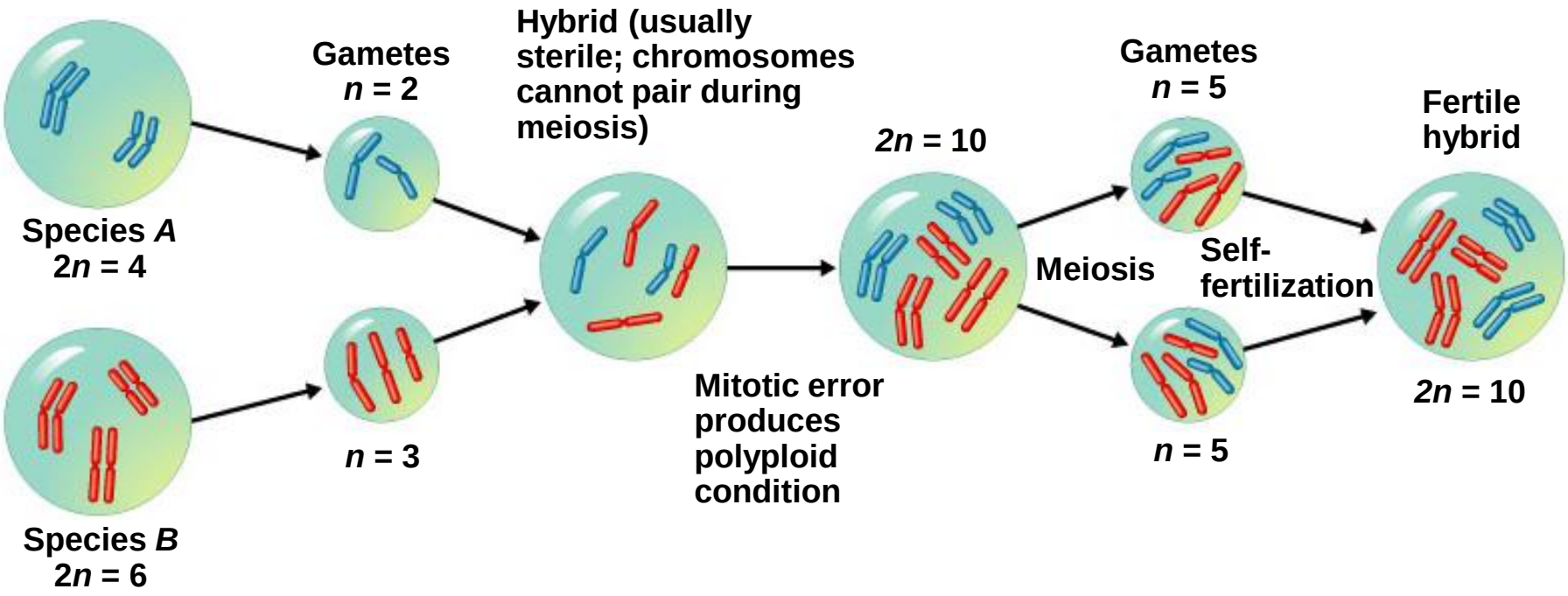
Sympatric Speciation

Polyploidy in plants —— *autopolyploids*



Sympatric Speciation

Polyploidy in plants —— *allopolyploids*



Many domesticated plants are the result of sympatric speciation

- ***Ancestral species***

AA

Triticum monococcum **(2*n* = 14)**

BB

Wild *Triticum* **(2*n* = 14)**

DD

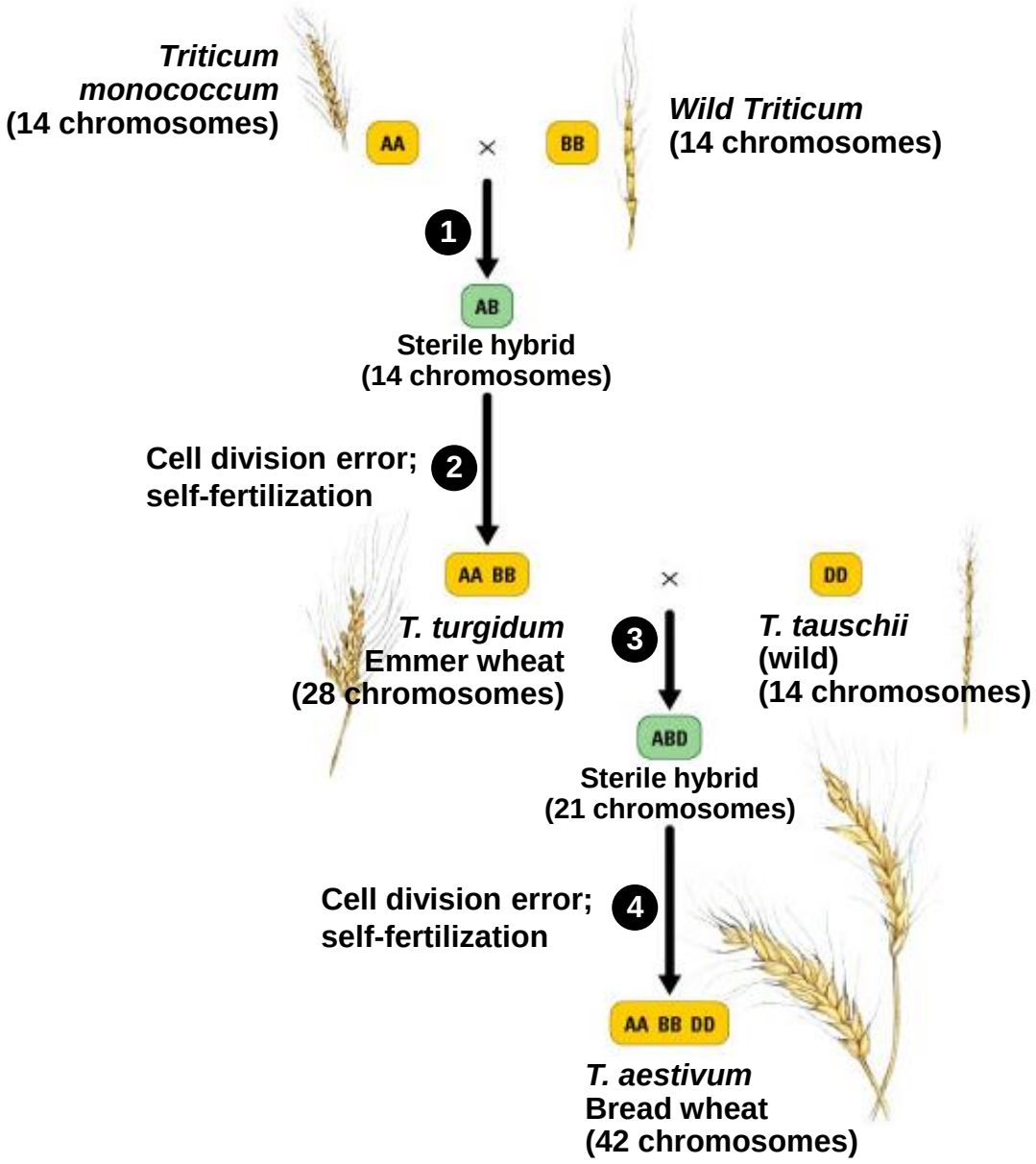
Wild *T. tauschii* **(2*n* = 14)**

- ***Derived domesticated species***

AA BB DD

T. aestivum **(bread wheat)** **(2*n* = 42)**

Many domesticated plants are the result of sympatric speciation



六倍体的普通小麦是一个天然的杂交物种

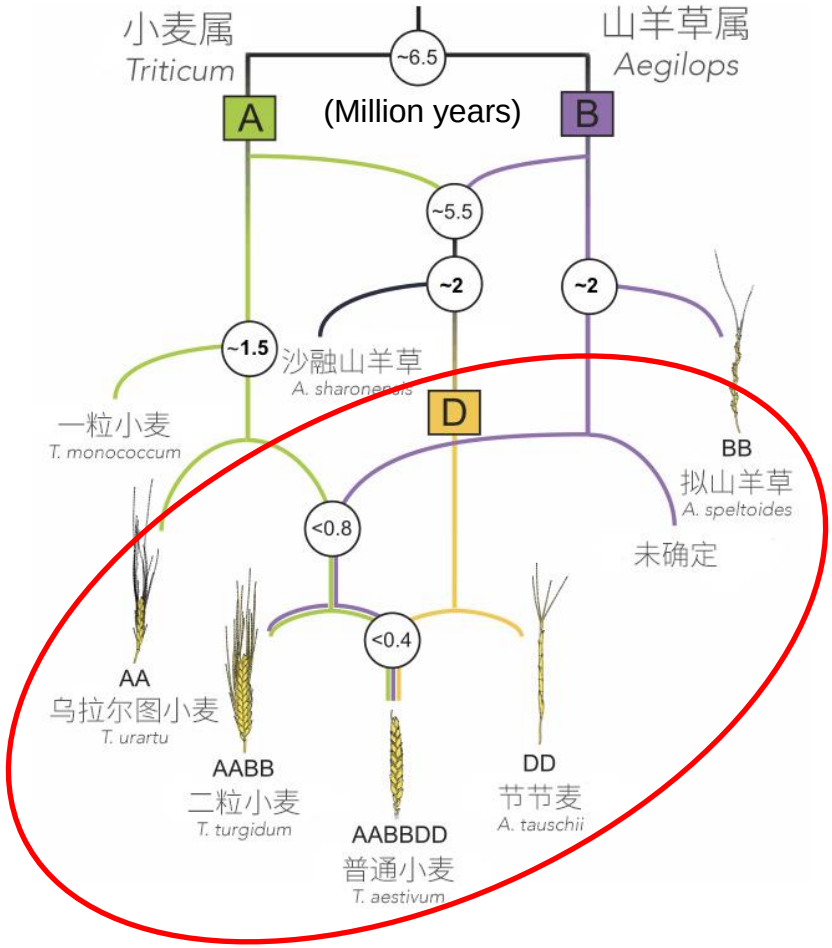
乌拉图小麦 X 拟斯卑尔脱山羊草

↓

二粒小麦 X 节节麦

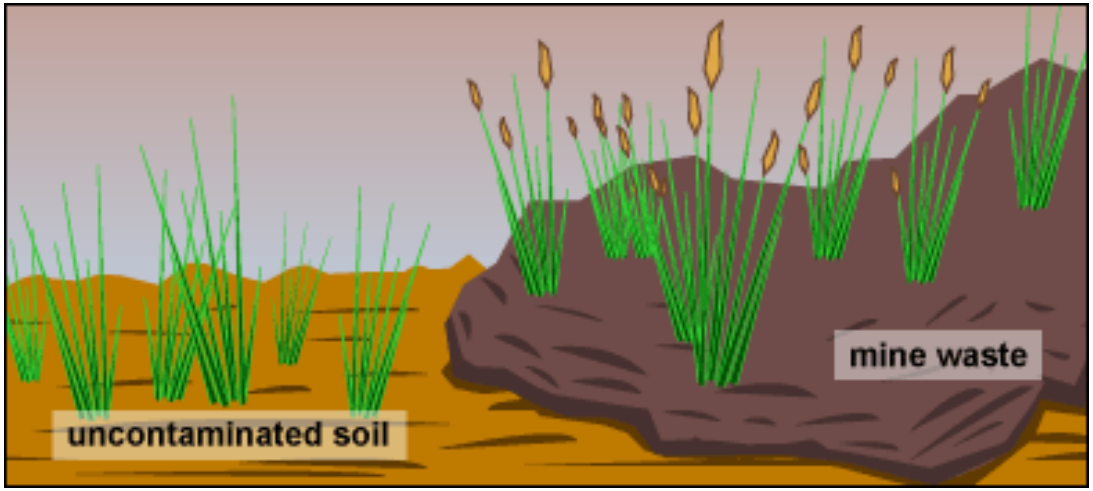
↓

普通小麦



Marcussen et al. *Science*, 2014.

Parapatric Speciation/邻域物种形成



- Continuously distributed
- Environmental differences (disruptive selection)→ unequal gene flow (nonrandom mating) → increase in the dimorphism (phenotypic differences) → reproductive isolation.

Most Basic & Debated Question

☞ ***Is speciation an adaptive process?"***

- **No, not surely!**
- **No doubt different species occupy different niches and have different coadapted genetic traits. But, this does necessarily mean that speciation is inherently adaptive!**

☞ ***Another viewpoint for speciation:***

- **Speciation is an adaptive process**

Botanical Namenclature

植物的命名法

植物类群的命名必须严格遵循《国际植物命名法规》
International Code of Botanical Nomenclature (ICBN)

- 每一植物类群或物种只有一个合法的拉丁学名（scientific name）
- 植物种的学名采用双名法（binomial system）进行命名
- 优先律原则
- 有效发表和合格发表——一个合法的拉丁学名必须是有效发表和合格发表的。
- 命名模式

Binomial System/双名法

双名法——指在用拉丁文给植物命名时，每一种植物的学名都由两个拉丁词或拉丁化的字构成，第一个词是属名，第二个词是种加词；一个完整的学名还需加上给该种植物命名的命名人。

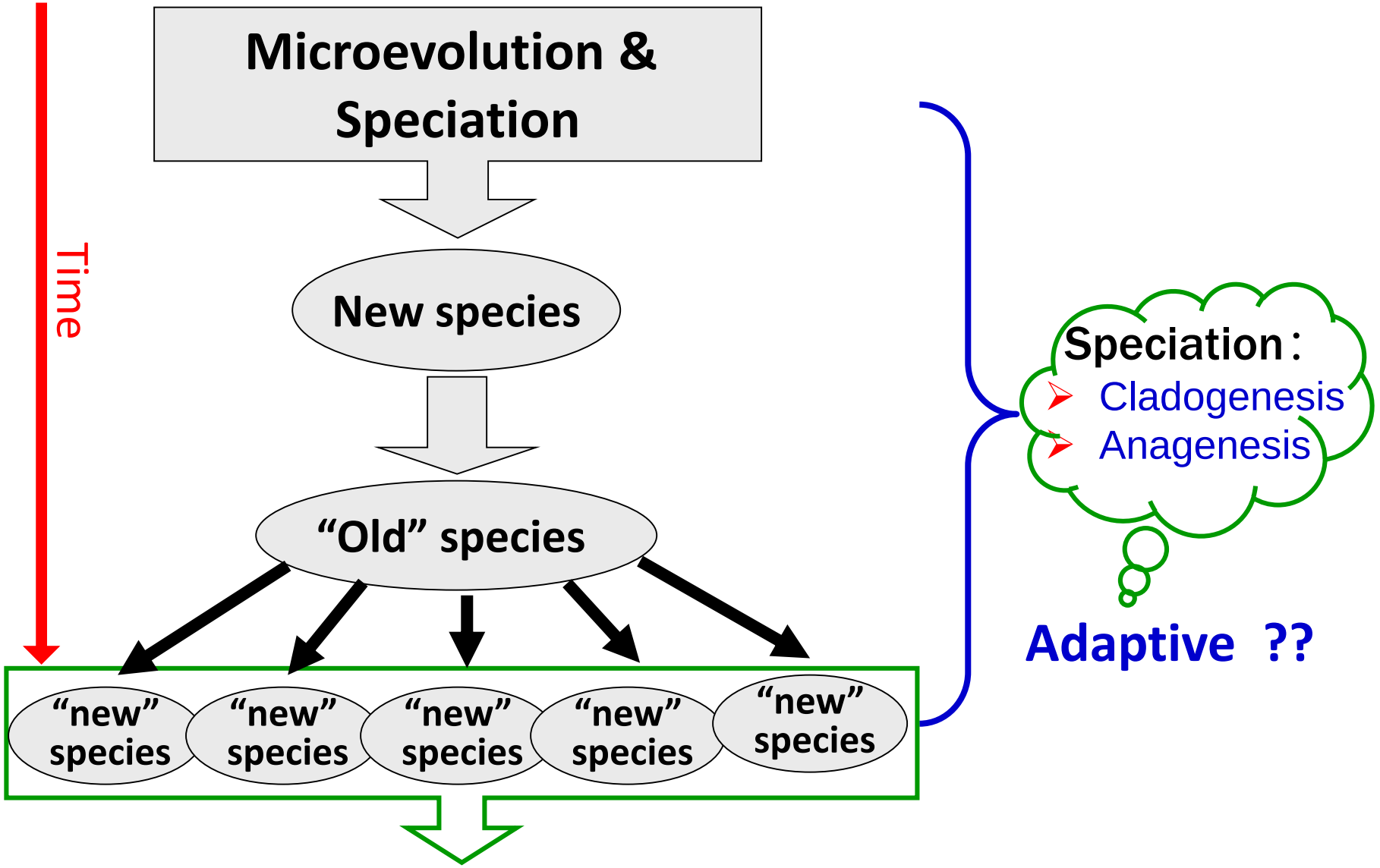
种名/物种学名 = 属名 + 种加词 + 定名人

☞ 植物学名的书写形式：属名的第一字母必须大写，种加词要小写。例如：

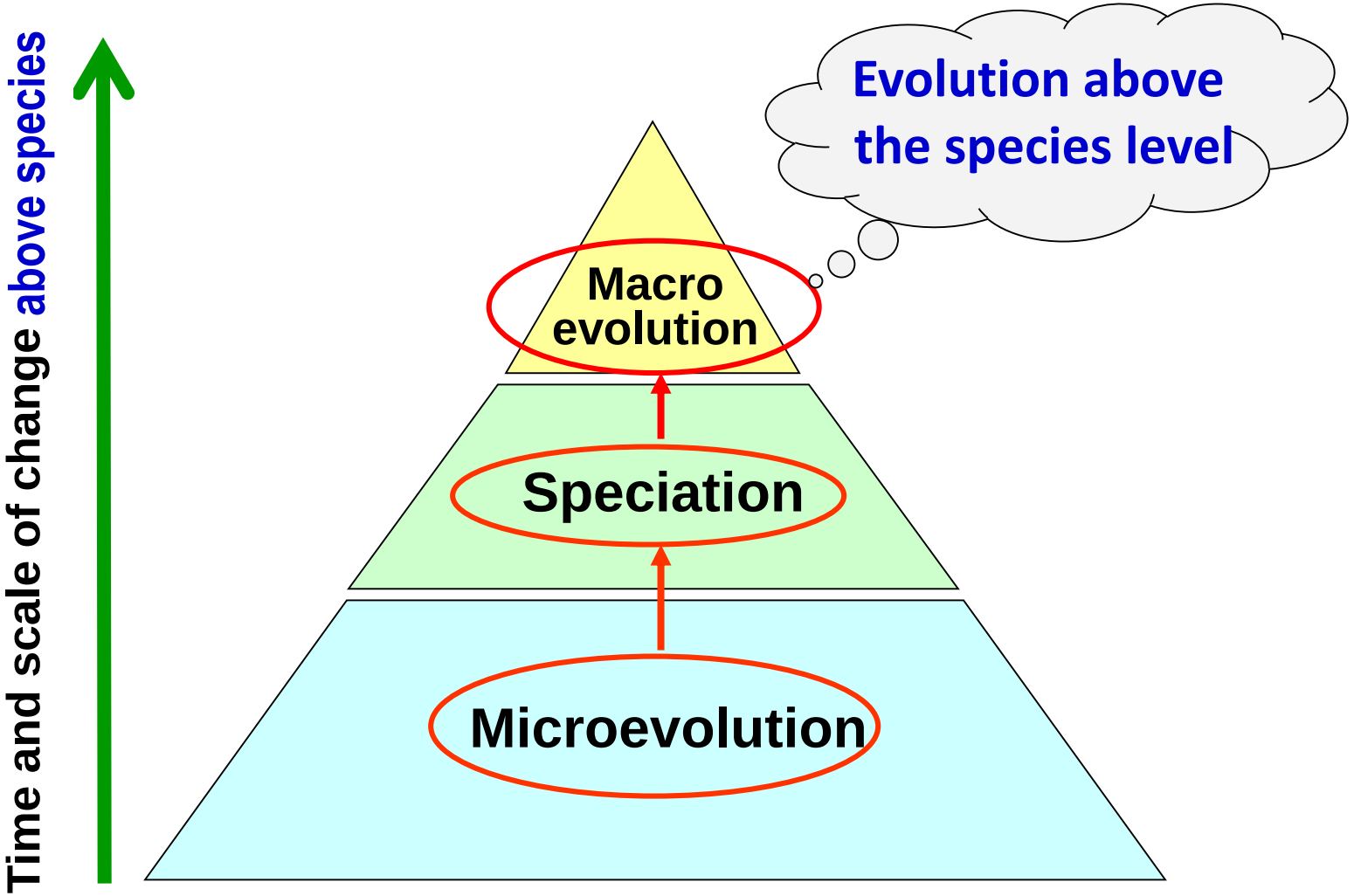
银杏 ***Ginkgo biloba*** L.

小麦 ***Triticum aestivum*** L.

单瓣月季 ***Rosa chinensis*** Jacq. var. ***spontanea*** (Rehd. et Wils.) Yu et Ku


Microevolution & Speciation
Time
New species
"Old" species
"new" species
"new" species
"new" species
"new" species
"new" species
Speciation:
Cladogenesis
Anagenesis
Adaptive ??
Same or different habitats / niches ??

Evolution – change *through time*



Questions and Discussion

1. Why the majority of point mutations are harmless?
2. Define the terms population, species, gene pool, relative fitness, and neutral variation.
3. Why natural selection is the only mechanism that consistently produces adaptive change?
4. Explain the role of population size in evolution.
5. List four reasons why natural selection cannot produce perfect organisms.