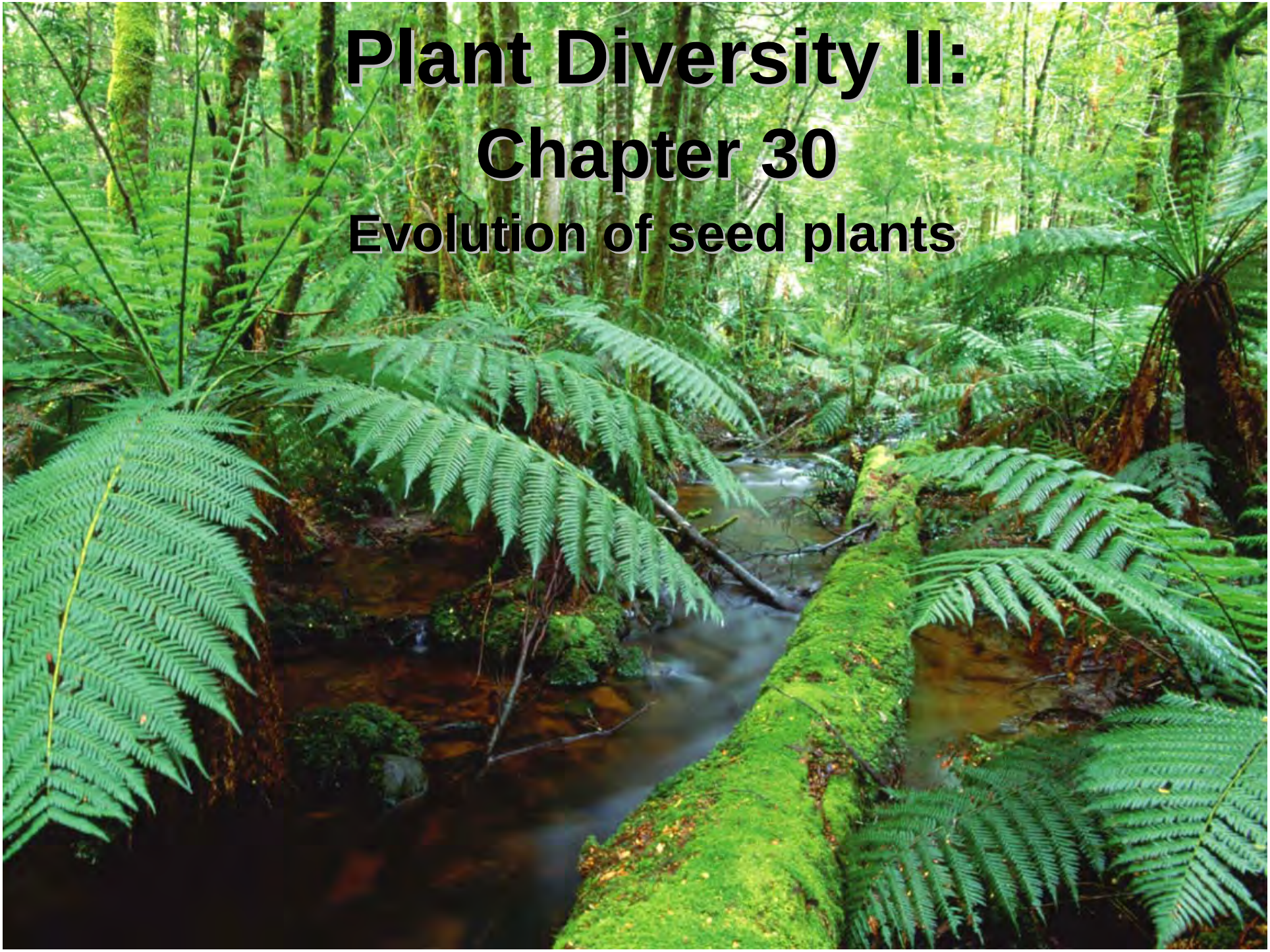
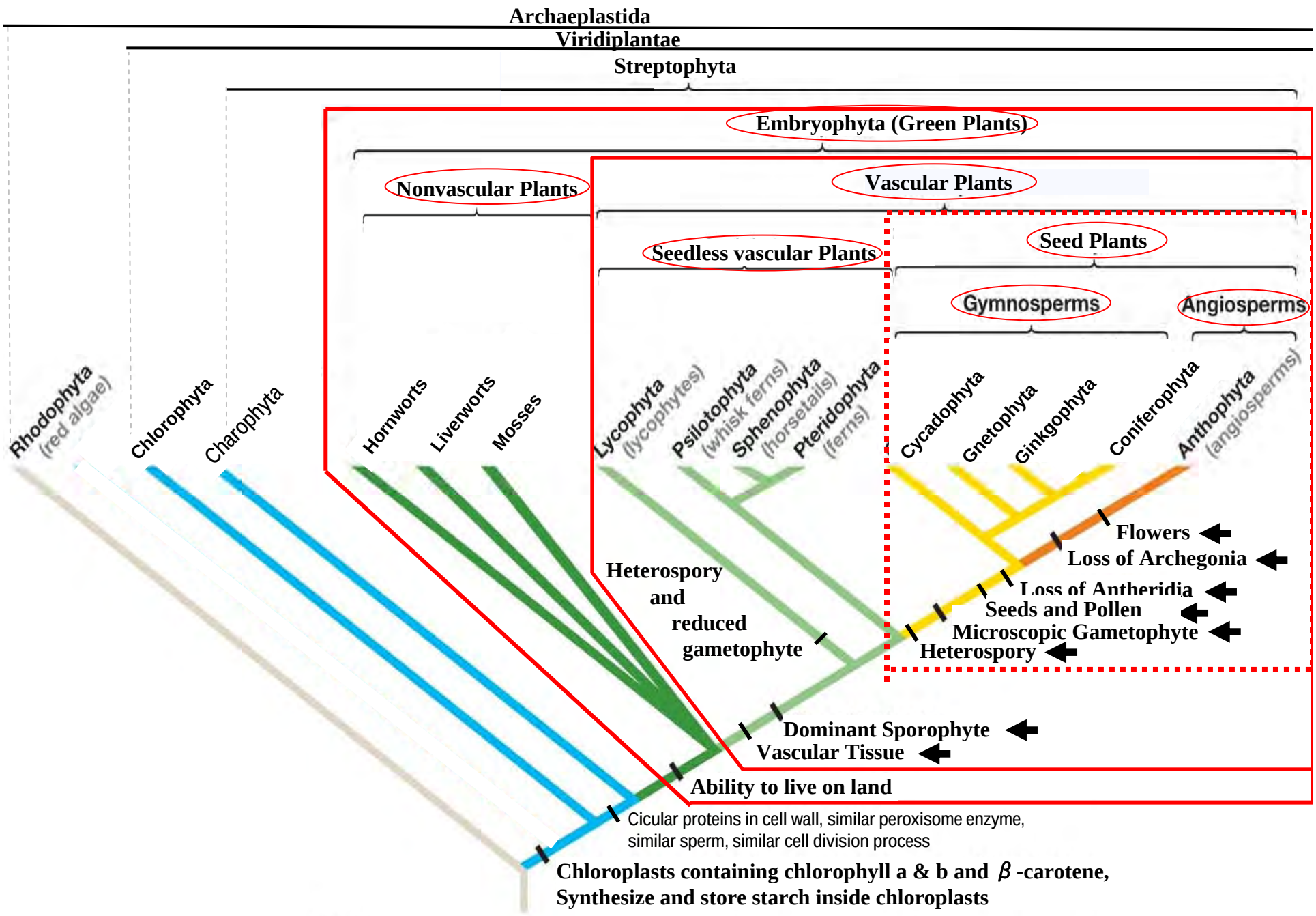


Plant Diversity II: Chapter 30

Evolution of seed plants

Evolution of SEED Plants



3

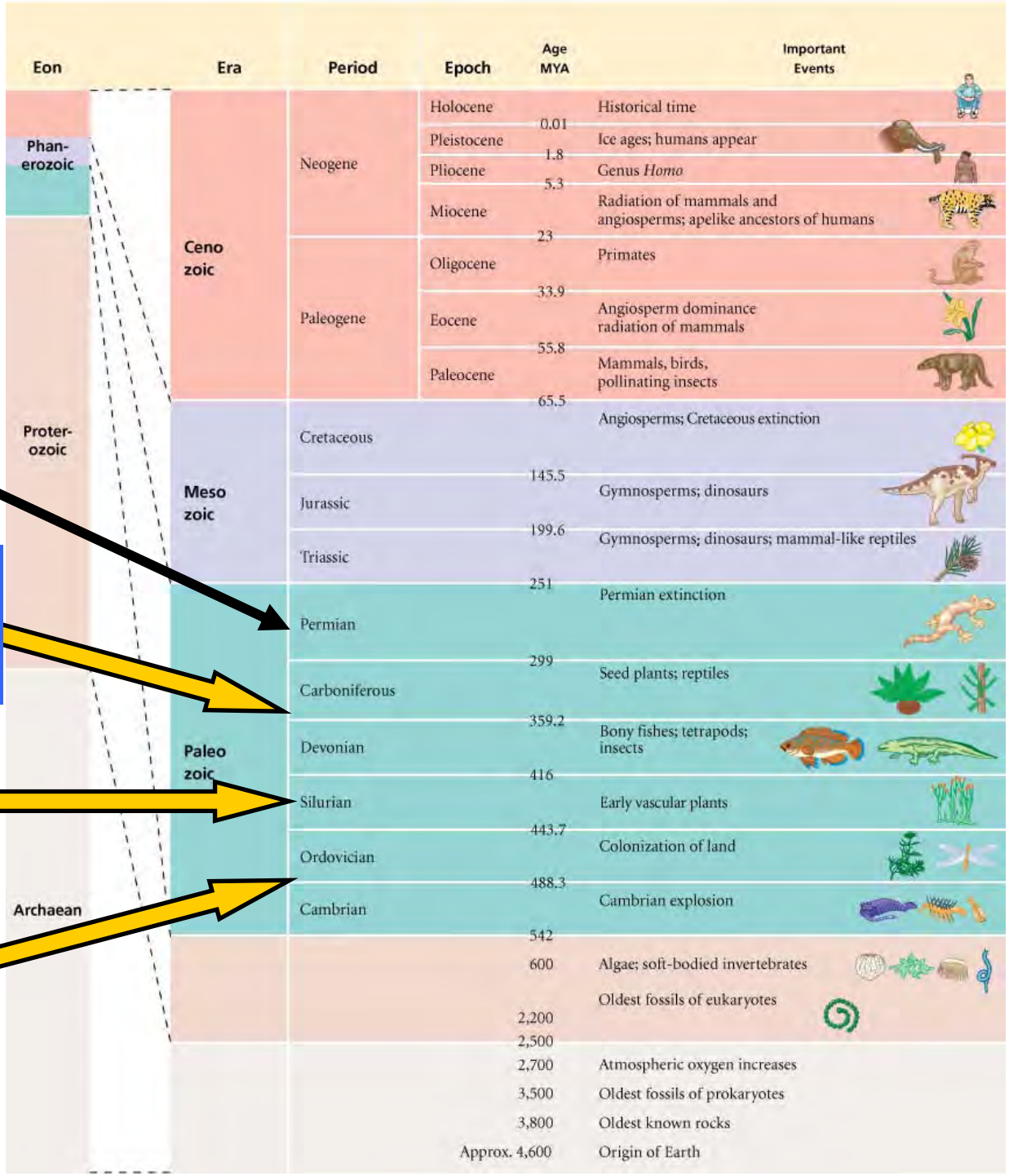
History of Plants

Seed plants have dominated for ~275my since mid-Permian

Seed plants (~360mya) (Carboniferous)

Vascular plants (~420mya) (Silurian)

Non-vascular land plants (~475mya) (Ordovician)

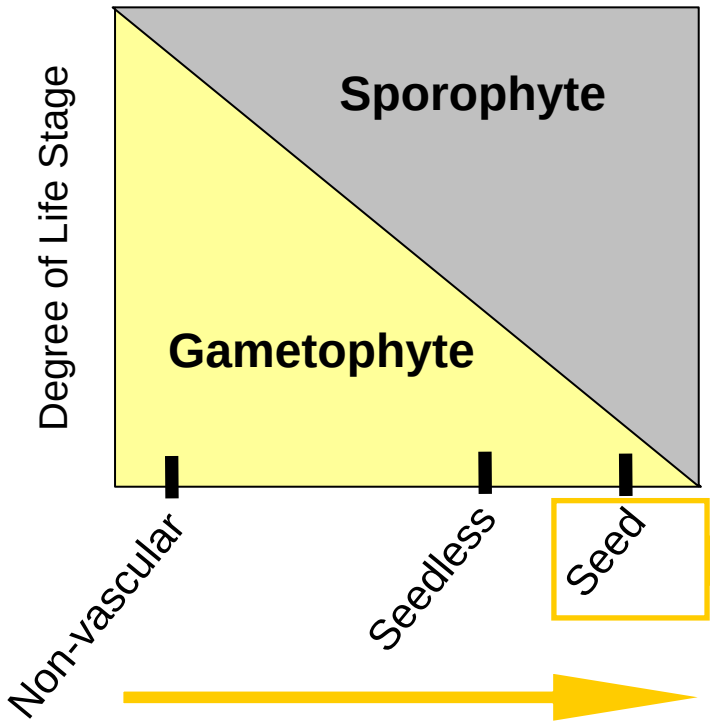


5 Derived Traits of Seed Plants

- Reduced Gametophyte
- Heterospory
- Ovules & seeds
- Pollen

6 Derived Traits of Seed Plants

Reduced Gametophyte



Evolutionary trend towards:

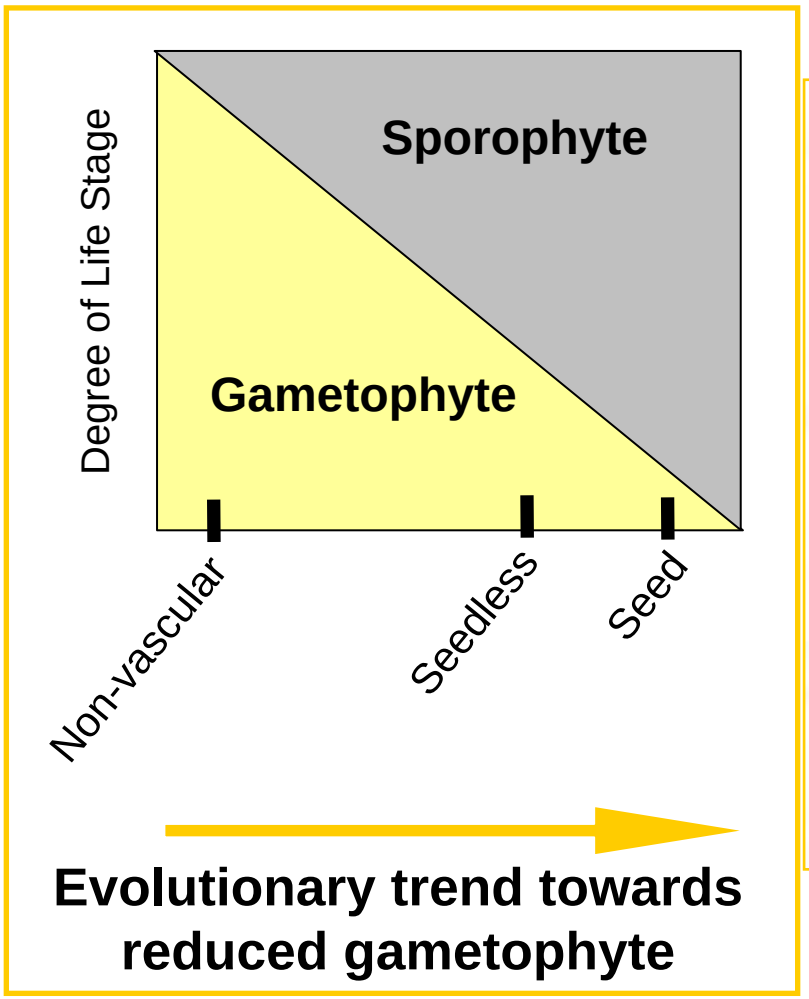
(A) reduced portion of life cycle spent as gametophyte

(B) reduced gamtophyte size

Seed plant gametophytes develop from spores retained INSIDE sporangia.

7 Derived Traits of Seed Plants

Reduced Gametophyte



Non-vascular

Vascular Seedless

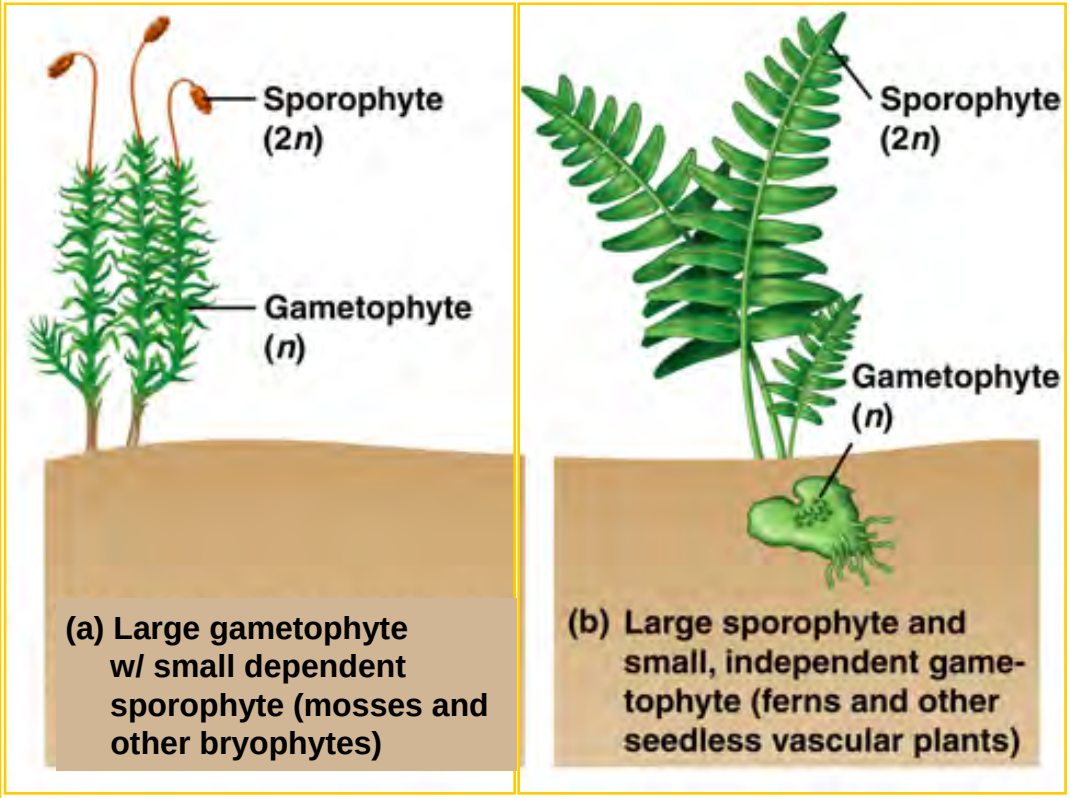
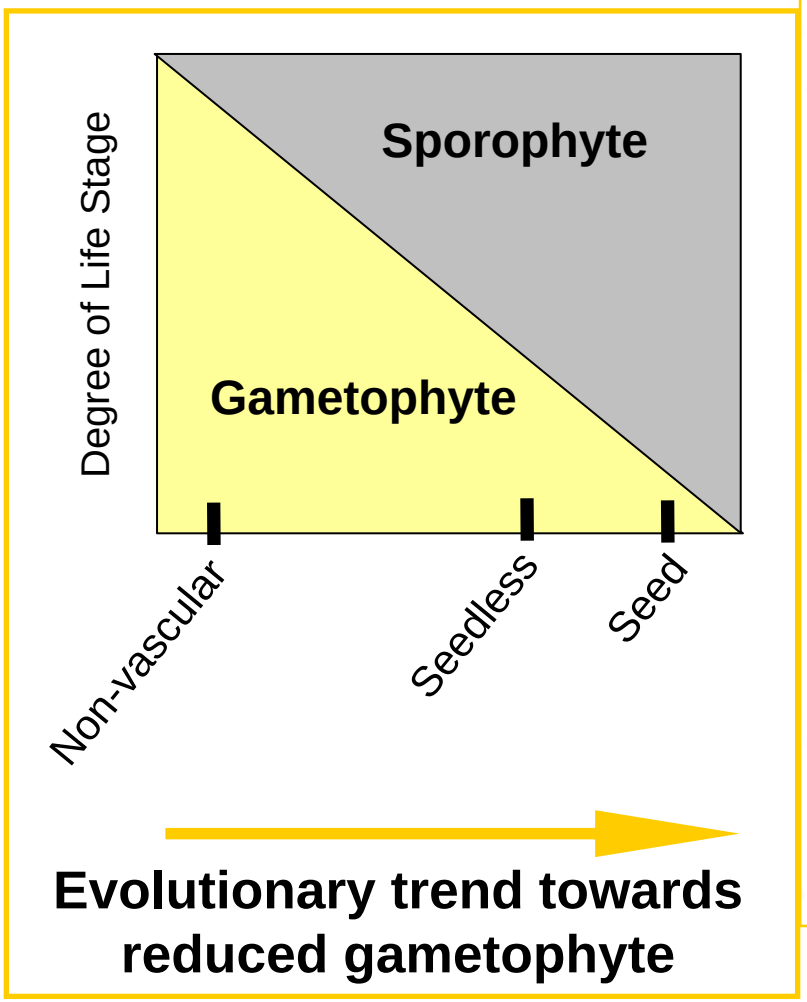


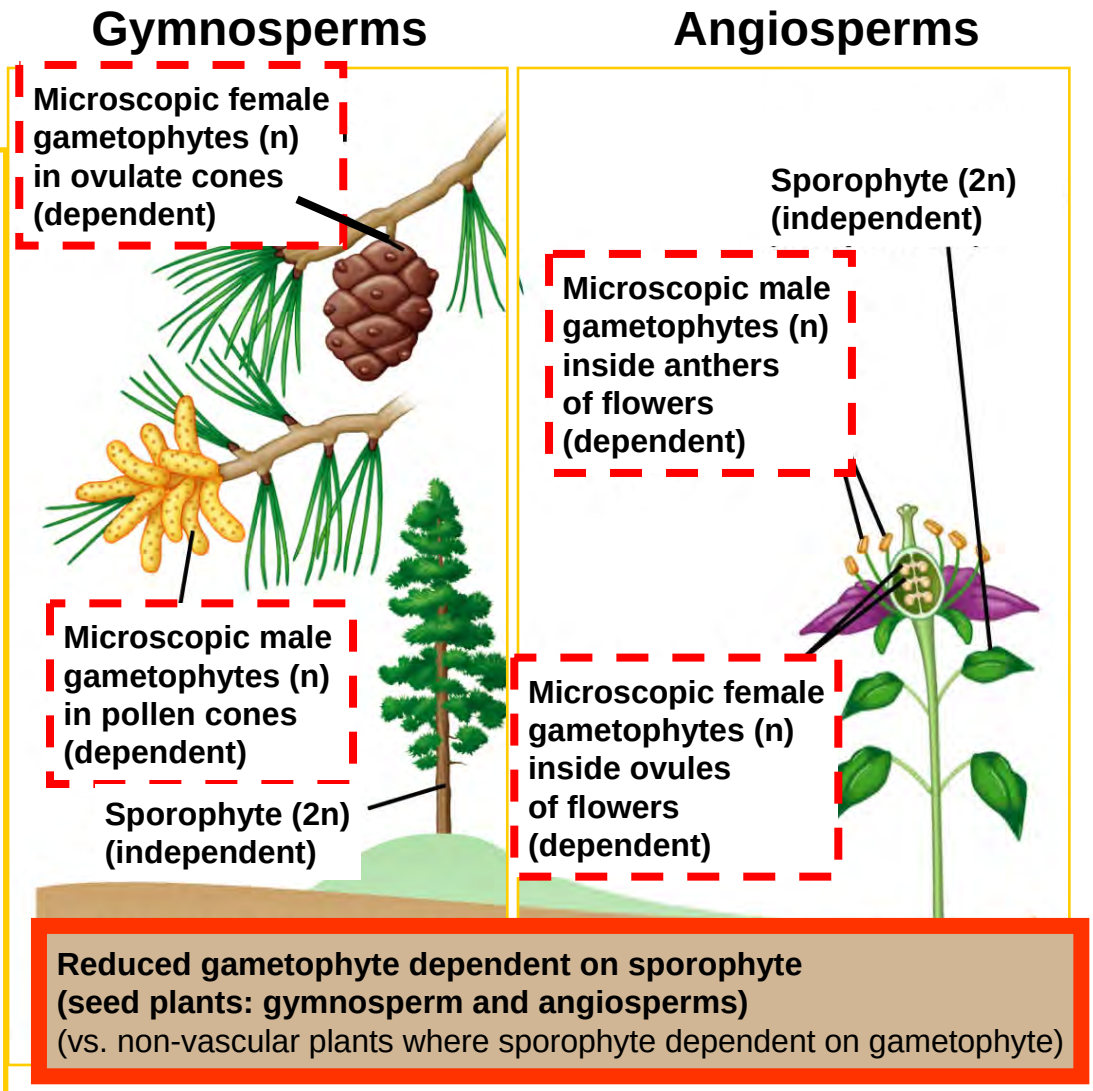
Figure 30.2 (Campbell et al)

8 Derived Traits of Seed Plants

Reduced Gametophyte



Vascular Seed plants



Reduced gametophyte dependent on sporophyte (seed plants: gymnosperm and angiosperms)
(vs. non-vascular plants where sporophyte dependent on gametophyte)

Figure 30.2 (Campbell et al)

Evolutionary advantages of a miniaturized gametophyte stage

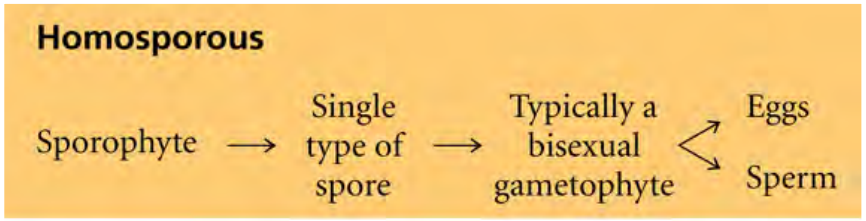
1. ♀ gametophyte (which produces the egg) can more easily receive:
   a. nutrition from sporophyte.
   b. protection by sporophyte from environmental stress (e.g. desiccation & UV radiation).

2. Water unnecessary for:
   a. reproduction
      - Tiny ♂ gametophyte (and its sperm) easily packaged/delivered in small capsule (pollen grain) via wind/animals long distances directly to ♀ gametophyte

   b. colonization
      - Allows colonization of dry places

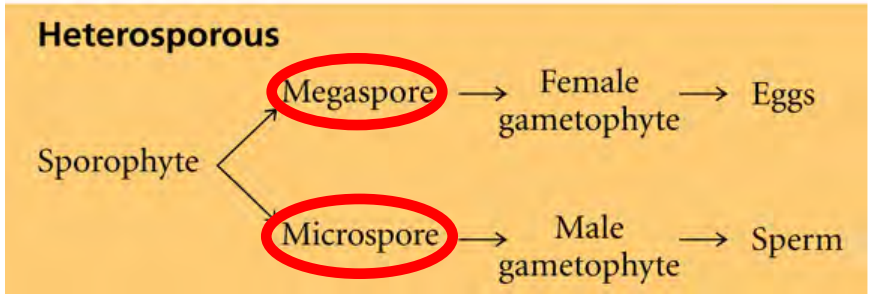
10 Derived Traits of Seed Plants

Heterospory



Homosporous:

- Sporophyte produces 1 kind of spore inside of a sporangium
- Germinates into a bisexual (usually) gametophyte
- Homospory occurs in most seedless plants



Megaspore = female spore

Microspore = male spore

Heterosporous

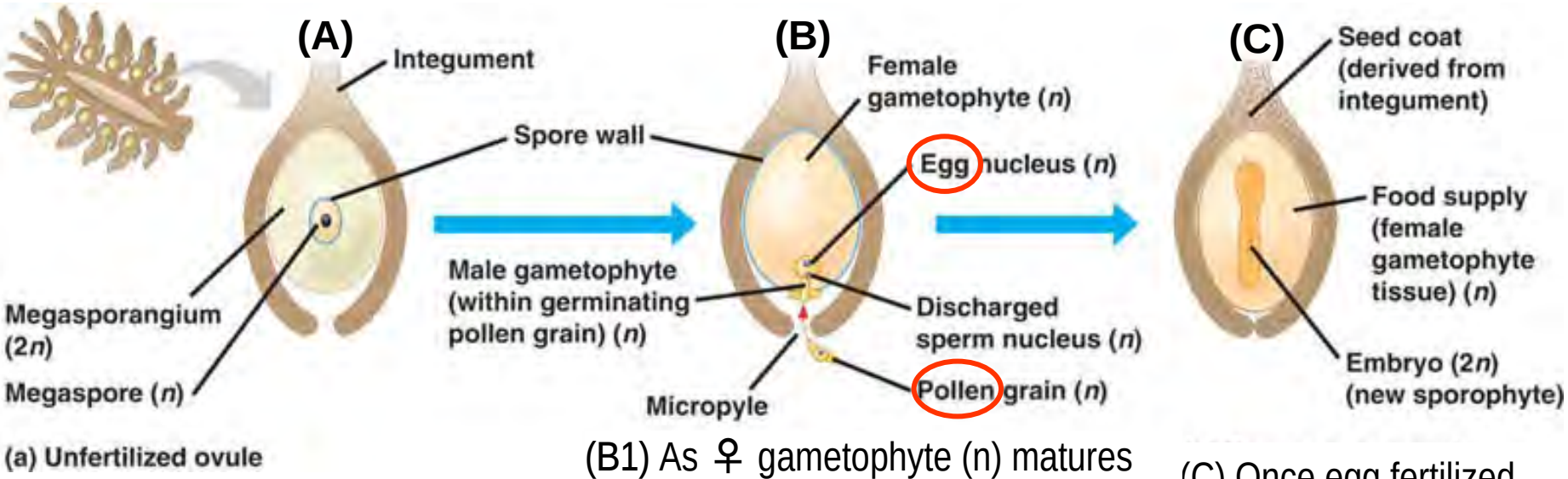
- Sporophyte produces one megaspore (♀) inside of each megasporangium and many microspores (♂) inside of each microsporangium
- Micro- and megaspores germinate into separate MALE and FEMALE gametophytes
- Heterospory occurs in ALL seed plants and a few seedless plants

Figure on page 613 (Campbell et al)

12 Derived Traits of Seed Plants

Gymnosperm fertilization

Ovules & Seeds



(A) Megasporangium on sporophyte (2n) produces megaspore (n) which develops into ♀ gametophyte (n) inside megasporangium

(A) Initially, **Ovule** = Megasporangium (2n) w/ megaspore (n) + integument
(B1) Later, Ovule = Megasporangium w/ ♀ gametophyte + integument

(B1) As ♀ gametophyte (n) matures (inside megasporangium) its archegonium (n) (gametangium) produces the egg (gamete)(n))

(B2) Pollen grain (♂ gametophyte (n) in sporopollenin), goes to ♀ gametophyte (n) and discharges sperm to fertilize egg (sperm (n) + egg (n)= zygote (2n))

(C) Once egg fertilized, ovule now called seed

Seed = Embryo (2n) + Seed coat + ♀ gametophyte (n) (food for embryo)

Figure 30.3 (Campbell et al)

SEEDS

- Fertilized ovule develops into a seed
- **Contain an embryonic plant and a food supply**
  (derived from ♀ gametophyte)
- Can last long periods of dormancy.
- Contain energy for germination
  - Until plant finds light and begins photosynthesis

Pine seed (w/seed coats removed)

Bean embryo after germination

14 Derived Traits of Seed Plants

Pollen

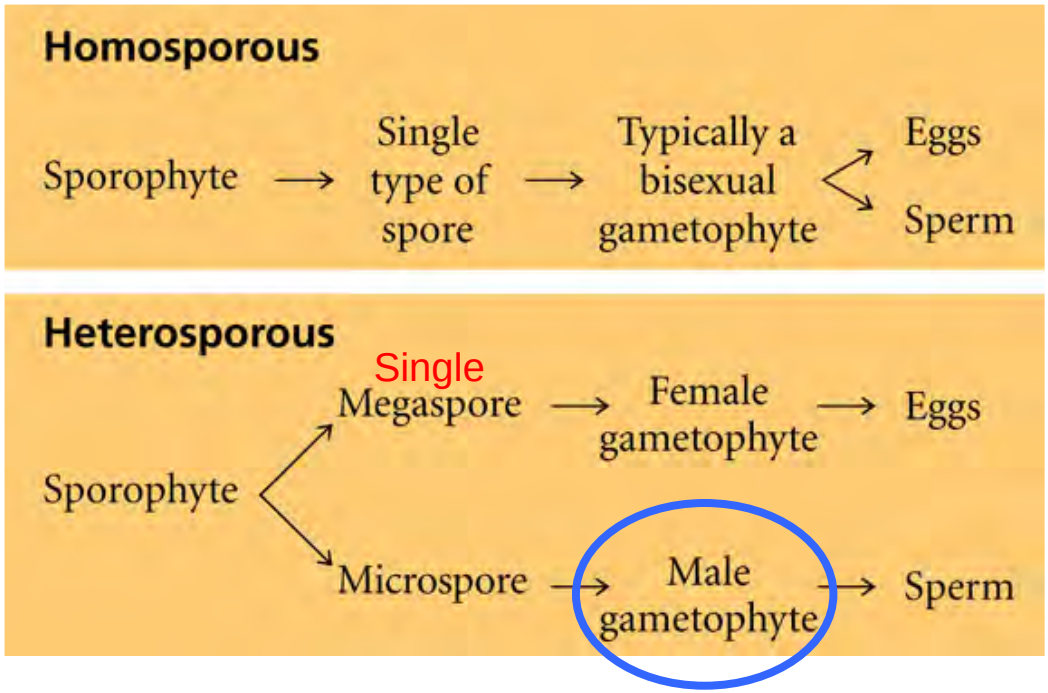


Figure on page 613 (Campbell et al)

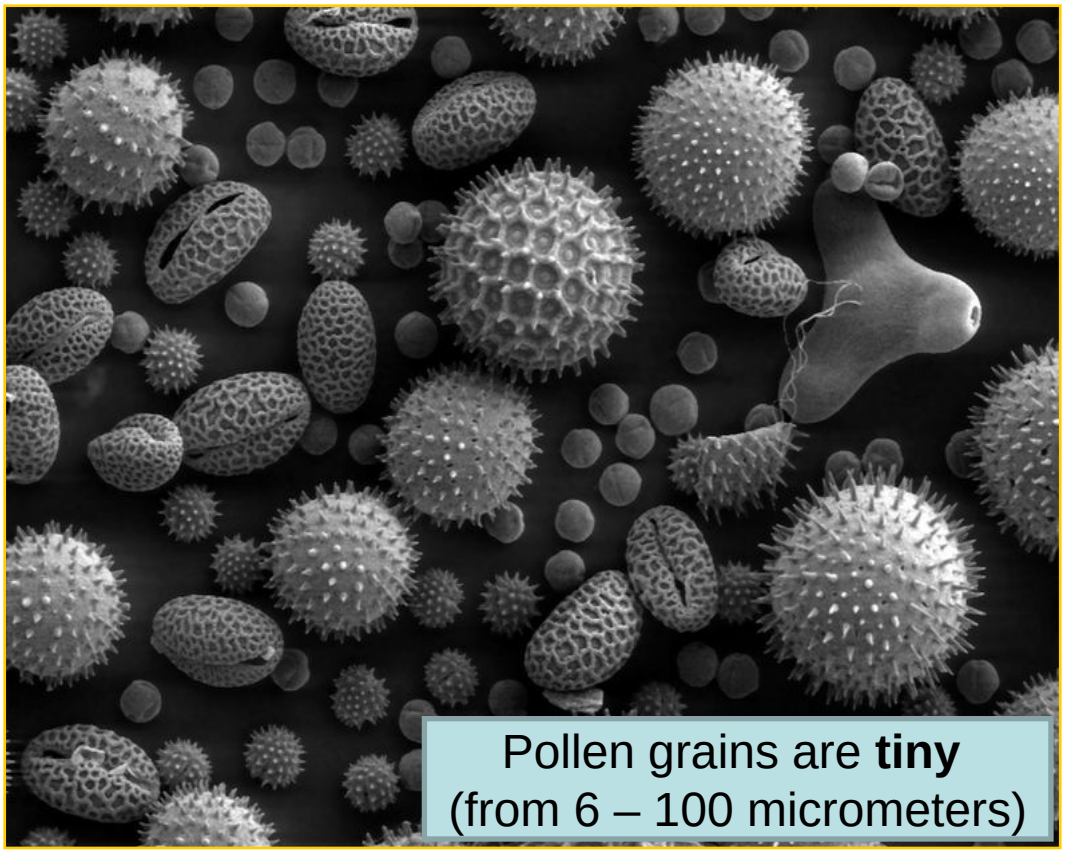
15 Derived Traits of Seed Plants

Pollen

- Each microspore develops into a pollen grain
  - containing a **male gametophyte**
  - surrounded by a sporopollenin coat (makes it durable and waterproof)

- Pollen transferred to ovule via various methods (e.g. wind or animals).
  i.e. it is **water Independent!**

- If Pollen grain reaches the female gametophyte it germinates.
  - i.e. It gives rise to sperm and a pollen tube that breaks out of pollen grain, burrows towards ovule and discharges sperm



Pollen grains are **tiny**
(from 6 – 100 micrometers)

Pollination

Movement of immature ♂ gametophyte, in pollen grain,
near the immature ♀ gametophyte, in the ovule
(i.e. prior to sperm or egg development and fertilization)

1. Wind pollinated plants:
   - Most gymnosperms (non-flowering seed plants)
   - Only 10% (25,000) of the angiosperm species are wind-pollinated.
     - Includes all the cereal plants such as wheat, rice and maize.
     - Also includes most of the trees found in forests.
     - Flowers are usually small and inconspicuous, do not produce nectar or have any scent (since don't need to attract animal pollinators).

2. Animal pollinated plants:

20

Wind pollinated plants liberate gigantic quantities of pollen

•Must produce huge quantities of pollen to increase chance of pollination.

•1 anther on a maize flower produces 3000 pollen grains

(total = 18 million pollen grains per plant!)

allergic rhinitis

Pollination

2. Animal pollinated plants:

Insects

Birds

Bats

Insect pollinated plants:

(many angiosperms, few gymnosperms)

- Insects are **ATTRACTED** to flowers by advertising colors and or smells
- Insects are **REWARDED**
  - Either they eat some of the pollen and/or nectar to make it worth their while
- Results in **POLLINATION** When pollen grains on ♂ flower stick to insect and are transferred to ♀ flower

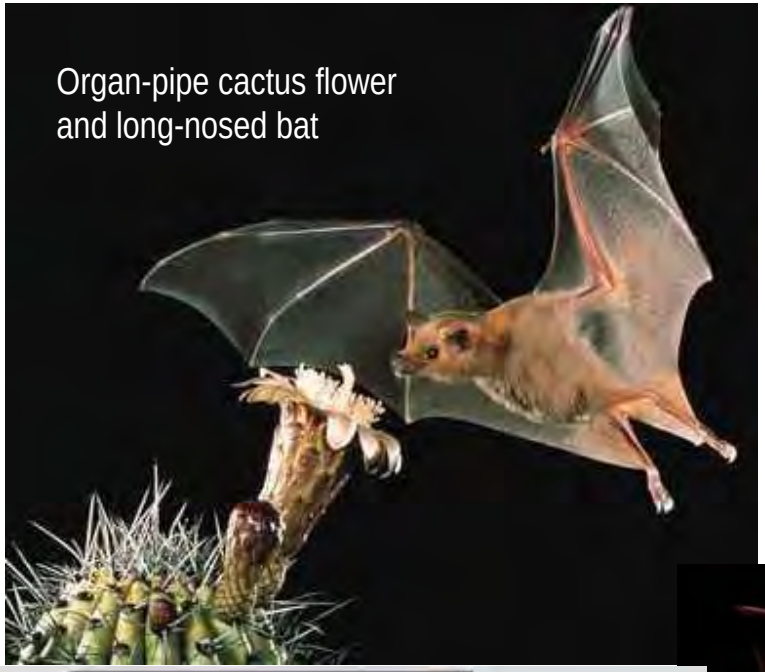
Insect pollination is a form of INSECT – PLANT MUTUALISM

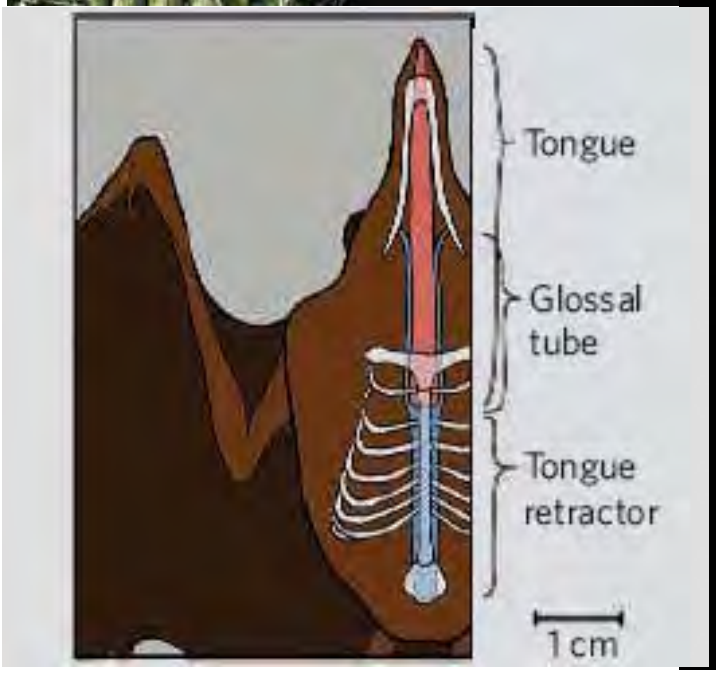
Bird pollinated plants: (some angiosperms only)

Hummingbird pollinated flowers:

Lots of nectar – hidden down long structure – deters nectar thieves

25 Bat pollinated flowers (some angiosperms only)





27

Pollination vs. Fertilization

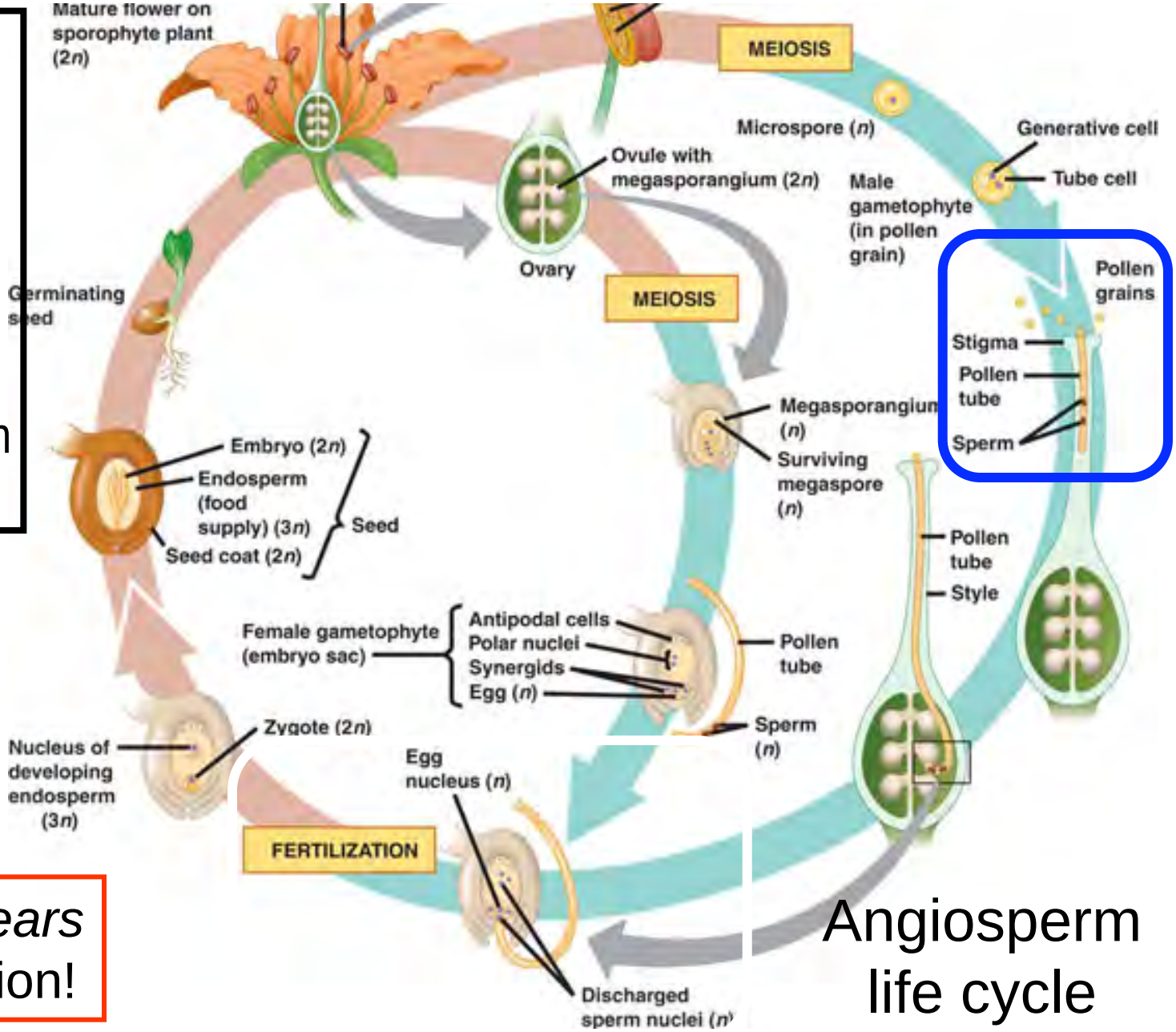
Pollination:

Movement of immature ♂ gametophyte in pollen grain, near immature ♀ gametophyte, in the ovule

Fertilization:

Joining of sperm & egg cells within ovule

May occur *years* after pollination!



Angiosperm life cycle

Spore vs. Seed

	Spores	Seeds
Description	A haploid cell made in the sporangium of the sporophyte via meiosis	A sporophyte embryo (2n) + nutrients (n) (remnants of ♀ gametophyte)
# cells	1	Many
Energy reserves?	No	Yes
Protection	Sporopollenin layer	Seed coat
Destiny	Will become gametophyte Nonseed plant: After dispersed via wind germinates into independent gametophyte Seed plant: Microspore becomes ♂ gametophyte which is packaged as pollen Megaspore becomes ♀ gametophyte in ovule (which becomes seed)	Will become sporophyte

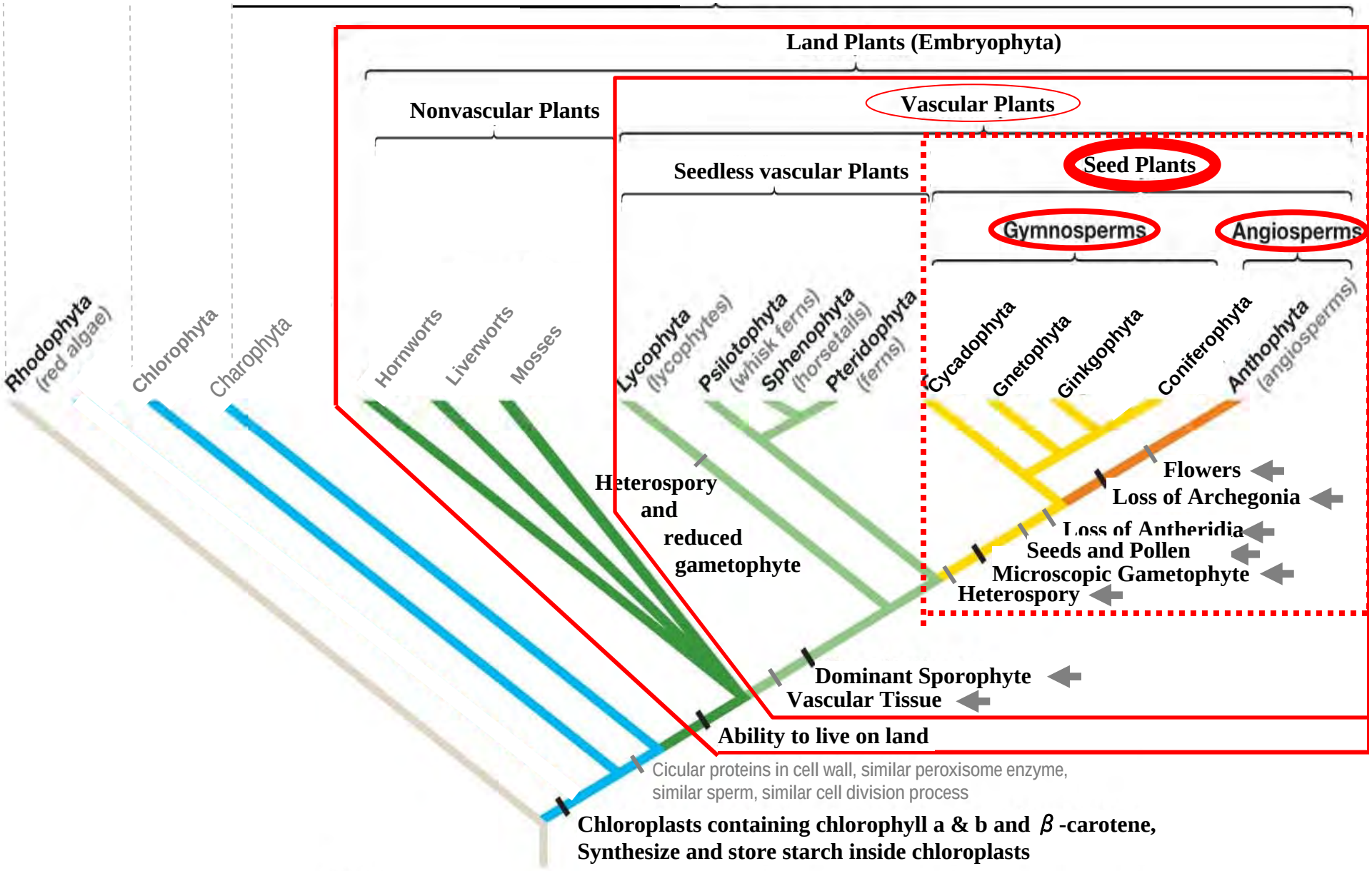
Spore vs. Pollen

	Spores	Pollen
Description	A haploid cell made in the sporangium of the sporophyte via meiosis	An immature ♂ gametophyte (n) in a protective layer
# cells	1	Multicellular
Energy reserves?	No	No
Protection	Sporopollenin layer	Sporopollenin layer
Destiny	Will become gametophyte Nonseed plant: After dispersed via wind germinates into independent gametophyte Seed plant: Microspore becomes ♂ gametophyte which is packaged as pollen Megaspore becomes ♀ gametophyte in ovule (which becomes seed)	Upon arrival at ovule will develop a pollen tube and sperm which will fertilize egg in ovule.

Spore vs. Gamete

	Spores	Gamete
Description	A haploid cell made in the sporangium of the sporophyte via meiosis	Haploid cell made in gametangium of gametophyte (n) via mitosis
# cells	1	1
Energy reserves?	No	No
Protection	Sporopollenin layer	None
Destiny	Will become gametophyte Nonseed plant: After dispersed via wind germinates into independent gametophyte Seed plant: Microspore becomes ♂ gametophyte which is packaged as pollen Megaspore becomes ♀ gametophyte in ovule (which becomes seed)	Sporophyte after fusion w/ another gamete Nonseed plant: Begins to mature into sporophyte immediately. Seed plant: embryonic sporphyte in seed matures later.

SEED Plant Diversity & Reproduction



Gymnosperms

Defining trait:

- Seeds *not* enclosed in ovaries

("naked" seed)

- 4 clades

Ginkgophyta

Cycadophyta

Gnetophyta

Coniferophyta

Gymnosperms:

Adaptations to dry conditions

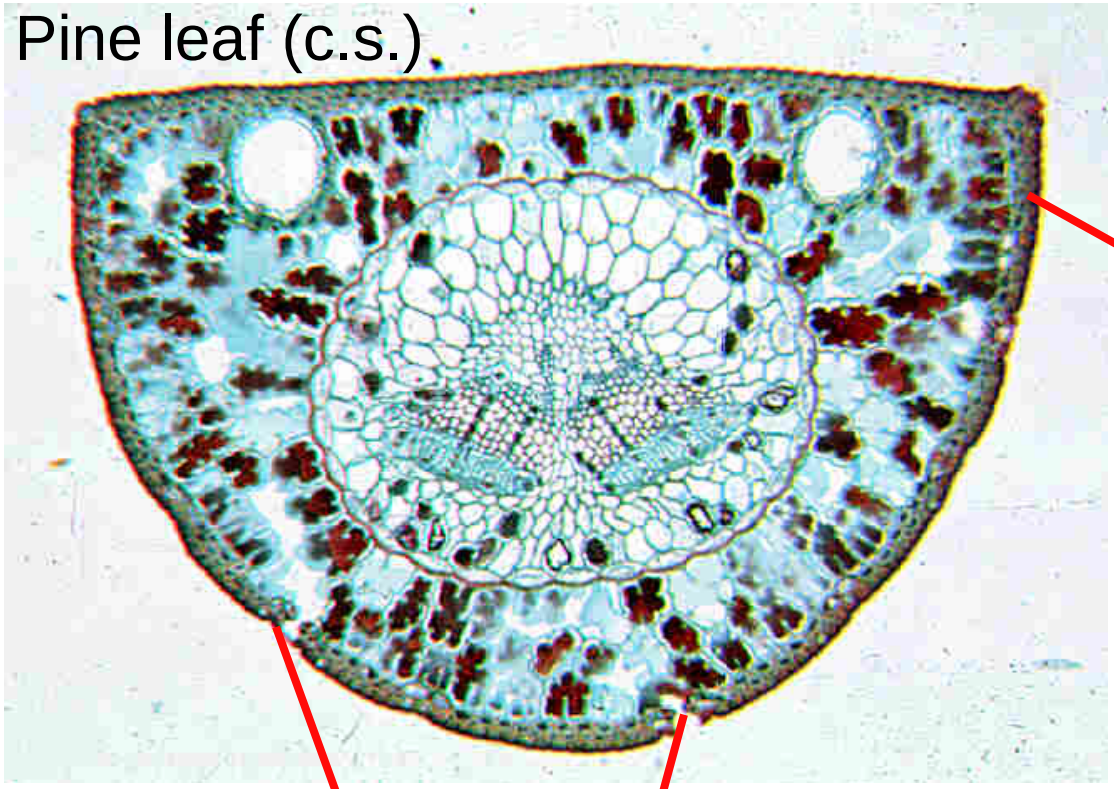
1. Needles

or

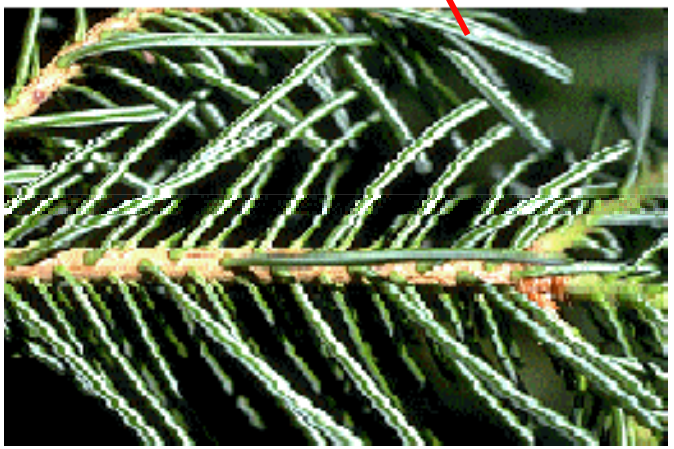
Thick, leathery leaves

Gymnosperms:

Adaptations to dry conditions



2. Thick, waxy cuticle



3. Sunken stomata

4. Relatively few stomata

Ginkgophyta
(1 extant species)

- Only <u>one extant species</u> in this phylum!
- Extinct in wild?
- *Male* trees commonly used as ornamentals
- *Deciduous*
  - Drop all leaves seasonally
- *Dioecious*,
  - ♂ and ♀ plants are separate
- <u>Flagellated</u> sperm

Ginkgo biloba

36

Cycadophyta
(~130 extant species)

- Flourished during Mesozoic era
  "Age of Dinosaurs/Cycads"
- Tropical distribution
- Look like palms,
  w/ large cones in center
- *Dioecious*
- Flagellated sperm

Cycads & ginkgos =
only **seed** plants w/ flagellated sperm
(found in all non-seed plants)

38

Gnetophyta

(~80 extant species)

- Includes 3 genera w/ no clear morphological synapomorphies.
- Have similarities in their vascular tissue to angiosperms (i.e. vessel elements)

Ephedra: source of ephedrine

Welwitschia

Gnetum: fleshy seeds (not fruit!)

39

Coniferophyta

(~600 extant species)

Pines, redwoods, firs, juniper, etc

Douglas Fir

Sequoia

Common juniper

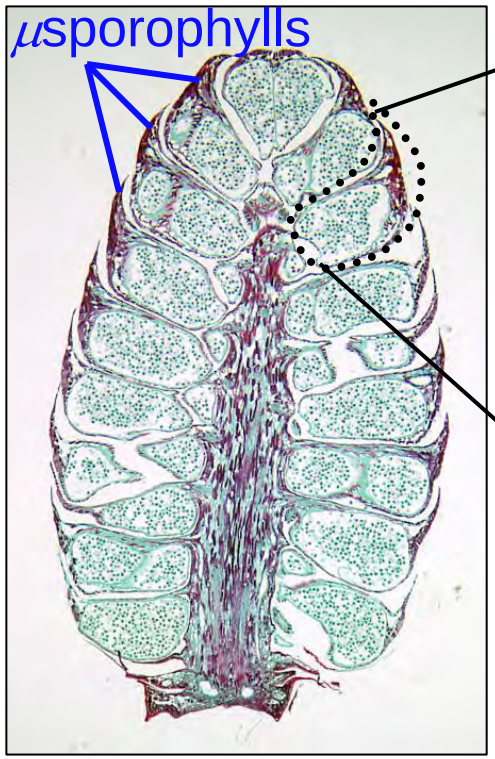
Bristlecone pine

European larch

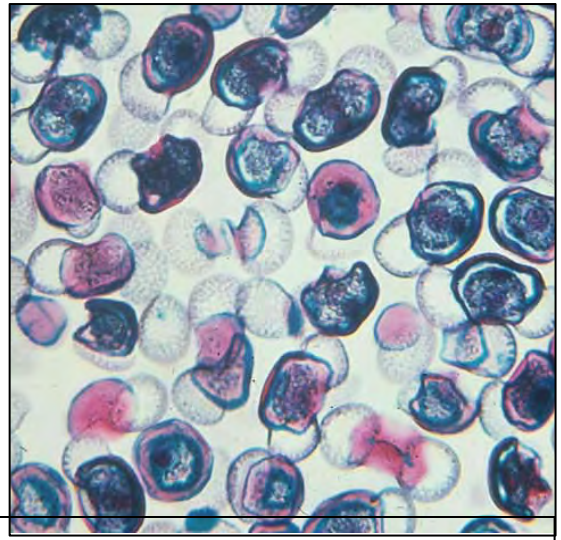
Figure 30.5 (Campbell et al)

Male cone

Microsporophylls
w/ Microsporangium
w/ Microspores
- Develop into pollen grain
- ♂ gametophyte enclosed in sporopollenin wall



microsporangium



Pollen grains, w/immature male gametophytes

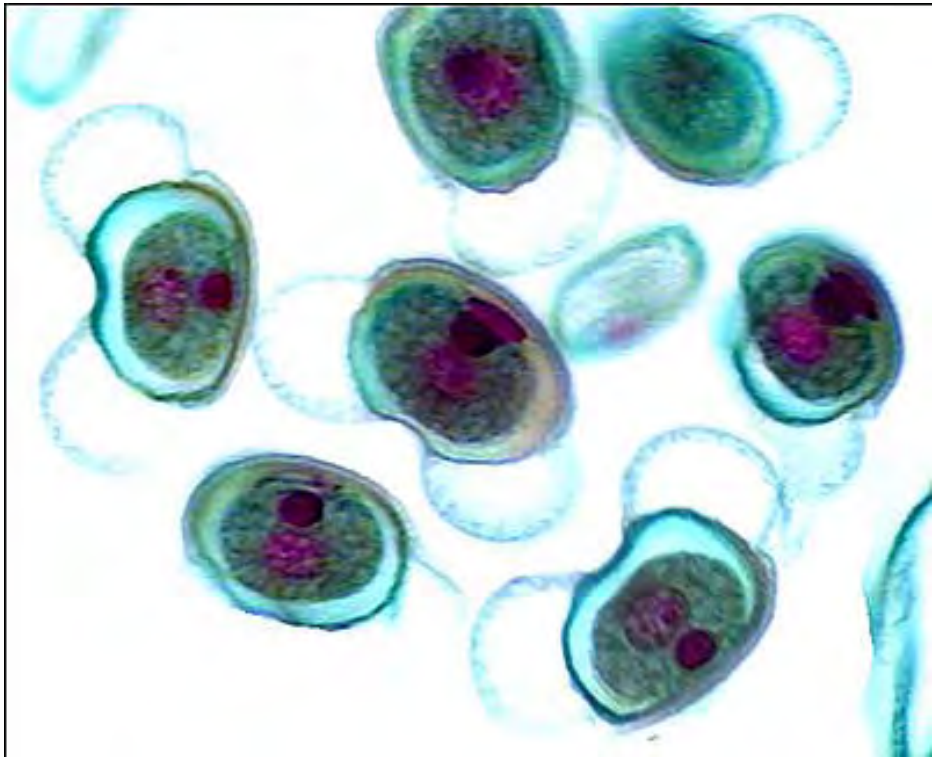
41

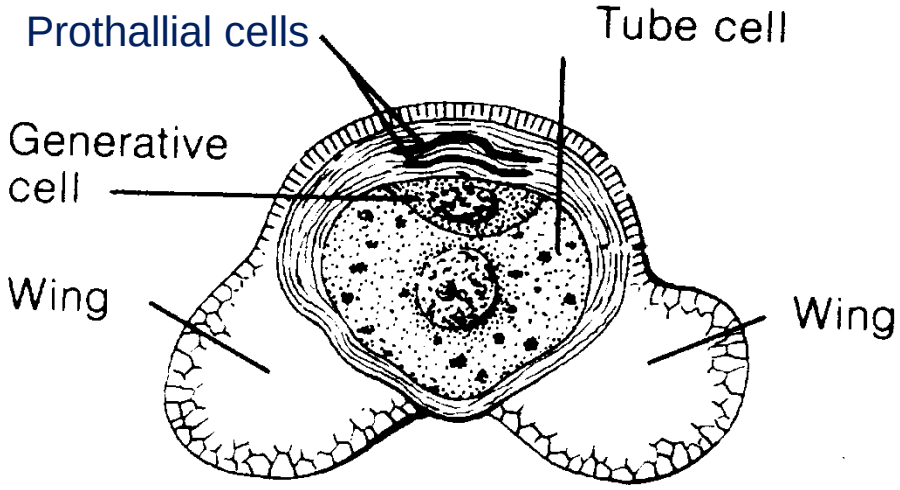
Pollen

Immature male gametophytes

- Made of only FOUR cells!
  - 1 tube cell (will form pollen tube)
  - 1 generative cell (will form sperm)
  - 2 prothallial cells (sterile; ? function)

- <u>Does NOT have an antheridium</u>
  - sperm form from generative cell



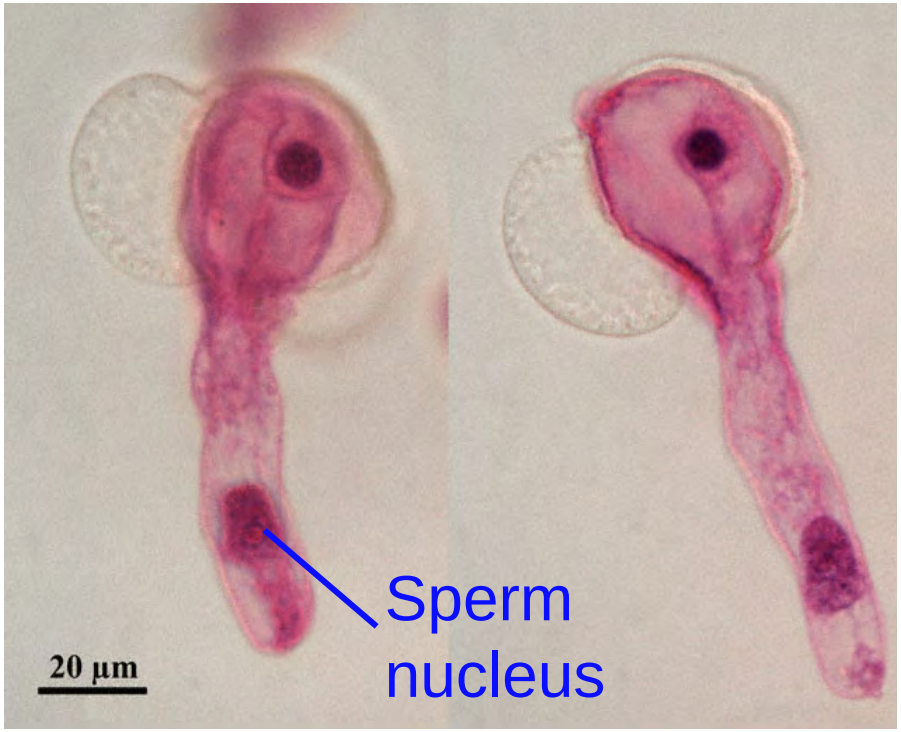


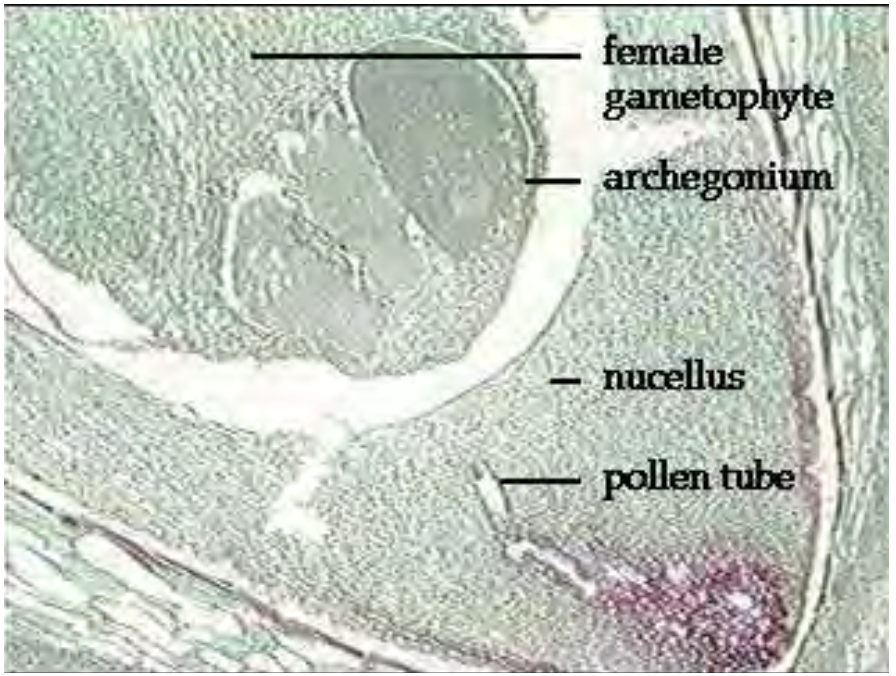
Pollen tube formation & spermatogenesis

- After pollen grain arrives near ovule it begins to develop.
- Tube cell divides into pollen tube which grows toward developing egg in archegonium of ♀ gametophyte
- Generative cell moves to tip of tube and divides into 2 sperm (mitosis)

TAKES ONE YEAR

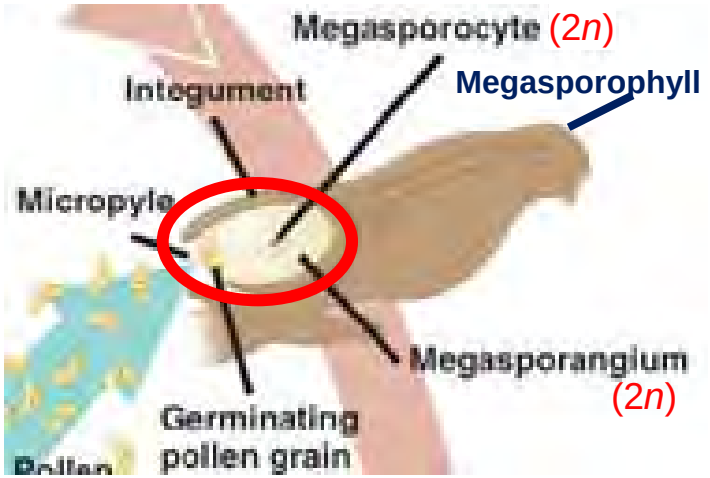
While this happening…





Female cone

At time of pollination ovule is immature
(and so is ♂ gametophyte in pollen)



Ovule =
Megasporangium
+ integument

Megaspore (2n)

Pollen grain reaches ovule
& pollen tubule burrows through
ovule wall to megaspore inside.

Pollen near ovule

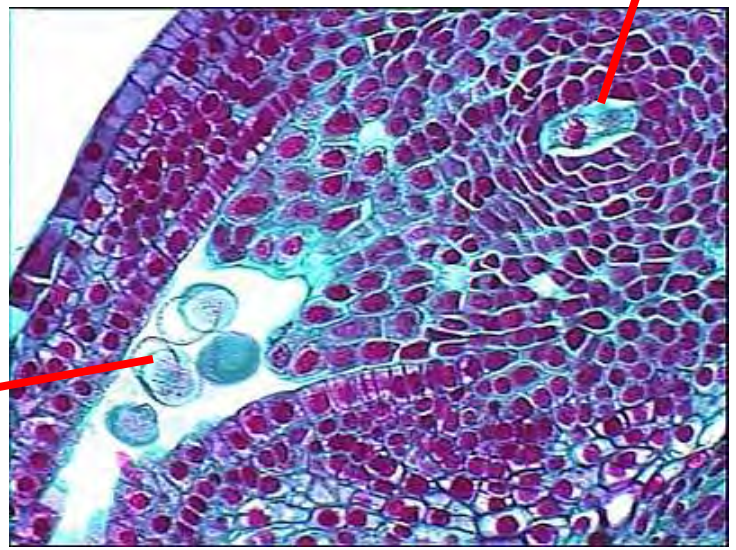


Figure 30.6 (4) (Campbell et al.)

Ovule maturation

TAKES ONE YEAR

Megasporangium (2n)

↓

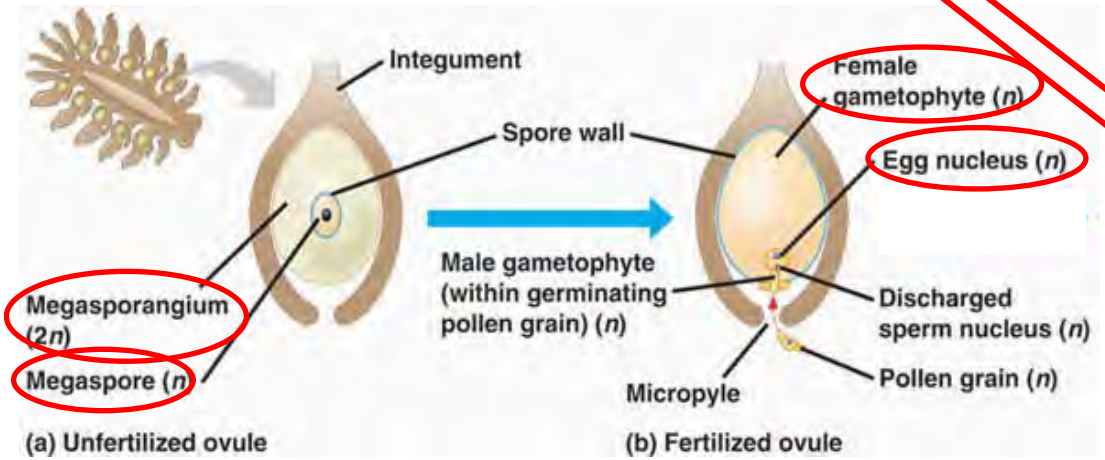
Megaspore (n)

↓

female gametophyte (n)

↓

Egg (n)
(in archegonium)



Megaspore (n) in megasporangium develops into female gametophyte (n) which produces egg (gamete)(n) in archegonium (gametangium)

Figure 30.3 and 30.6 (Campbell et al.)

45

Fertilization occurs one year after pollination

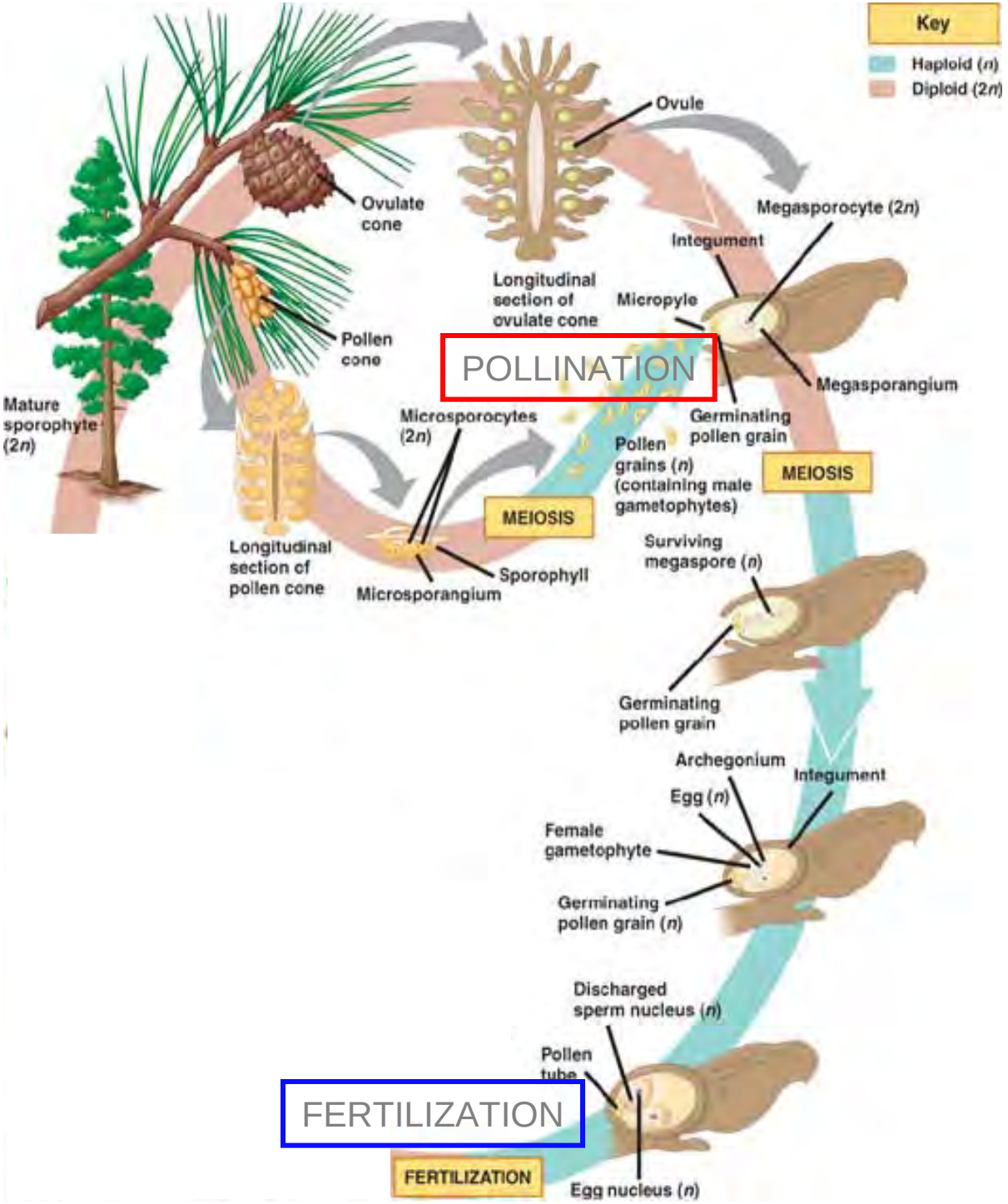
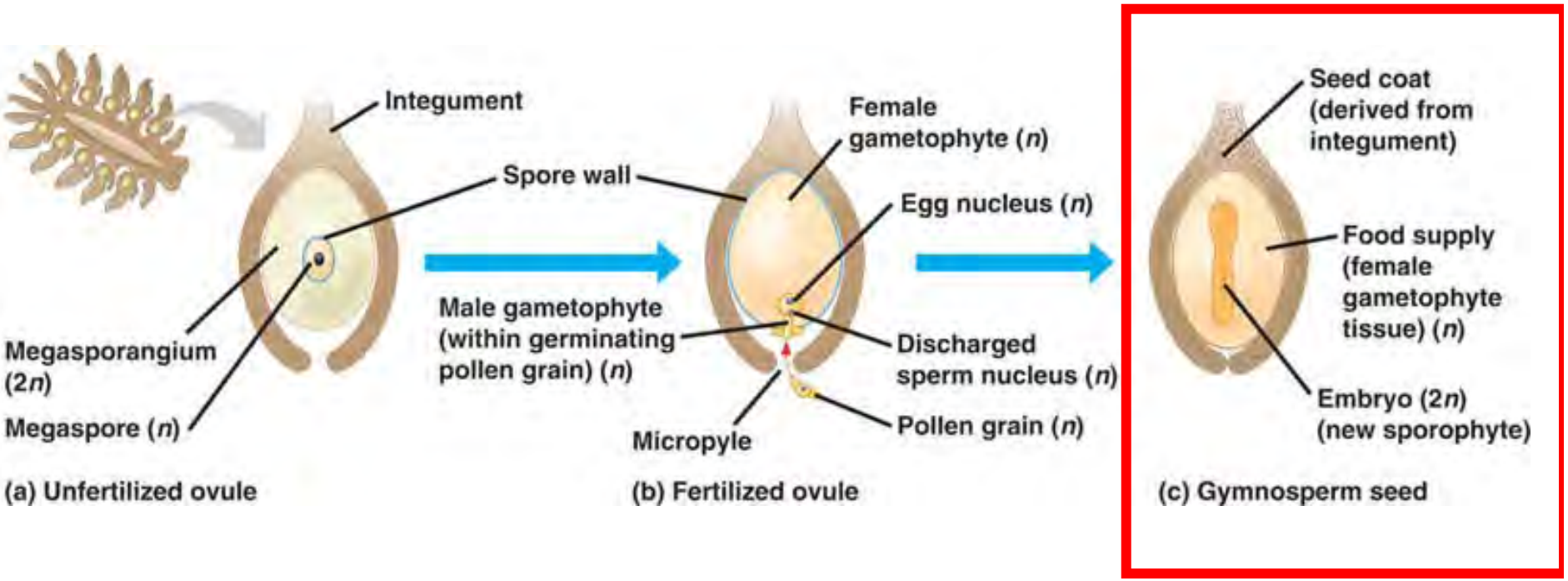


Figure 30.6 (Campbell et al.)

From Ovule to Seed

Seed = Sporophyte Embryo (2n) + food supply (n) + seed coat



After fertilization, seed takes ONE more YEAR to complete development

- Fertilized egg (zygote)(2n) develops into embryo (multicellular 2n) (embryo = new sporophyte)
- Female gametophyte tissue becomes food for embryo

Figure 30.3 (Campbell et al)

47

Dispersal

wind,
water,
animals

Seed dispersal occurs a minimum of:

- One year after fertilization
- Two years after pollination

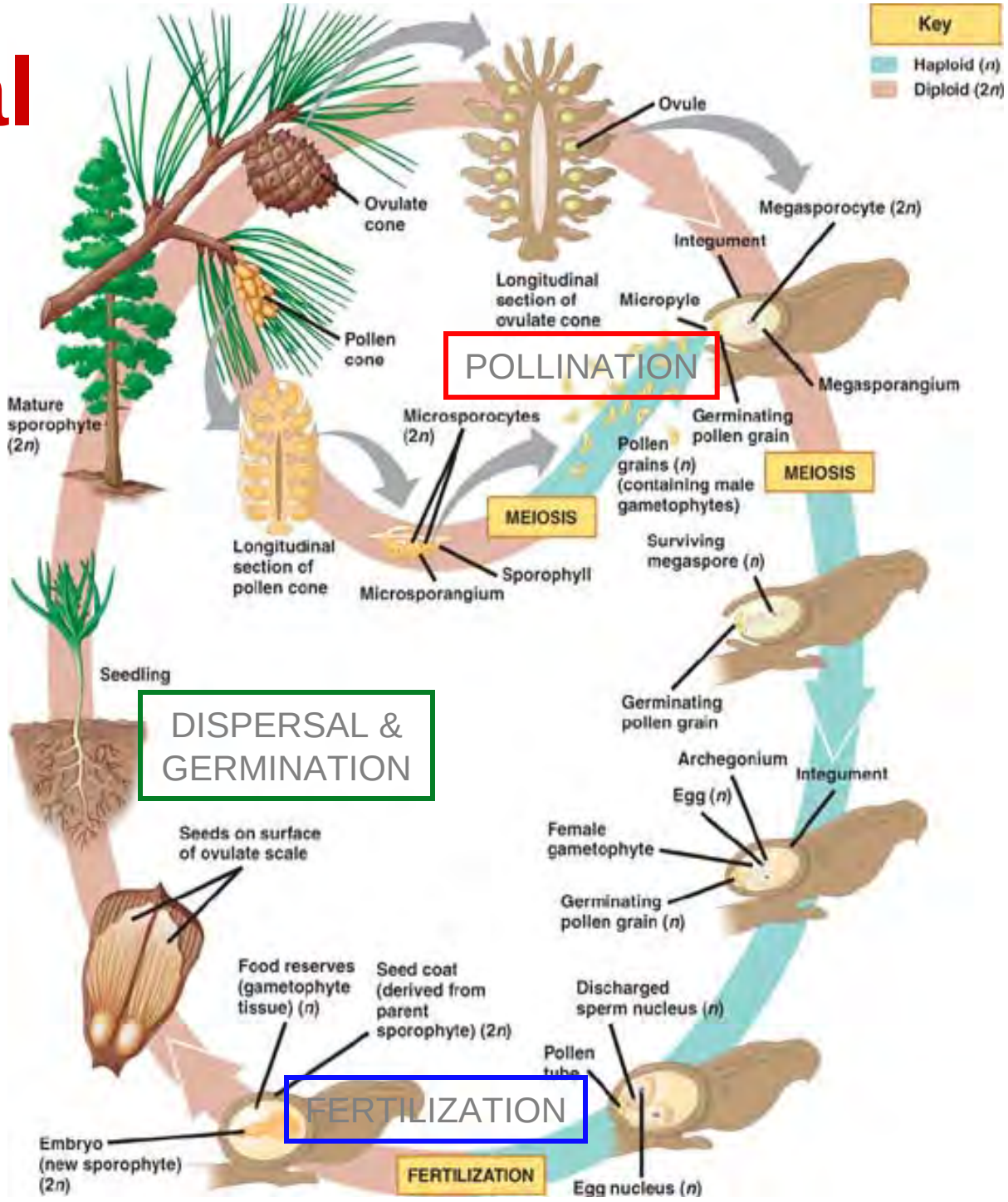
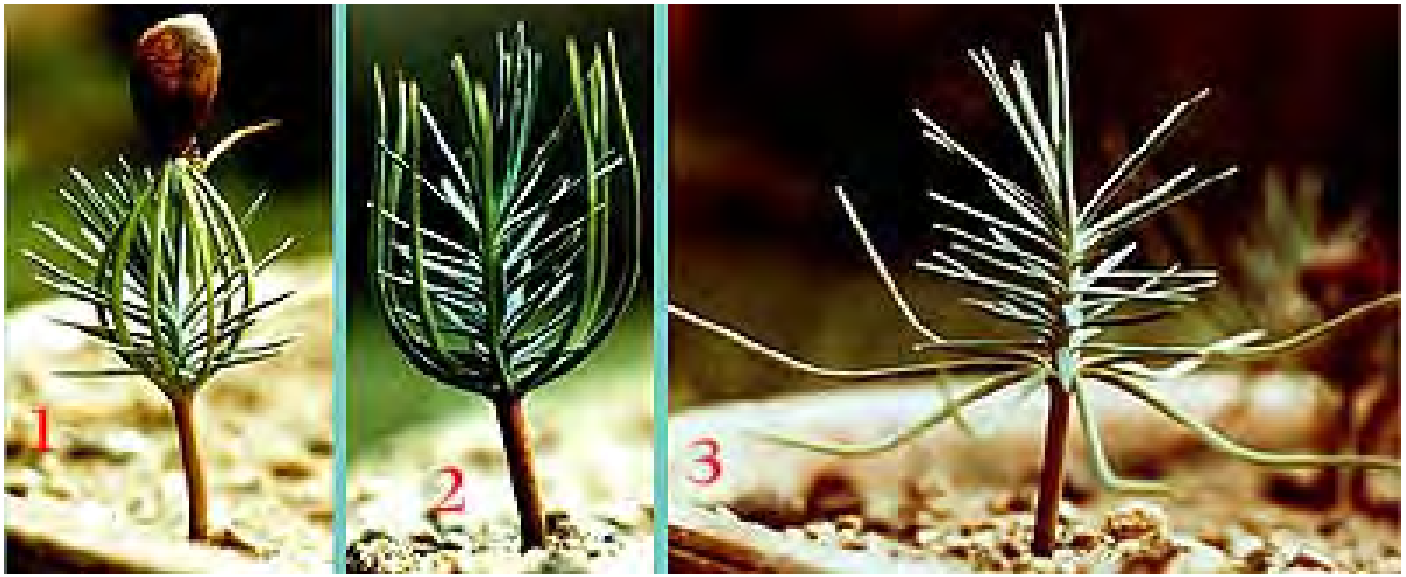


Figure 30.6 (Campbell et al.)

Germination

Seed grows into sporophyte

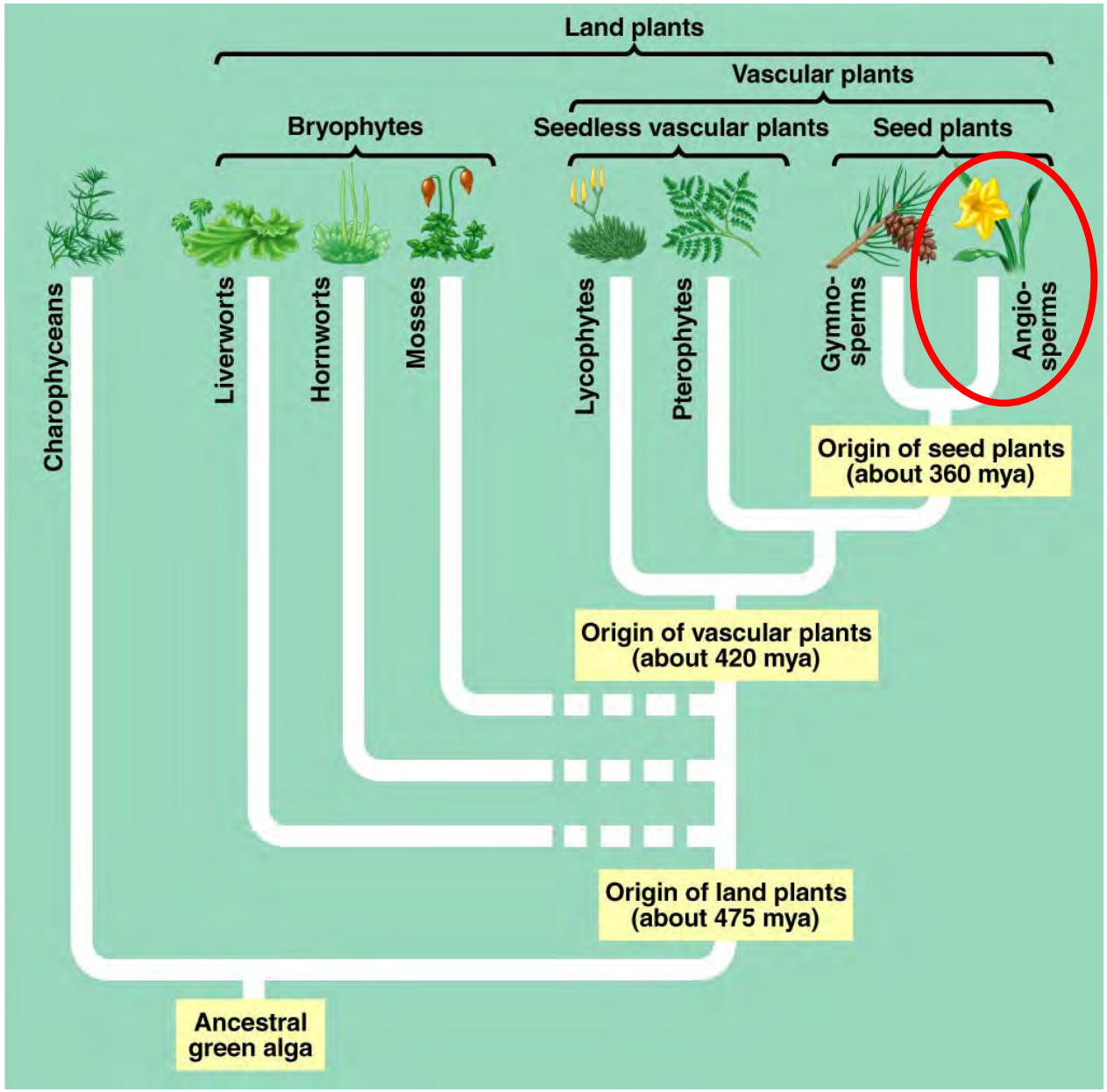


After *dormancy* lasting days to millennia!

Summary of Gymnosperm Life Cycle

Sporophyte dominant
Heterosporous
Spores retained within sporangium
Offspring disperse as seeds
No antheridia; archegonia reduced
Don’t need water film (except gingko and cycads)
Nonmotile sperm (except gingko and cycads)

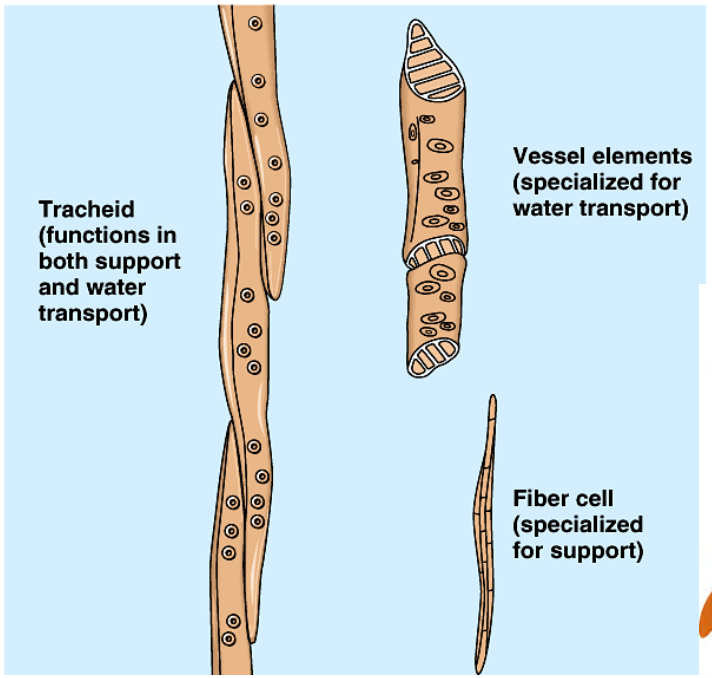
52 Angiosperms (flowering plants)



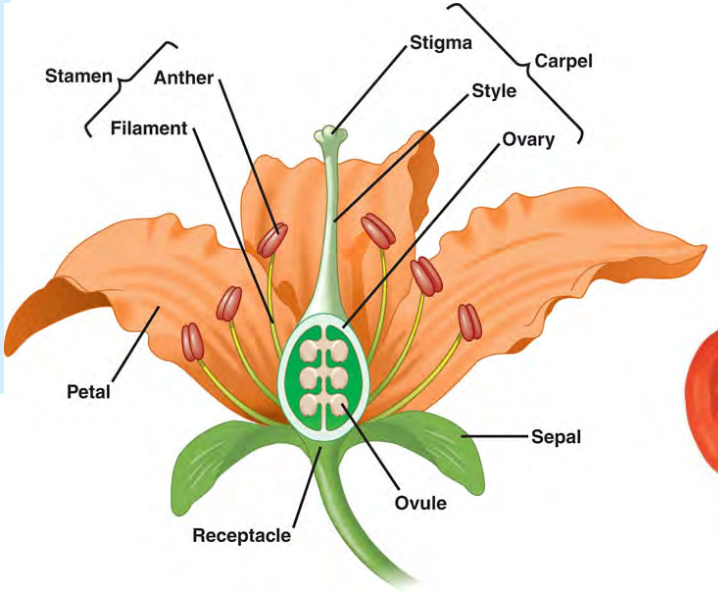
Secret of Success:

Specialized Tissues

1. Xylem components



2. Flowers



3. Fruit

Flower Structure & Function

Sepals:

Protect flower bud

Petals:

Attract pollinators

Stamens (=microsporophylls):

- μsporangia in anther
  - produce μspores
    - $\rightarrow$ μgametophyte $\rightarrow$ sperm

Carpels (=megasporophylls):

- Contains ovary w/ ovules
- Produce megaspores
  - $\rightarrow$ Megagametophyte
    - $\rightarrow$ eggs

1 or more fused carpels = pistil

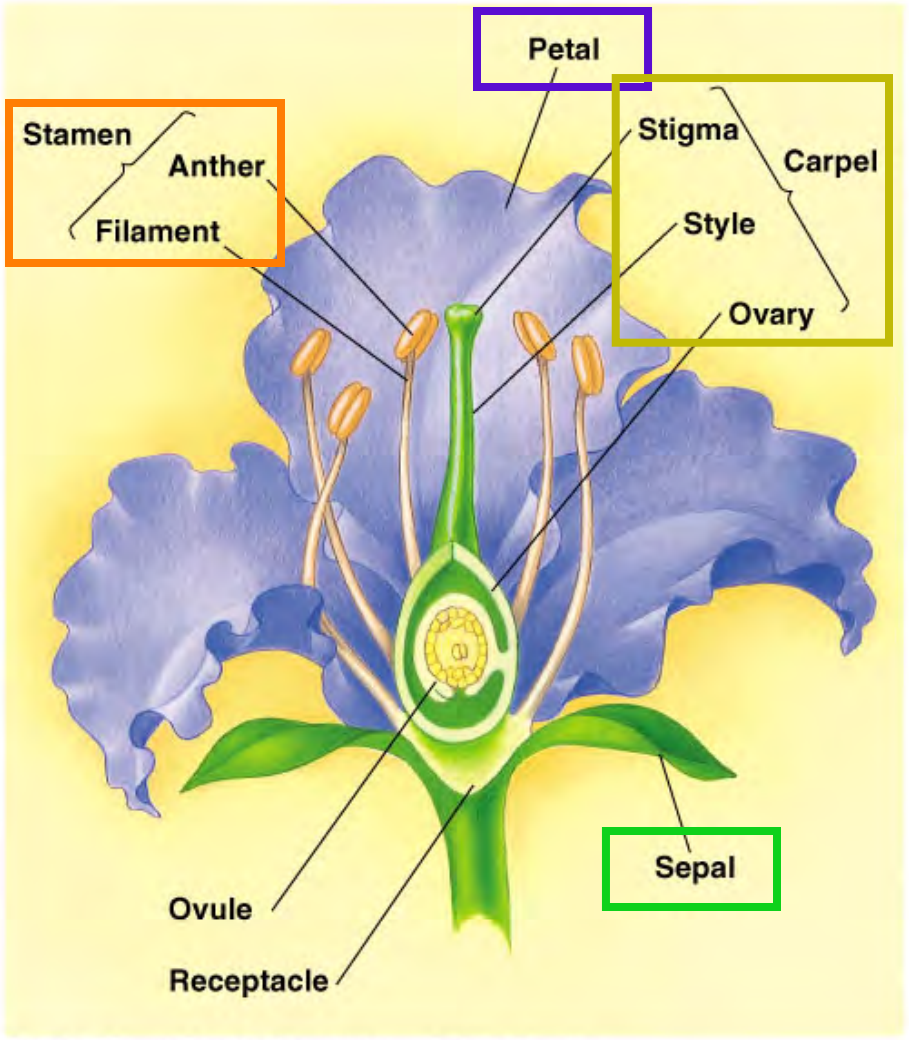
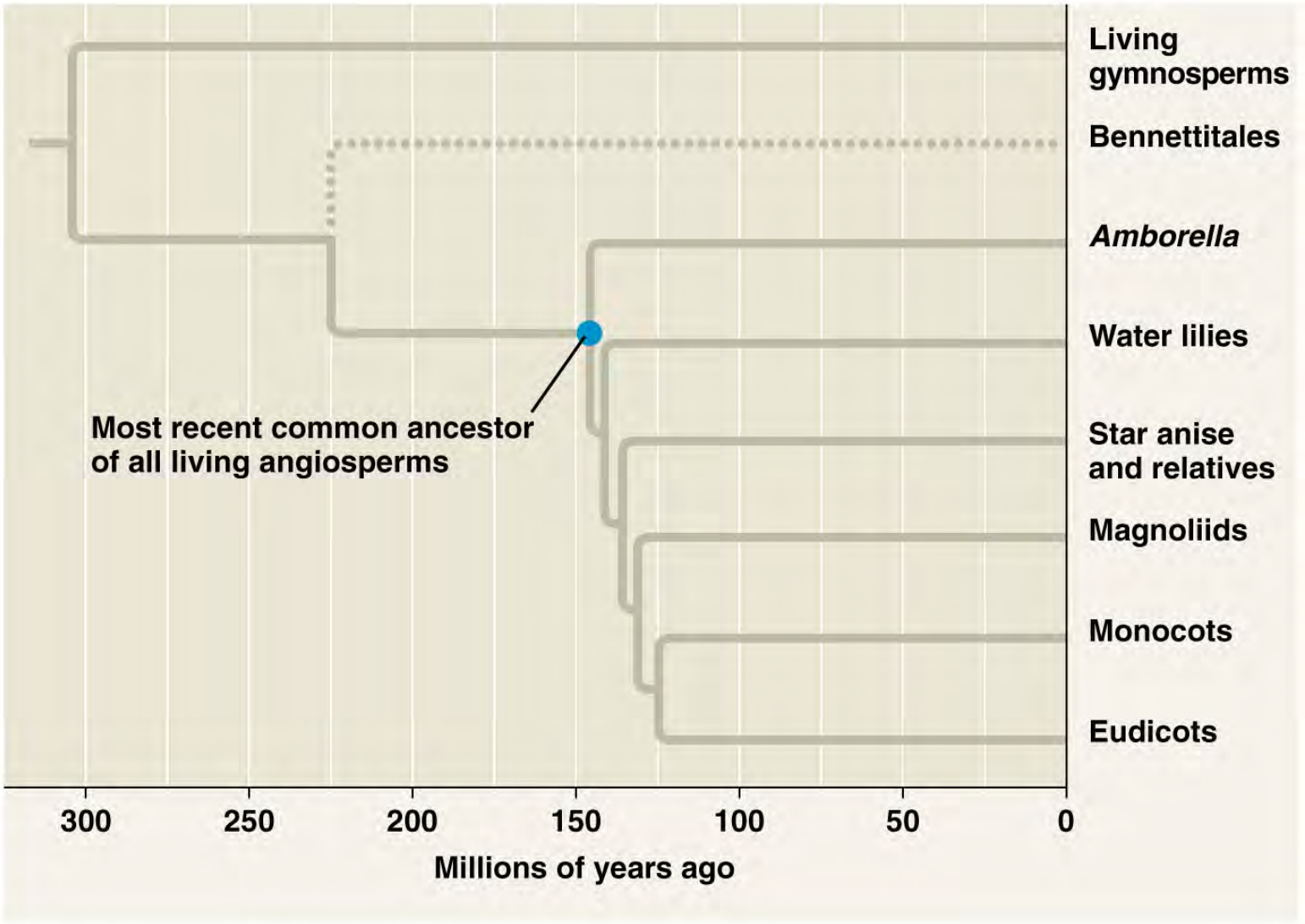


Figure 30.7 (Campbell et al.)

Angiosperm Diversity

3 major clades + several minor clades



(b) Angiosperm phylogeny

Magnoliids

Southern magnolia

cinnamon

avocado

Black pepper vines

Nutmeg = seed

Mace = seed covering

57

Monocots

Orchid

Lily

Pygmy date palm

Barley, a grass

Eudicots

Dog rose

Snow pea

Zucchini

Pyrenean oak

58

Characteristic traits:

Monocots

~1/4 of angiosperms

e.g. grasses, palms, lilies

vs.

Eudicots

~2/3 of angiosperms

e.g. roses, peas, oaks

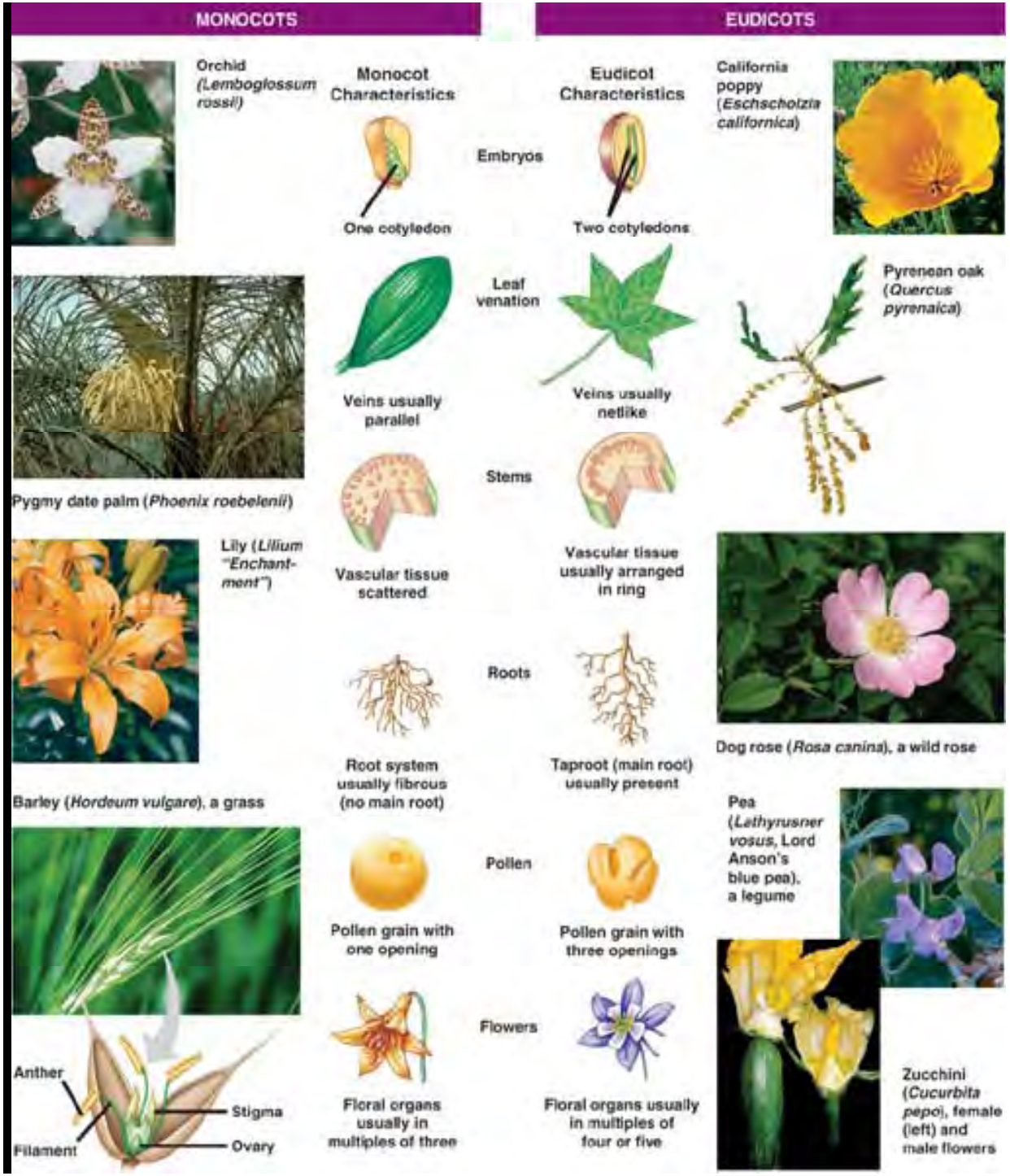


Figure 30.13 (Campbell et al)

Angiosperm Life Cycle

No antheridia or archegonia!

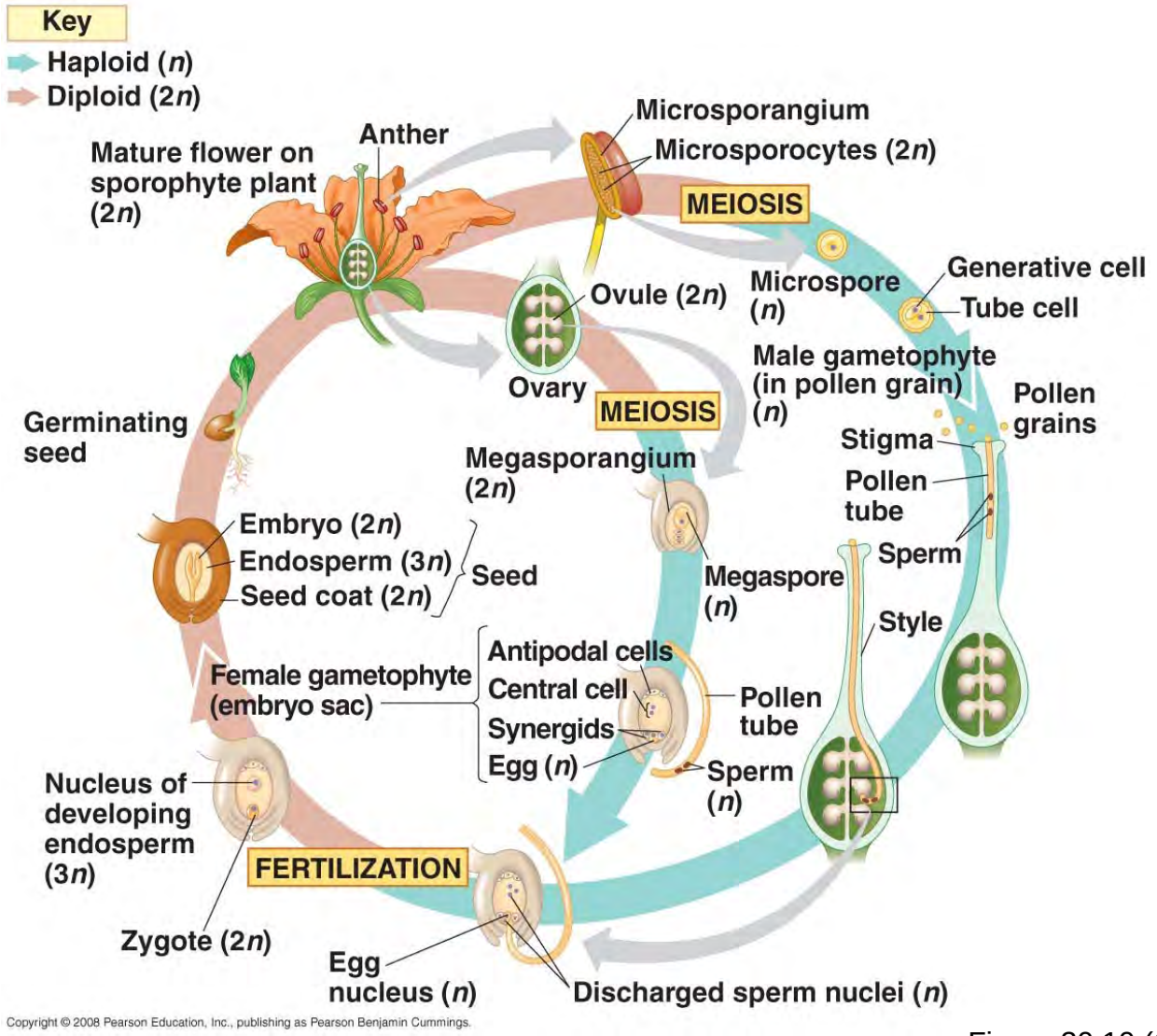
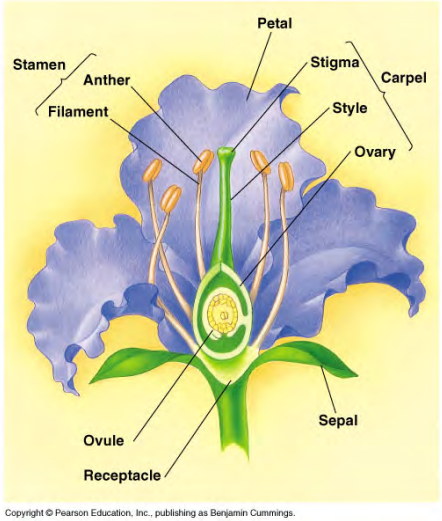


Figure 30.10 (Campbell et al.)

Male Gametophyte

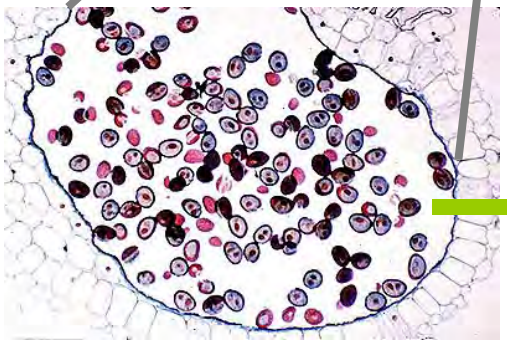
* Only <u>2 cells</u>: tube cell, generative cell

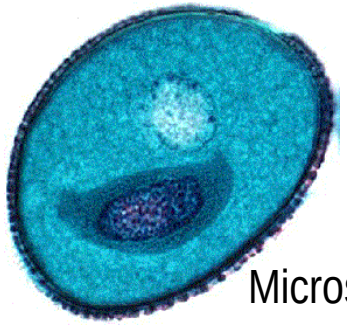


* vs. 4 cells in pine

* vs. many cells in non-seed plants

microsporangium

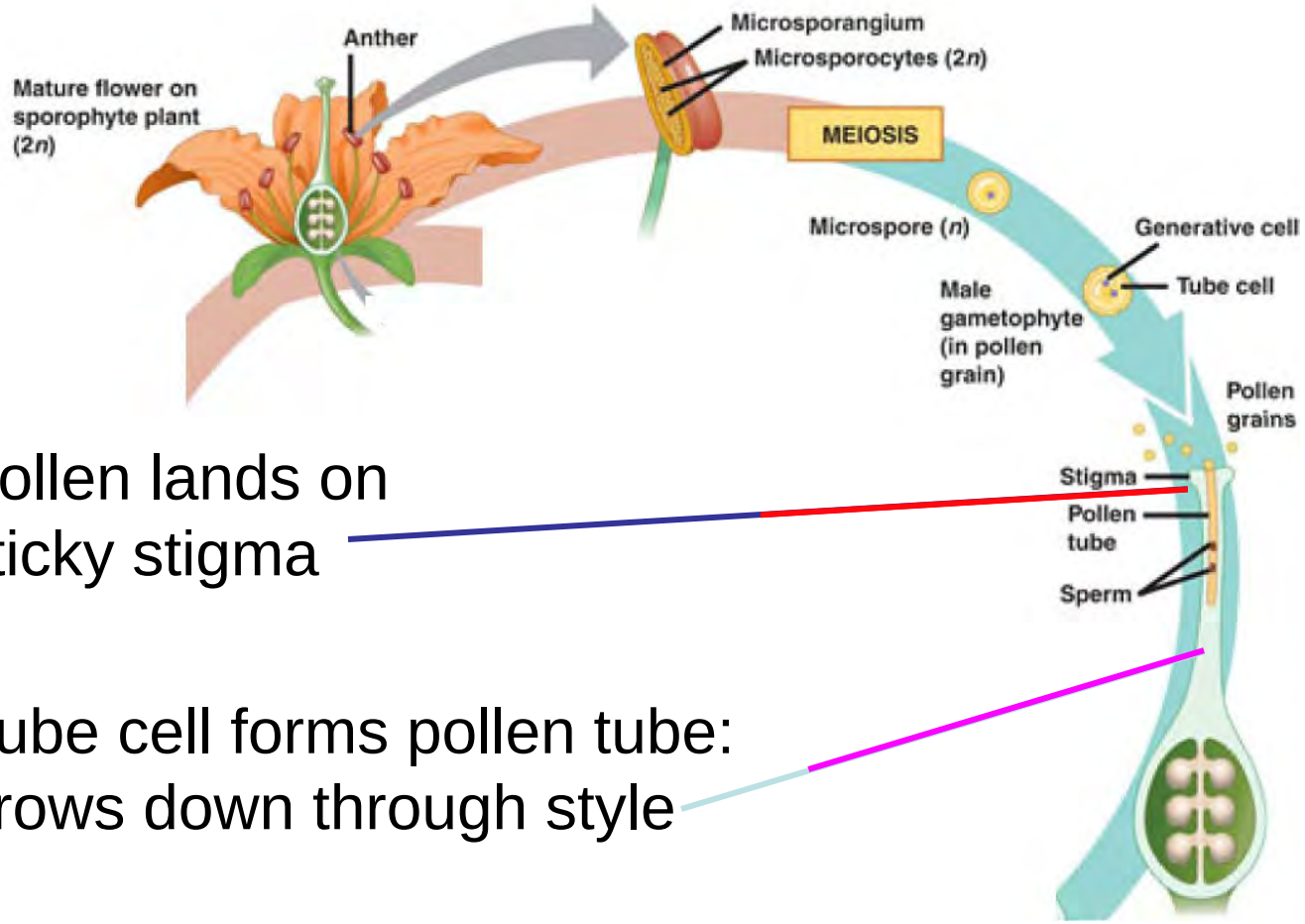




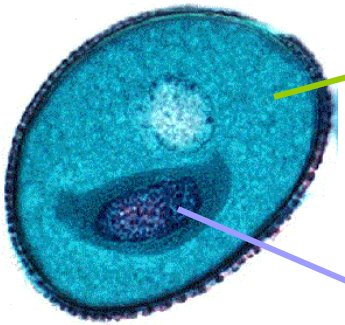
Microspore
→ male gametophyte

62

Pollination



1. Pollen lands on sticky stigma



2. Tube cell forms pollen tube: grows down through style

3. Generative cell divides into 2 sperm

*Like gymnosperms, sperm are not produced in an antheridium

Figure 30.10 (2, 4) (Campbell et al.)

63 Double fertilization

- In ovule, egg develops from 1 cell of the female gametophyte (NO Archegonium)

- Pollen tube (w/ 2 sperm) grows into ovule
  - 1st sperm (n) fertilizes egg (n) → zygote (2n)
  - 2nd sperm (n) fertilizes another cell of the female gametophyte (2n) → endosperm (embryo food supply) (3n)

Double fertilization
ONLY occurs in angiosperms.

Seed = Sporophyte Embryo (2n)
+ endosperm (3n)
+ seed coat

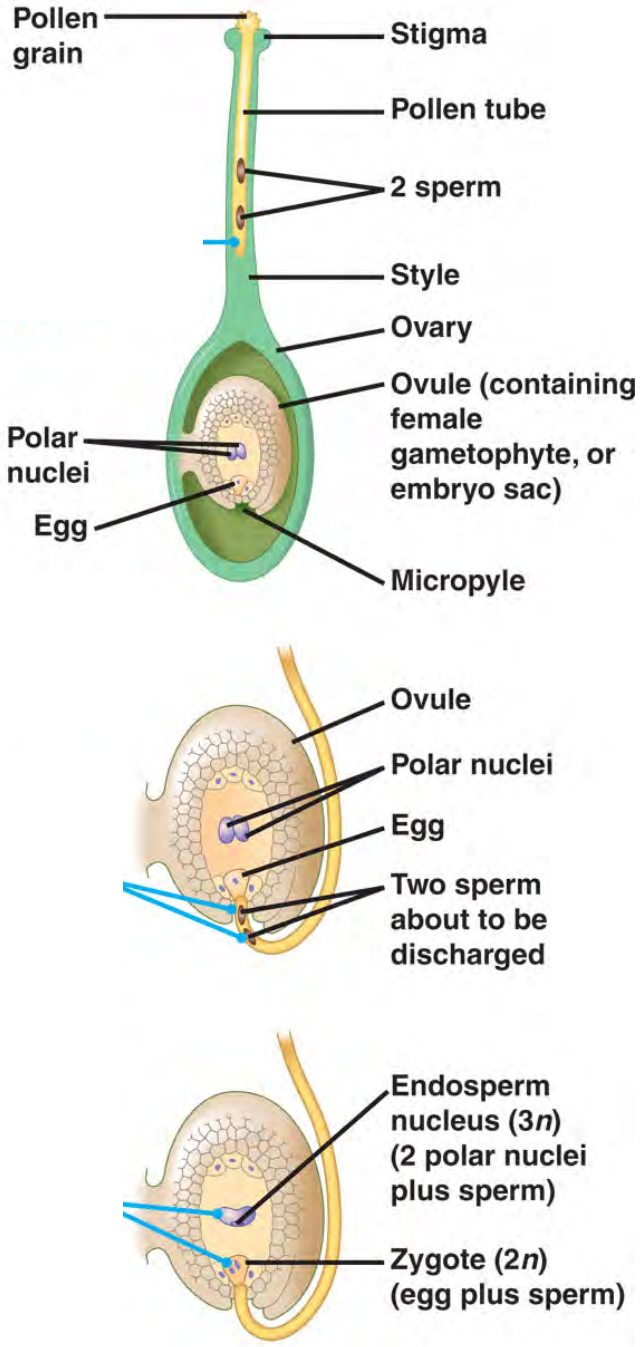
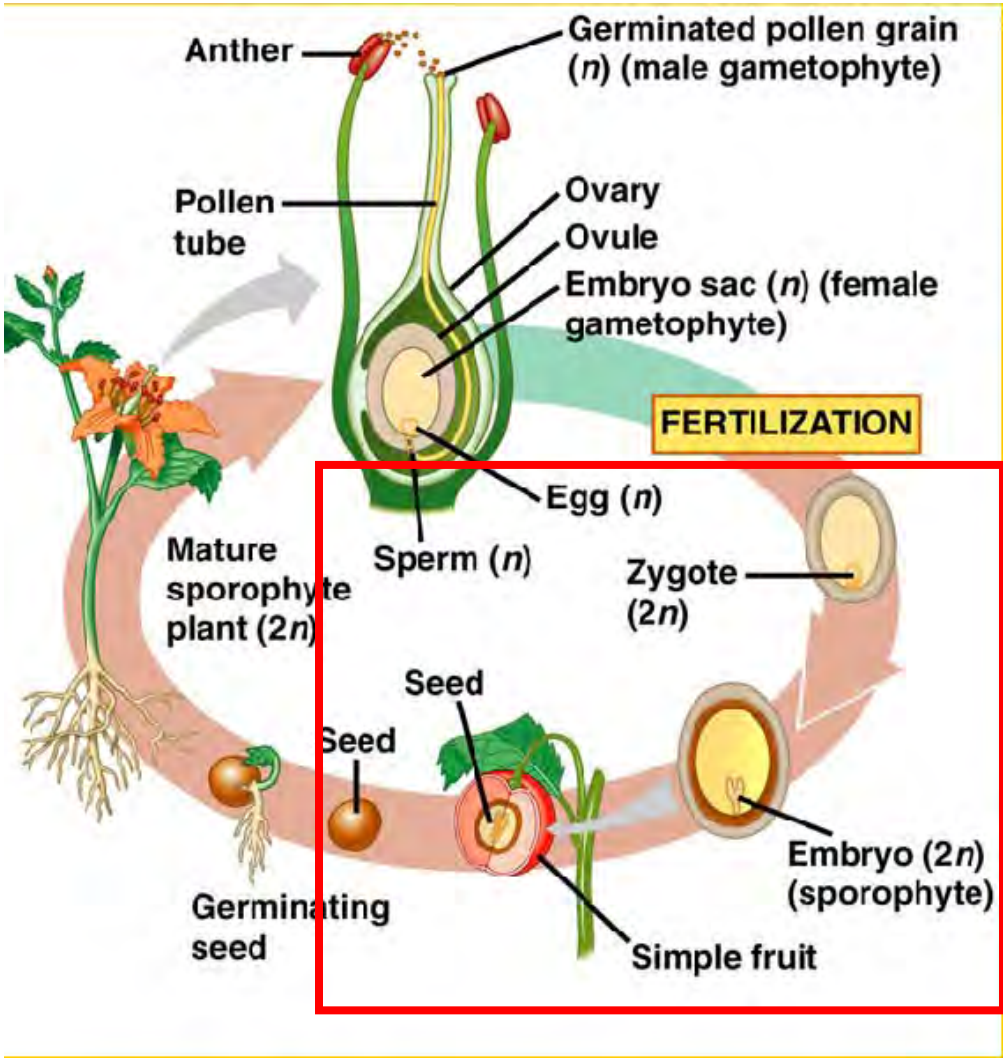


Figure 30.10 (3, 5) (Campbell et al.)

Fruit Development

Fruit = seed + thickened wall of ovary

Once the egg is fertilized, the surrounding ovary wall thickens forming a fruit.



Fruit Structure

Pericarp:

- Thickened wall of fruit
- Develops from ovary wall

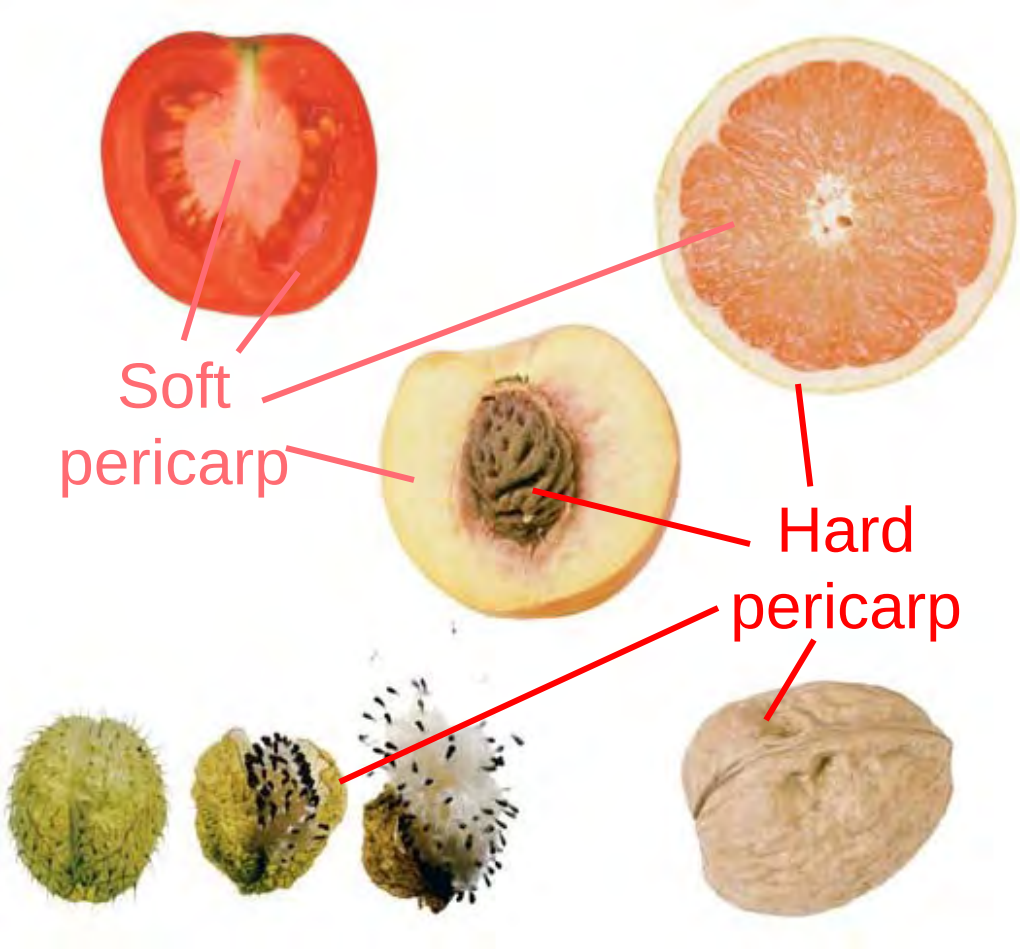
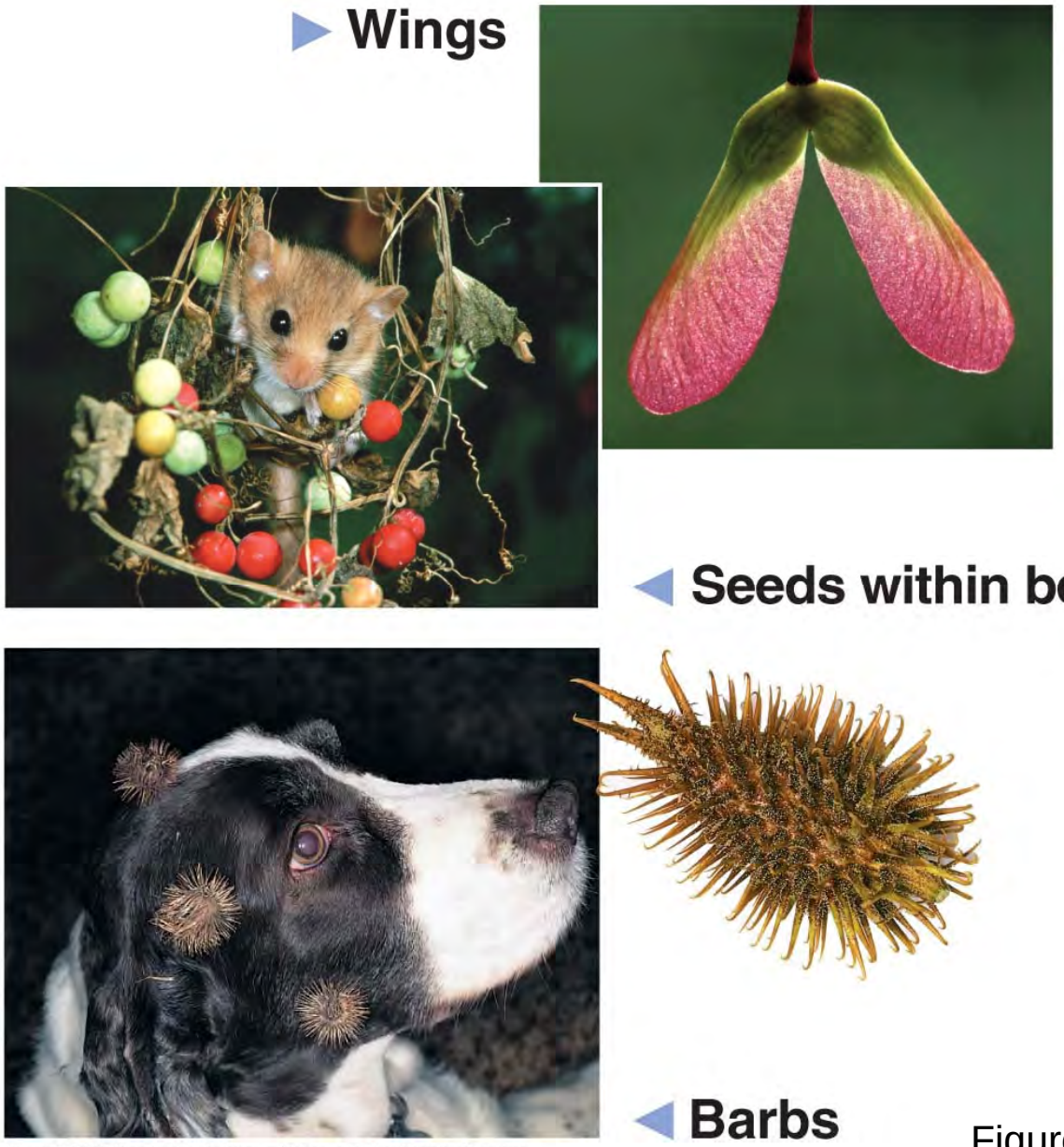


Figure 30.8 (Campbell et al)

Fruit & Dispersal



Winged fruits:
wind-dispersed

Fleshy & often colorful
Fruits with hard seeds:
Dispersed INSIDE animals

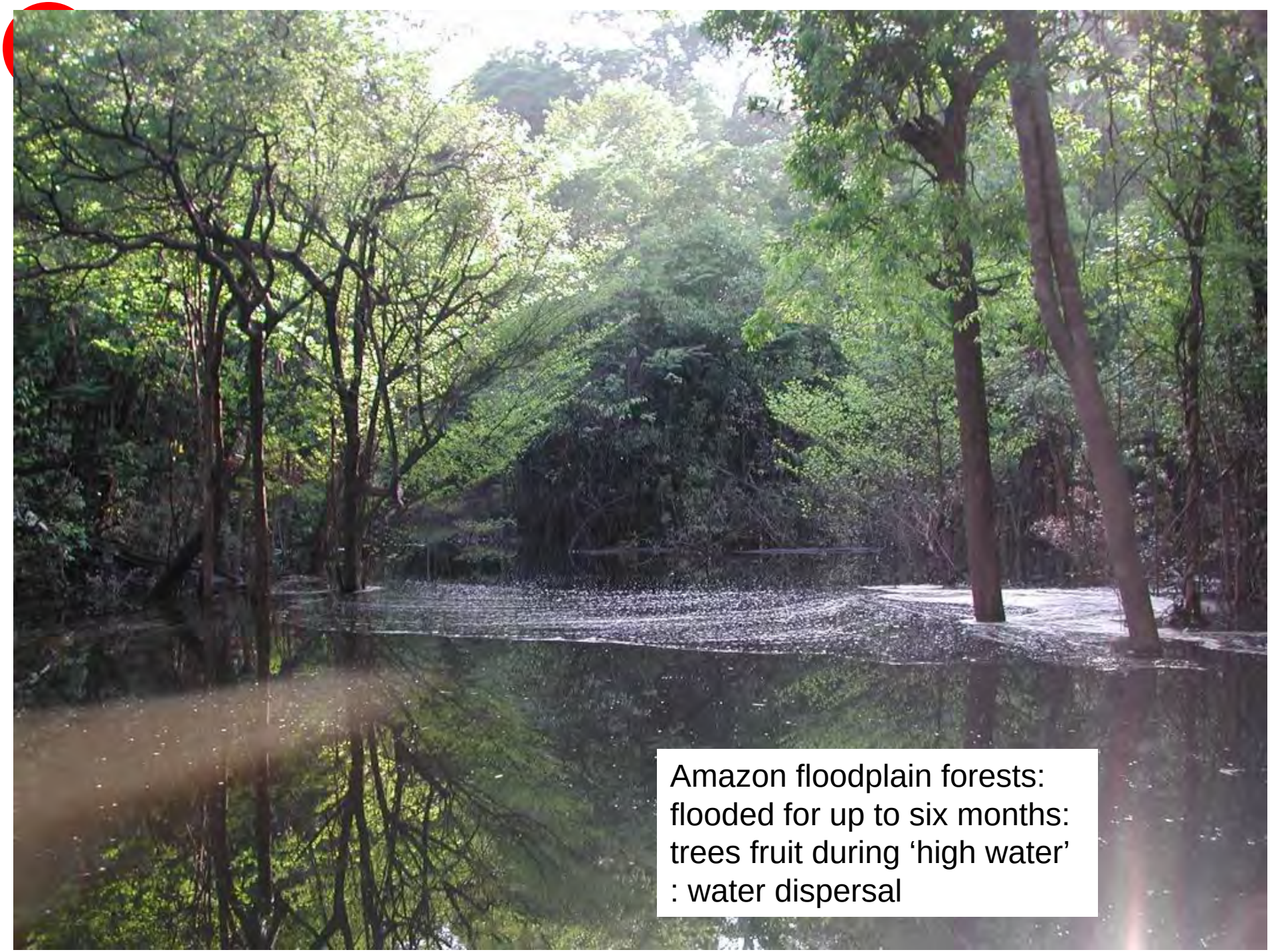
Light seeds with hooked
Structures: dispersed
ON animals

Figure 30.9 (Campbell et al)

Coconuts

Long distance marine dispersal

Huge, floating, energy packed seeds


Amazon floodplain forests:
flooded for up to six months:
trees fruit during ‘high water’
: water dispersal

Seed dispersal by fishes

seed predation by fishes

Readings on which you will NOT be tested

Fossil Angiosperms (on pg. 628)

Evolutionary links between angiosperms and animals (pg. 632)

Section 30.4

Figure 30.16

In general:

- You are NOT responsible for definitions of terms or sections included in the text but which were not discussed in lecture
- You are not responsible for the details of examples used in the text but not discussed in lecture. HOWEVER, these additional examples will help your understanding of concepts discussed and may be used on exams to test if you understand the general concepts.
- You ARE responsible for material covered in lecture but not included in the readings

Next Chapter

Chapter 32 – An Overview of Animal Diversity