Ethnobotany: BIOL 310
Study guide

Alexey Shipunov

Lectures

Contents

Outline

Homework

- Choose **3** plants from the project guidelines
- Create your 4-digit class ID

Herbarium movies and materials

See Web page

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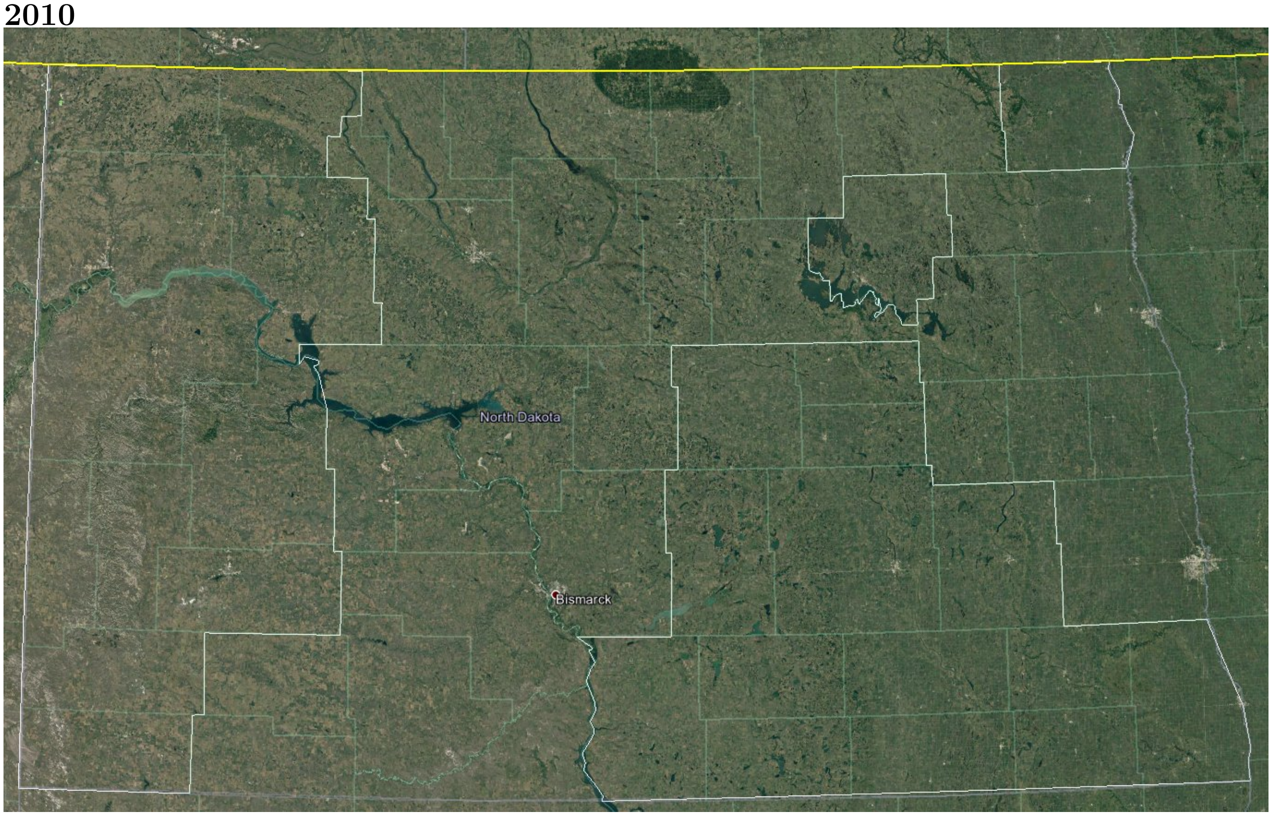

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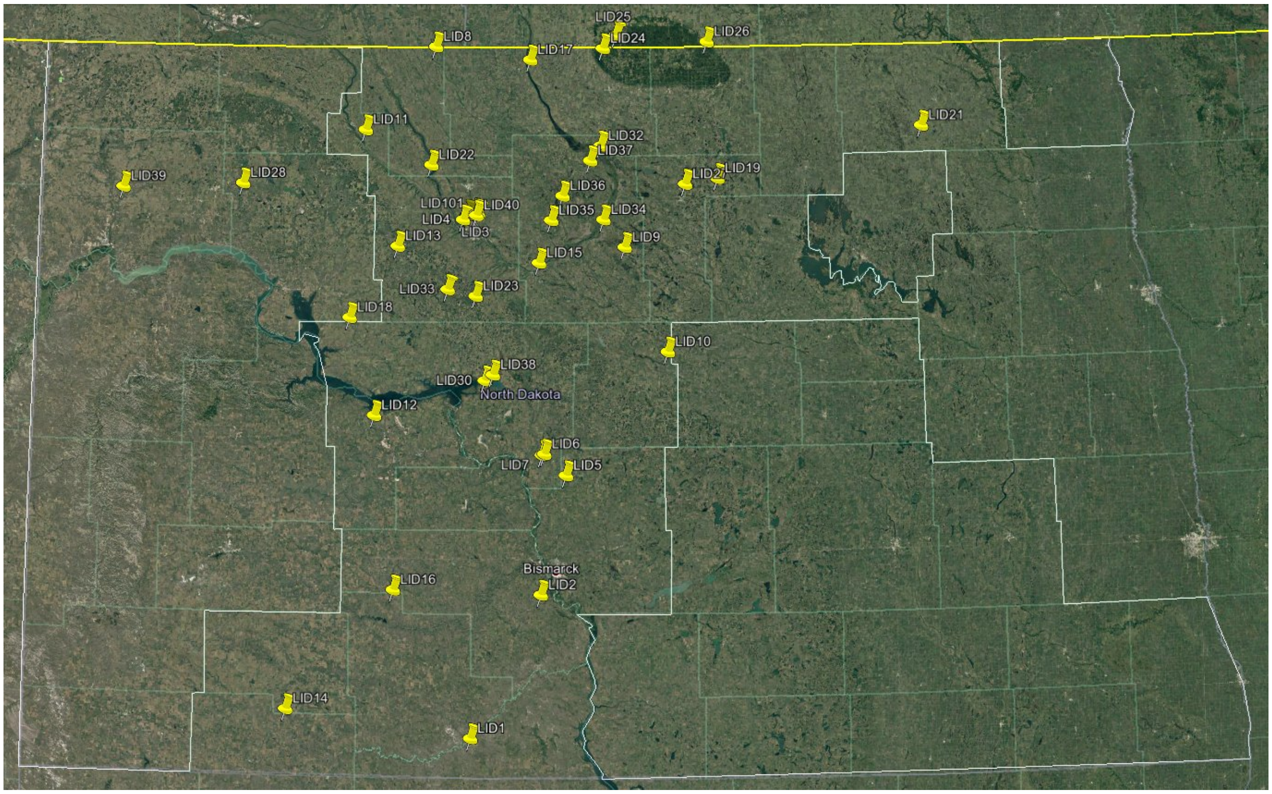
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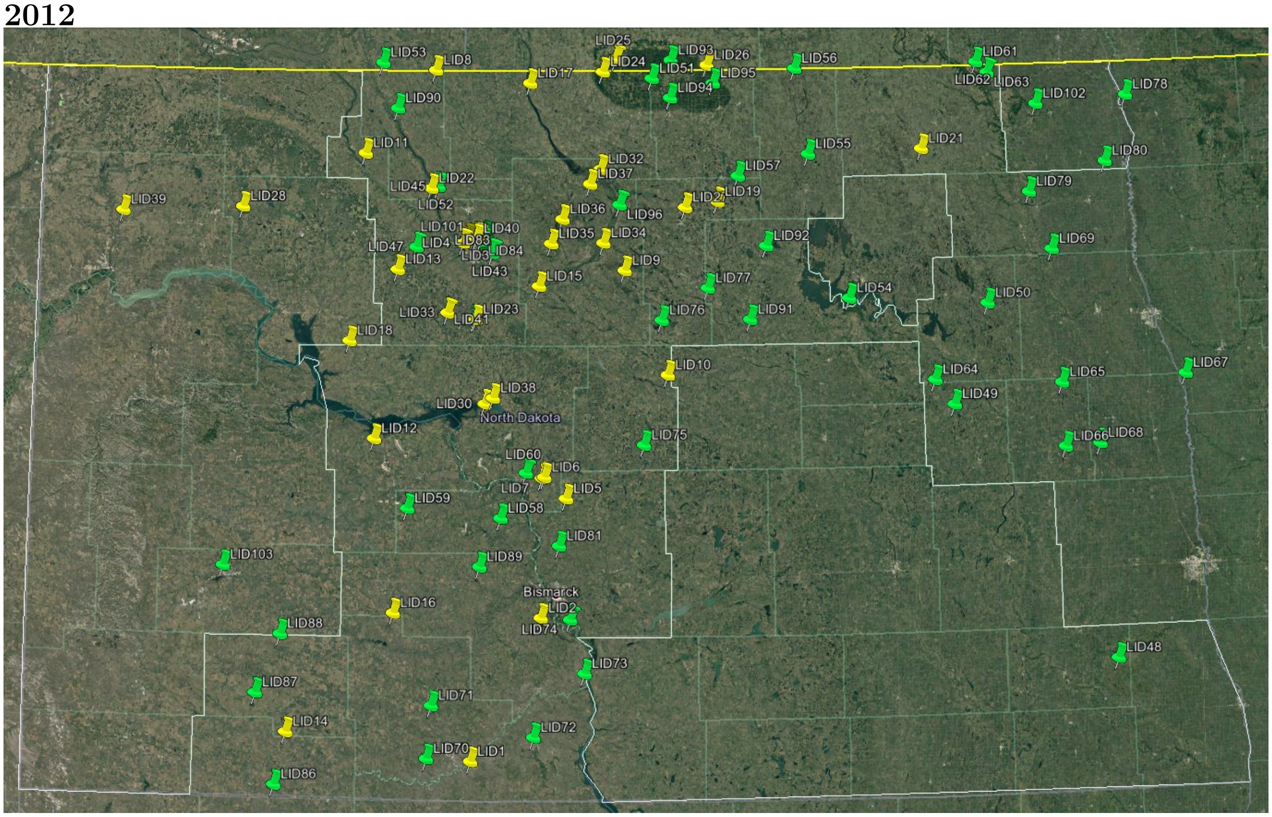
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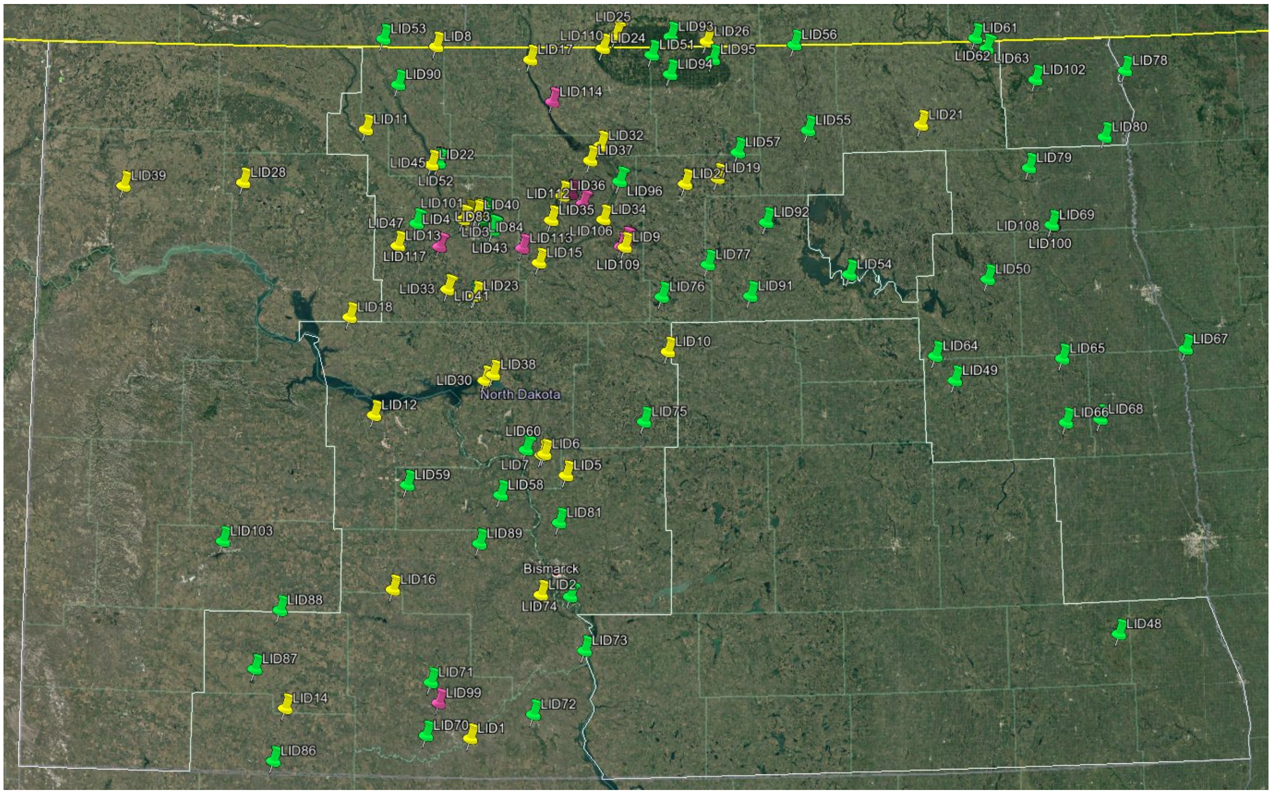
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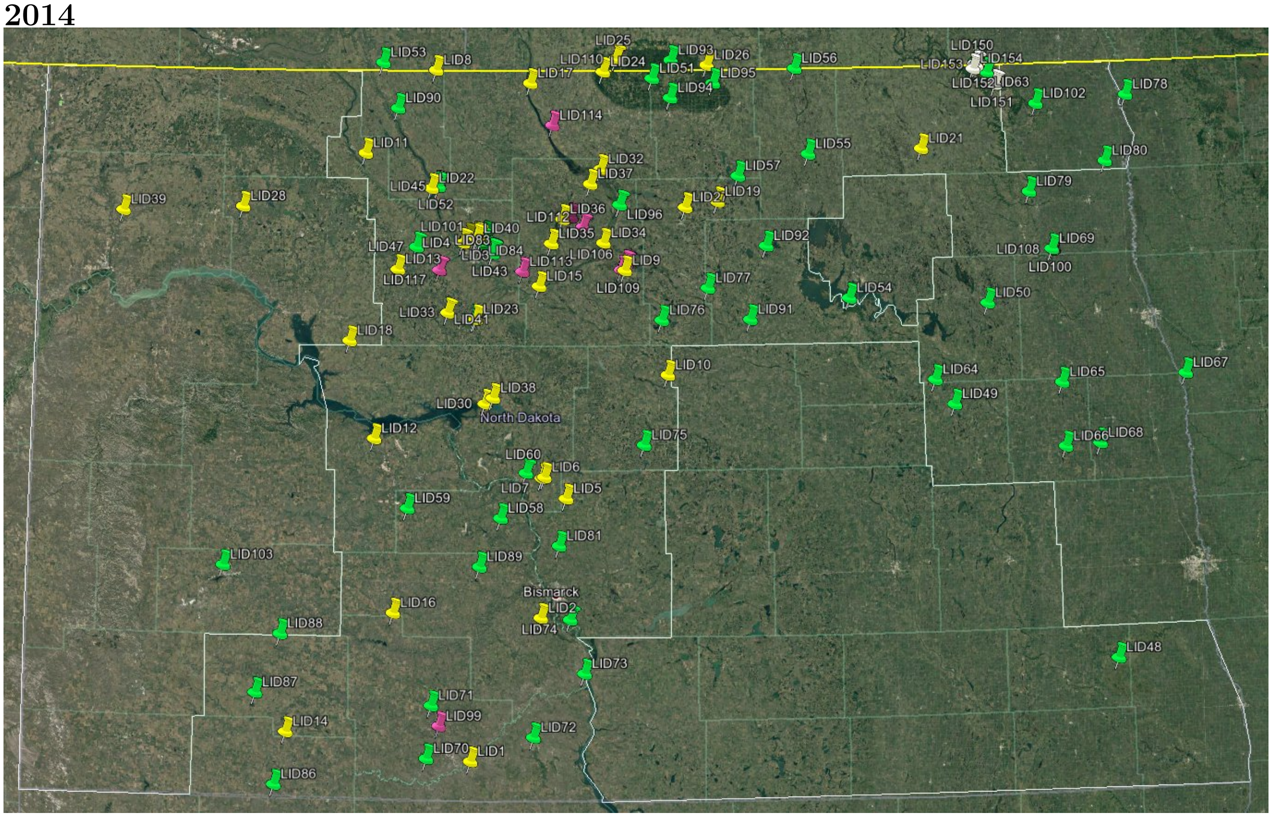
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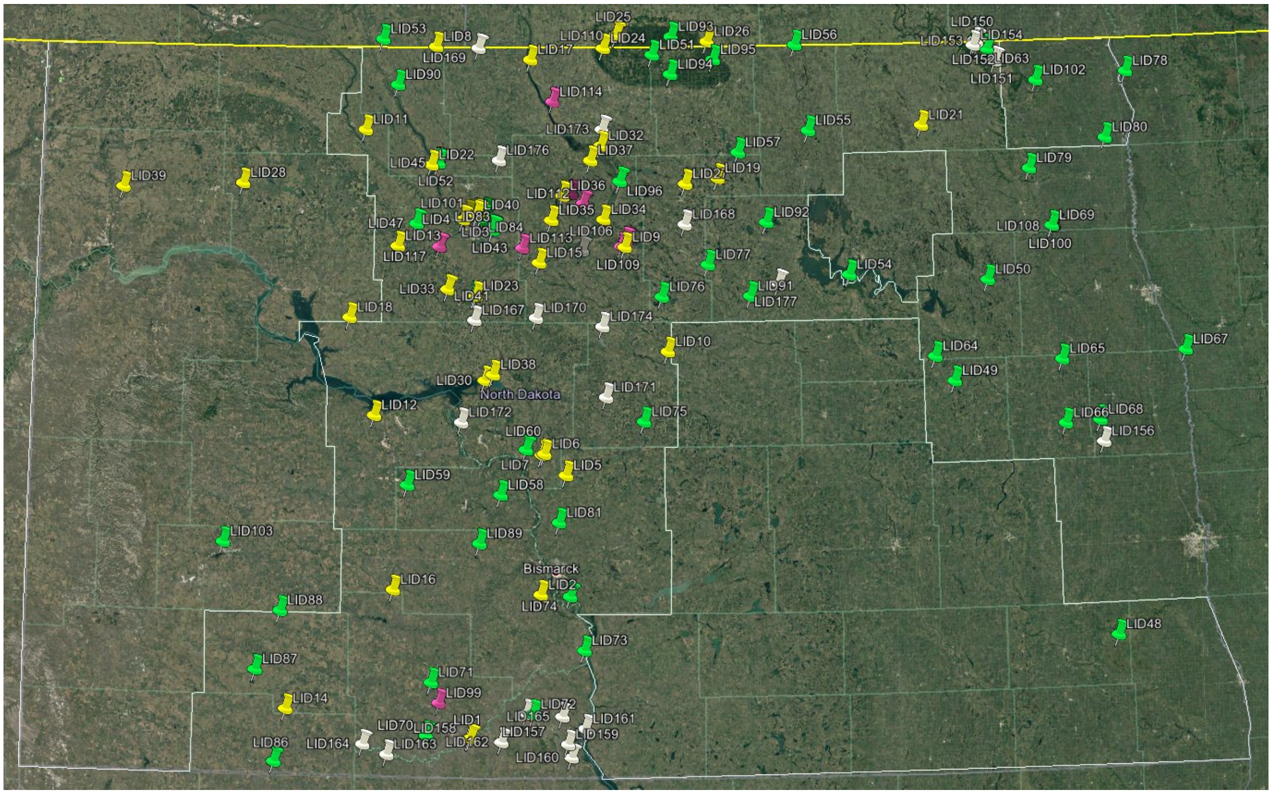
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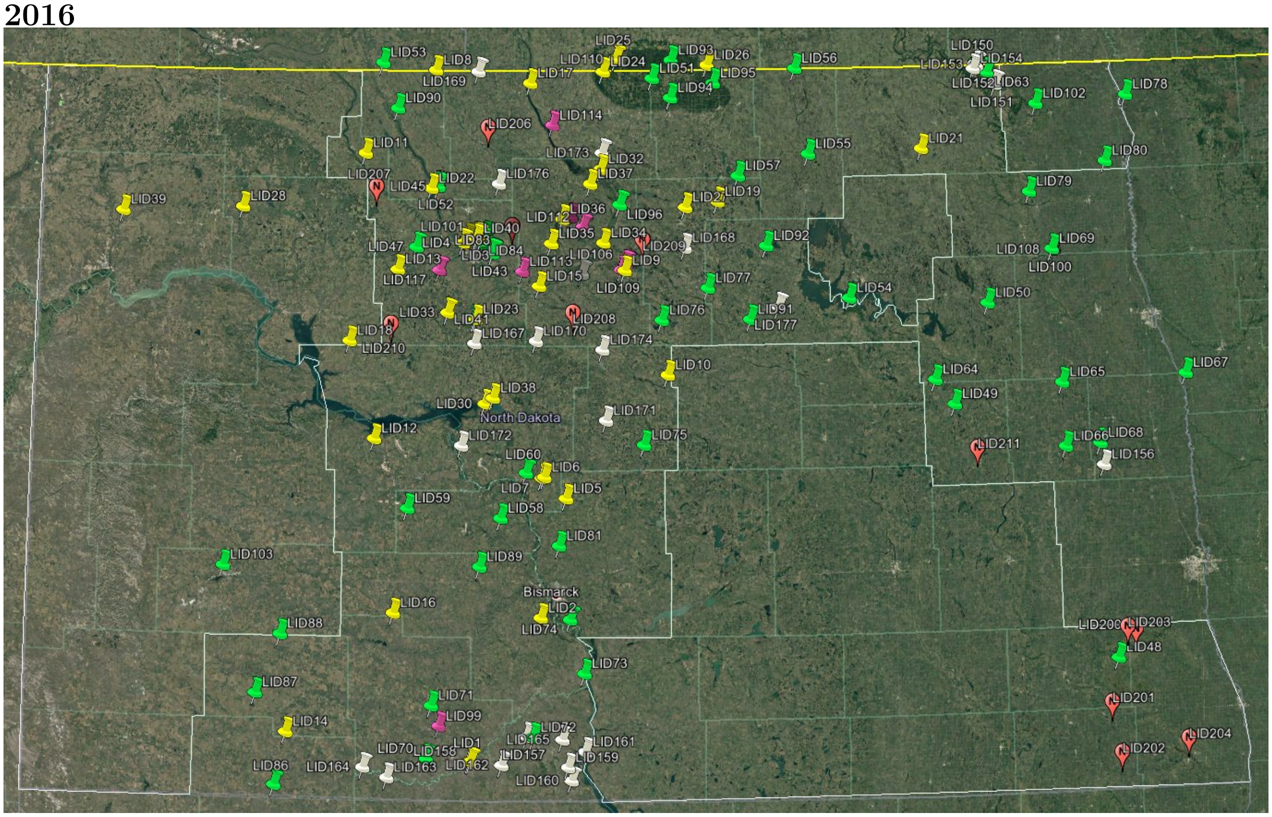
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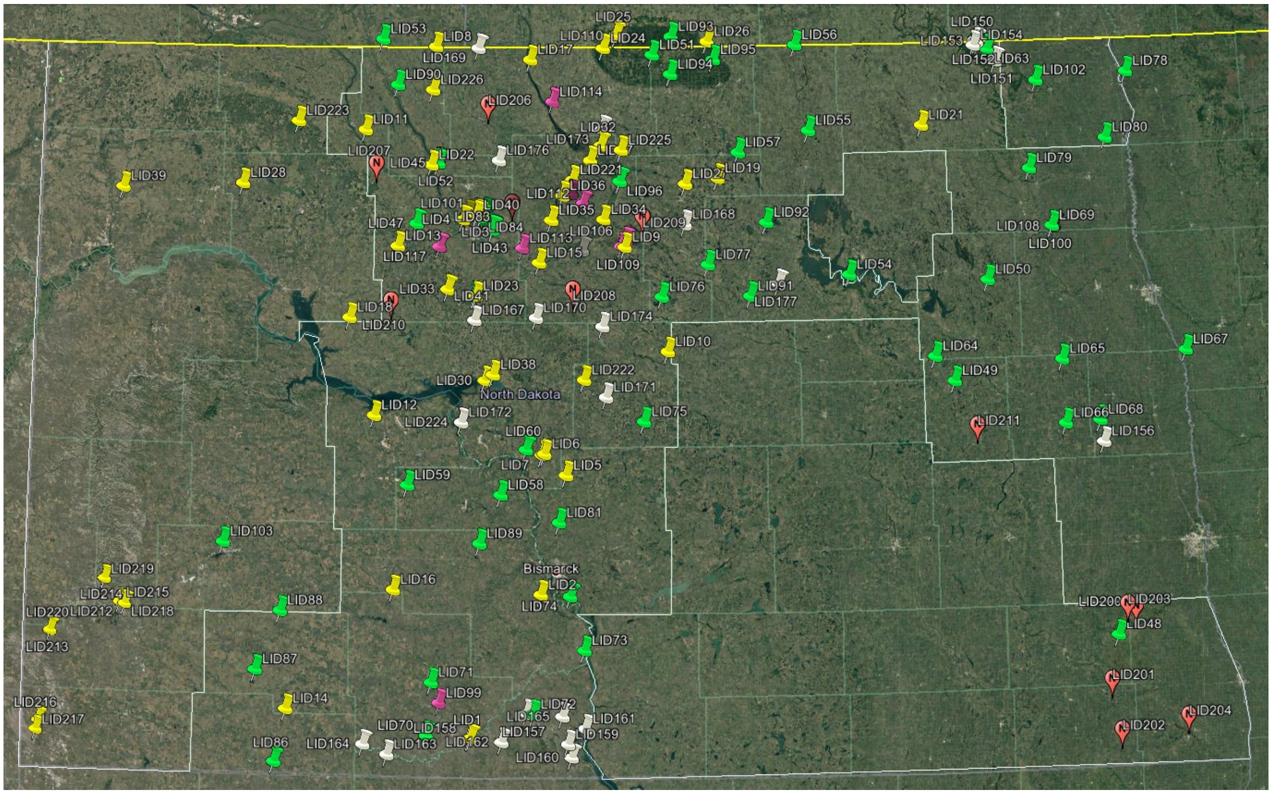

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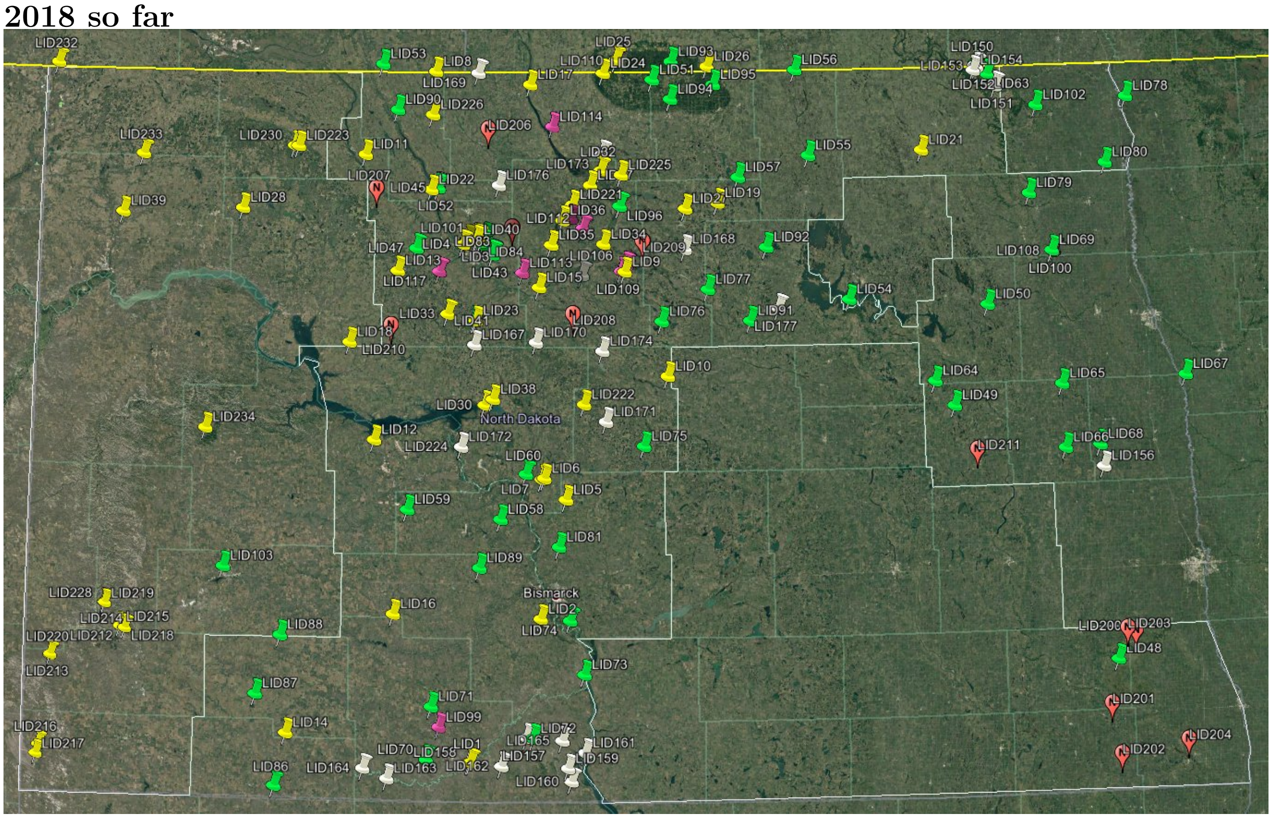
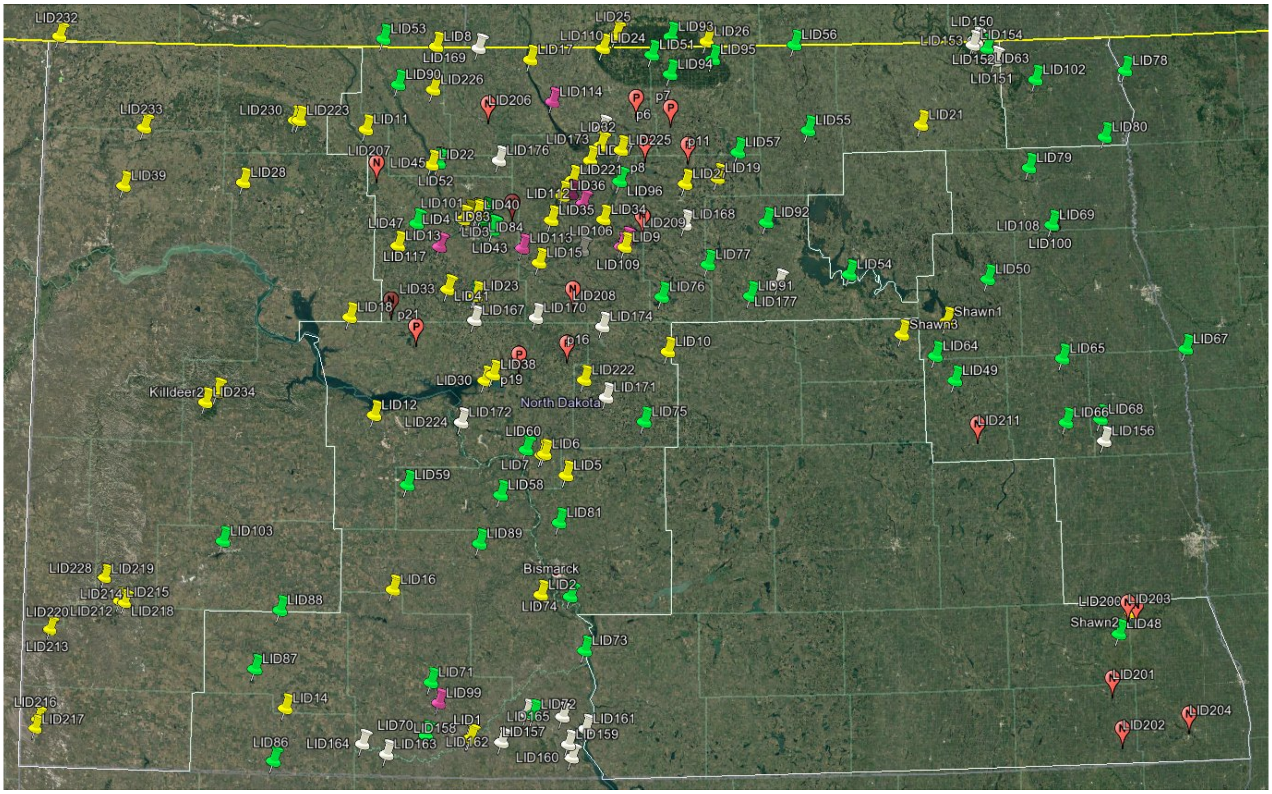


2018 plans



Help in greenhouse?

Volunteers to help on Friday, August 31st, 3pm?

1 Ethnobotany

1.1 Classification

Basics of scientific classification

- Every plant belongs to several embedded taxonomic groups
- Every group has **name** and **rank**
- Names usually are one Latin word, but species have **binary names**: name of genus + species epithet
- Most important ranks are (in sequence from bigger to smaller): **kingdom**, **family**, **genus** and **species**
- In addition, we will sometimes deal with **subspecies**, **variety**, and **cultivar**. The last is especially important for ethnobotany.

Subspecies, varietes and cultivars

- Subspecies is in essence the geographic race. Example: stinging nettle in Eurasia and North America, latter is *Urtica dioica* subsp. *gracilis*

- Variety is any distinguishable local variation. Example: bigger plantain with branched inflorescence, *Plantago major* var. paniculata
- Cultivar is a stable cultivated variety. Example: yellow roses, *Rosa banksiae* cv. 'Lutea'

Names of subspecies, varietes and cultivars

- Names of species and subspecies should be *italicized*.
- Genus name, first word of species name and cultivar name should be uppercased, others—lowercased.
- Binary species names are not perfect IDs because they change every time we change genus for the particular species.
- Programmers came up with UUID solution (like "urn:lsid:ipni.org:names:321286-2" for *Plantago major*), but these UUIDs are unfortunately not human-readable.

Taxonomic framework for cultivated plants

- All plants belong to its own kingdom, Vegetabilia.
- Most of cultivated plants are angiosperms (flowering plants, Angiospermae).
- In most cases, we will need to **memorize the family** of plant. This is important characteristic since families are stable natural units of common evolutionary origin.
- Families were first established by practical botanists, and proved to me extremely stable taxonomic groups, even when molecular tools came to science

Folk classification

- Folk classification is an ancient approach to plant diversity
- Folk taxonomic groups are created artificially, mainly for practical use (like "edible"/"non-edible")
- Typically, plant in folk classification belongs to so-called "genus-species" and then to bigger group. As an example, "raspberry" is genus-species and it in turn belong to "berries". In science, raspberry is a groups of species in genus *Rubus* which belongs to Rosaceae family.

Artificial classification of plant uses

This artificial classification will serve as a course plan:

1. **Main** plants (most important food sources): grains, starch-containing, legumes
2. **Sugar and oil** plants
3. **Fruits and vegetables**: fruits, vegetables, nuts
4. **Technical**: fiber, wood, latex, dye, feeding
5. **Aromatic and psychoactive**: spices, stimulating, narcotic
6. **Medicinal**: vitamin, ethereal oil, glycoside, alkaloid etc.
7. **Ornamental**: outdoor annuals, perennials, trees and shrubs, cut plants, indoor pot plants
8. **Harmful**: poisonous, weeds, spiny, stinging

- We will approach ethnobotany in accordance with artificial classification of plant uses

References

[1] A. Shipunov. *Ethnobotany* [Electronic resource]. 2011—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_310`

Outline

2 Main food source plants: grains

2.1 Introduction to grasses

Grasses (Gramineae, or Poaceae)

- One of the biggest family of flowering plants
- Grasses (except bamboos)
- Hollow stems
- No main root, underground rhizomes form "mats" (tussocks)
- Compound inflorescences
- Simplified, wind-pollinated flowers
- Fruit is *caryopsis*, seeds should be *threshed* from fruits

Groups inside a family

- C_3 grasses—bamboos, wheat (*Triticum*), rye (*Secale*), barley (*Hordeum*), rice (*Oryza*), indian rice (*Zizania*), oat (*Avena*)
- C_4 grasses—corn (Zea), sugar cane (*Saccharum*), sorghum (*Sorghum*), millet (*Panicum*)

C_3 and C_4 plants

- C_3 plants have photosynthesis effective when temperatures are "cool", below 24° C; if temperature increases, photorespiration makes photosynthesis less effective
- C_4 plants show much better results growing on temperatures higher than 24° C; they are best suited for tropics

Triticeae tribe

- Tribe is a taxonomic group which is bigger than genus but smaller than family
- Triticeae are small-sized grasses with one spike per stem, spike scales with long awns, caryopses rounded, contain high percent of starch and little amounts of proteins
- Several wild genera (most important are *Aegilops* and *Agropyron*: bluegrass and wheatgrass, North Dakota state grass is *Pascopyrum*), and cultivated **wheat** and **rye**

2.2 Wheat (*Triticum*)

Main features

- One of three most important plants ever
- 30% of world grains
- Yield is up to 2.4 tonnes/hectare (2,400 kilograms per 10,000 m^2); Guinness book record is 21 ton/ha (New Zealand, 2010)
- Main source of breads and bread-like products (similar products from other grains are growing hard much faster mostly because of more proteins)
- 70-75% of hydrocarbonates (starch) and 10% of proteins; 100 g give $\approx$ 350 calories
- However, wheat is not a rich source of lysine (indispensable amino acid), therefore, it is important to eat protein sources if menu is rich of wheat (pizza!)

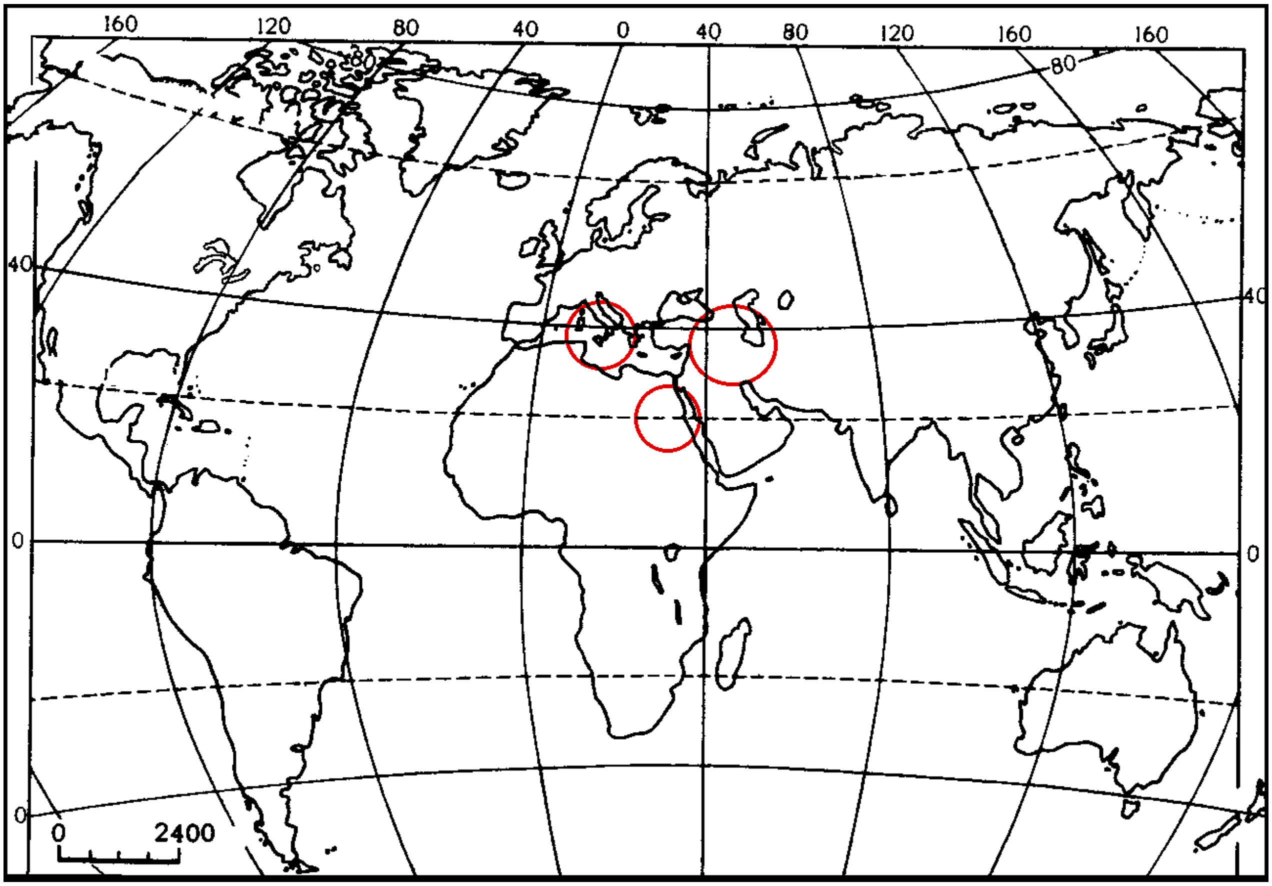
Morphology of wheats

- Annuals, root system of secondary and especially adventive (adventitious) roots (roots which grow out of the stem)
- From 1–6 long stems with spikes per plant
- Flowers have 3 stamens
- Both wind- and self-pollinated
- Genus has more than 20 species

History of cultivation

- One of the most ancient cultivated plant, first traces date $\approx$ 6–7,000 yr ago
- Main centers: West Asia (Iran, Mesopotamia and Caucasus), ancient Egypt, Mediterranean region
- During the history, "ancient" species (like eincorn) cede to "modern" species (like hard wheat)

Centers of wheat origin and cultivation



Features of wheat agriculture

- Wheats are well adapted to relatively dry regions, with amount of precipitation 600–800 mm per year (sometimes survive even with 400 mm)
- Easily endure small (!) droughts
- Temperatures for flowering should be in 18–28° C range; seedlings may survive under a snow; do not like high temperatures and do not give high yield in tropics (however, do not grow well in cold regions)
- Most critical for cultivation is the soil quality: should be light, well-aerated, rich of nitrogen (this is why wheats grow better after legumes)

Species and species groups

- Diploid species ($2n = 14$): eincorn
- Tetraploid species ($2n = 28$): emmer wheat, hard wheat
- Hexaploid species ($2n = 42$): common wheat

Common wheat is a "genetic monster" with the *chimeric genome.*

Summary

- Wheats (*Triticum*) are ancient cultivated plants, originated in West Asia
- Tetraploid and hexaploid wheats are intergeneric hybrids

For Further Reading

References

[1] P. Stamp. *Virtual cereal cultivar garden* [Electronic resource]. 2008. Mode of access: `http://www.sortengarten.ethz.ch/?content=start`

[2] A. Shipunov. *Ethnobotany* [Electronic resource]. 2011—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_310`

Outline

3 Main food source plants: grains

Species and species groups

- Diploid species ($2n = 14$): eincorn
- Tetraploid species ($2n = 28$): emmer wheat, hard wheat
- Hexaploid species ($2n = 42$): common wheat

Common wheat ia a "genetic monster" with the chimeric genome.

Spring and winter races

- Most cultivated species have two races
- *Winter race* does not flower if planted in spring; it typically grows under a snow and should be planted in autumn
- *Spring race* does not survive under snow; it should be planted in spring
- These two forms are partly genetically inherited; it is possible, however to change behavior from winter to spring (vernalization: hard selection + epigenetic effects)

3.1 Ancient wheats

Triticum monococcum

- Eincorn, or *Triticum monococcum* is probably the most ancient cultivated plants ever (cultivated from neolithic age)
- Do not require irrigation, survive with low precipitation but yield is also low
- In spikes, spikelets have only one flower
- Relatively tall (up to 1 m)
- Now cultivated rarely, one of the last centers of cultivation is Spain

Eincorn, *Triticum monococcum*

Triticum dicoccum

- Emmer wheat (farro, *Triticum dicoccum*) has fragile spike and more than one flower per spikelet
- Sustainable for droughts, bacterial and fungal infections, insects, lower temperatures but has extremely low yield
- Still cultivated in some European countries (Italy, Albania); main food source in Ethiopia
- Used also as a genetic source for hybridization and selection

Emmer wheat (*Triticum dicoccum*)

3.2 "Contemporary" wheats

Triticum durum, hard wheat

- Hard wheat (*Triticum durum*) is a second most cultivated wheat, probably of Mediterranean origin
- Small-sized, fast-growing
- Almost exclusively self-pollinated
- Has high yield and grains of best quality among wheats containing more proteins

Hard wheat (_Triticum durum_)

***Triticum durum* 2**

- Winter races are rare
- Requires irrigation
- Better suited for cultivation in tropics
- The highest diversity is now in Italy (widely used for a pasta!)
- Now widely cultivated in tropics (India, Africa)

***Triticum aestivum*, common wheat**

- Common (soft) wheat (*Triticum aestivum*) is a main cultivated wheat

- There are more than 4,000 cultivars of common wheat
- Small- and medium-sized but slow-growing when young
- Often cross-pollinated
- High yield, grains are rich of starch

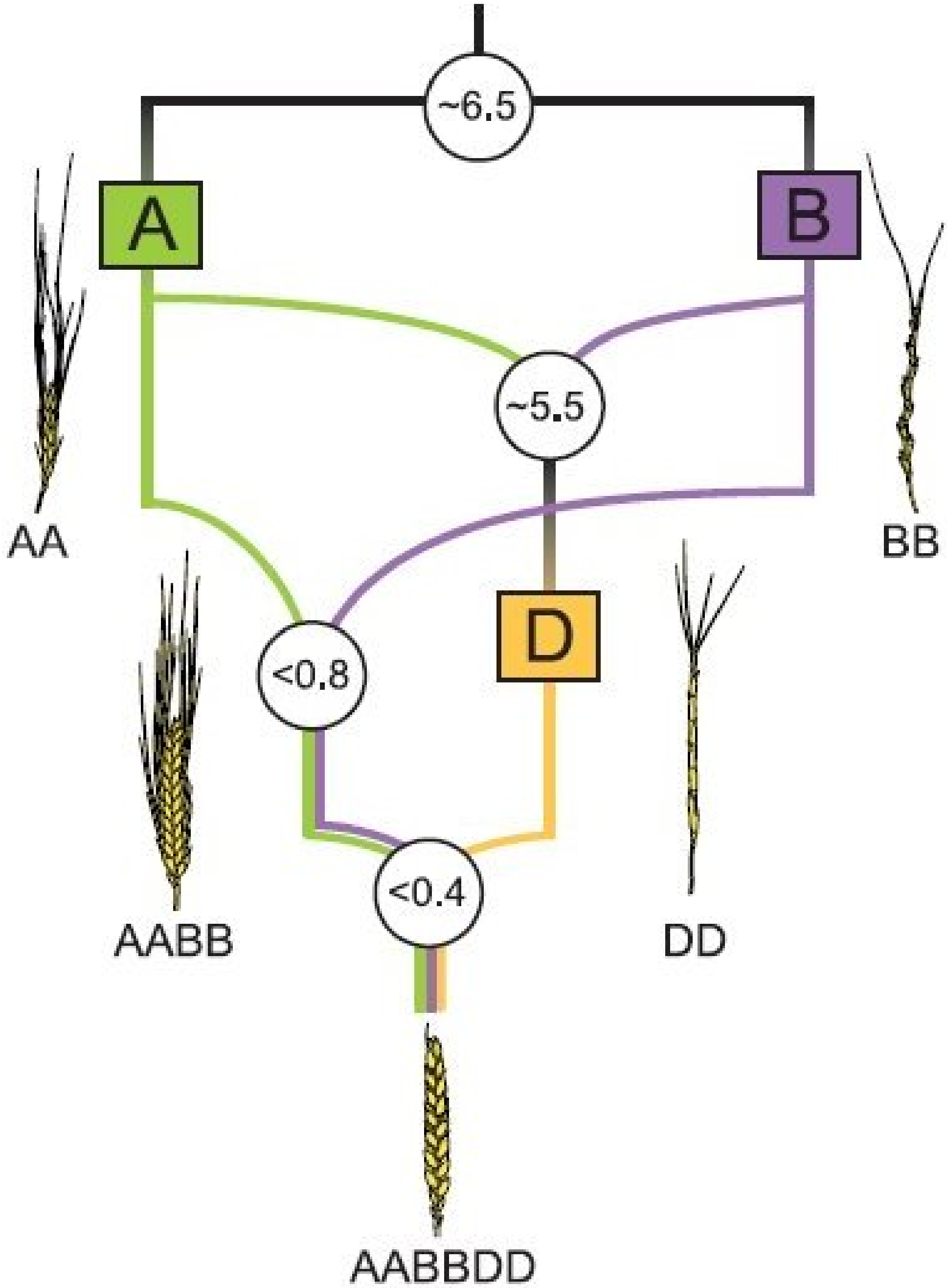
Common wheat (*Triticum aestivum*)

***Triticum aestivum* 2**

- Has many winter and spring races
- Typically, does not require irrigation

- Cultivated mostly in temperate and subtropical regions around the world
- Main cultivated wheat in U.S.

Origin of wheats



- Tetraploid and hexaploid wheats are **inter-generic hybrids** *allopolyploids* between diploid wheats and *Aegilops* (goatgrass)!
- Tetraploid wheats have genome AABB (A from diploid wheats, B from *Aegilops speltoides*)
- Hexaploid wheats have genome AABBDD (D from *Aegilops tauschii*)

Summary

- Wheats (*Triticum*) are ancient cultivated plants, originated in West Asia

- Tetraploid and hexaploid allopolyploid wheats are intergeneric hybrids

For Further Reading

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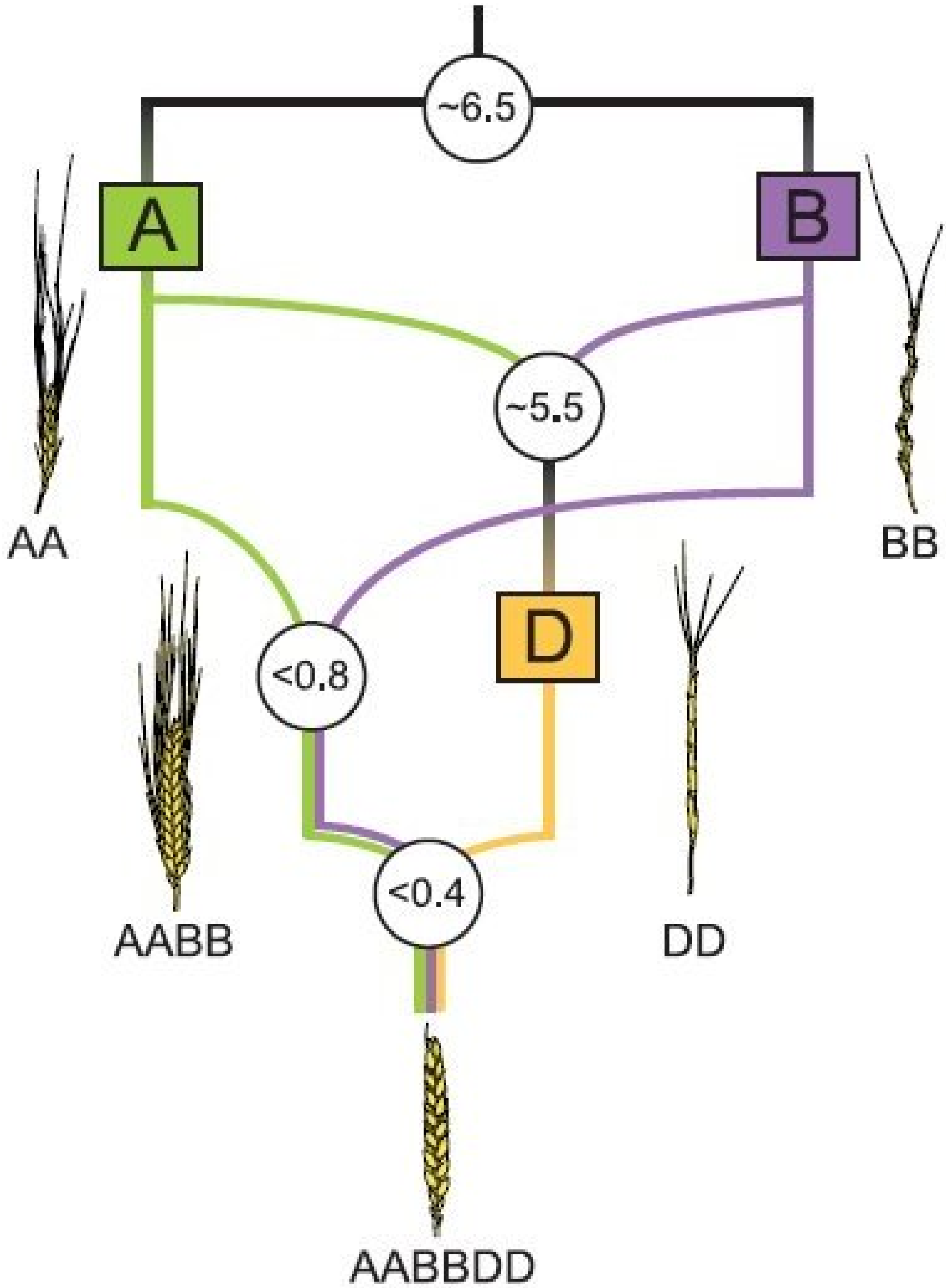
Outline

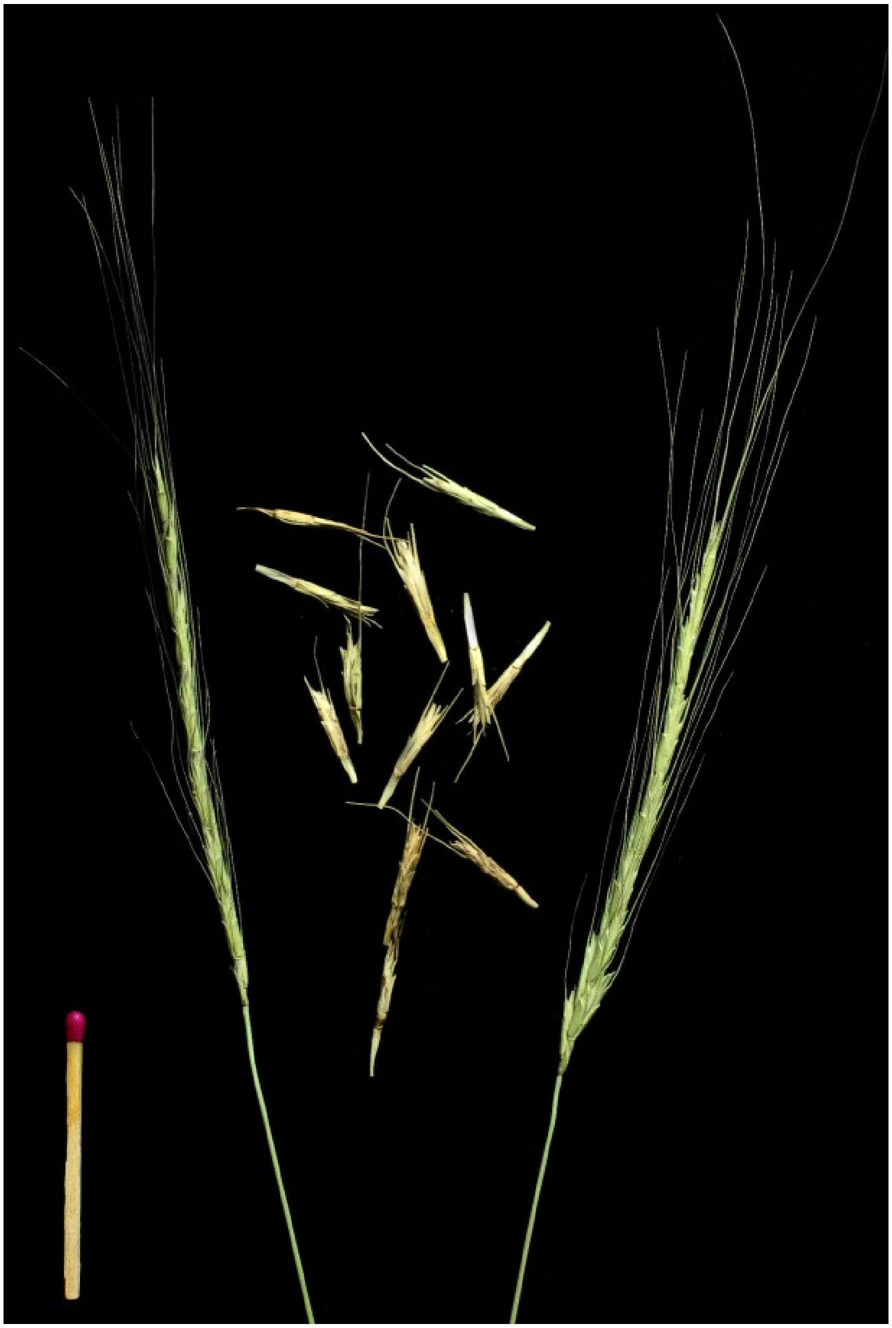
4 Main food source plants: grains

Origin of wheats



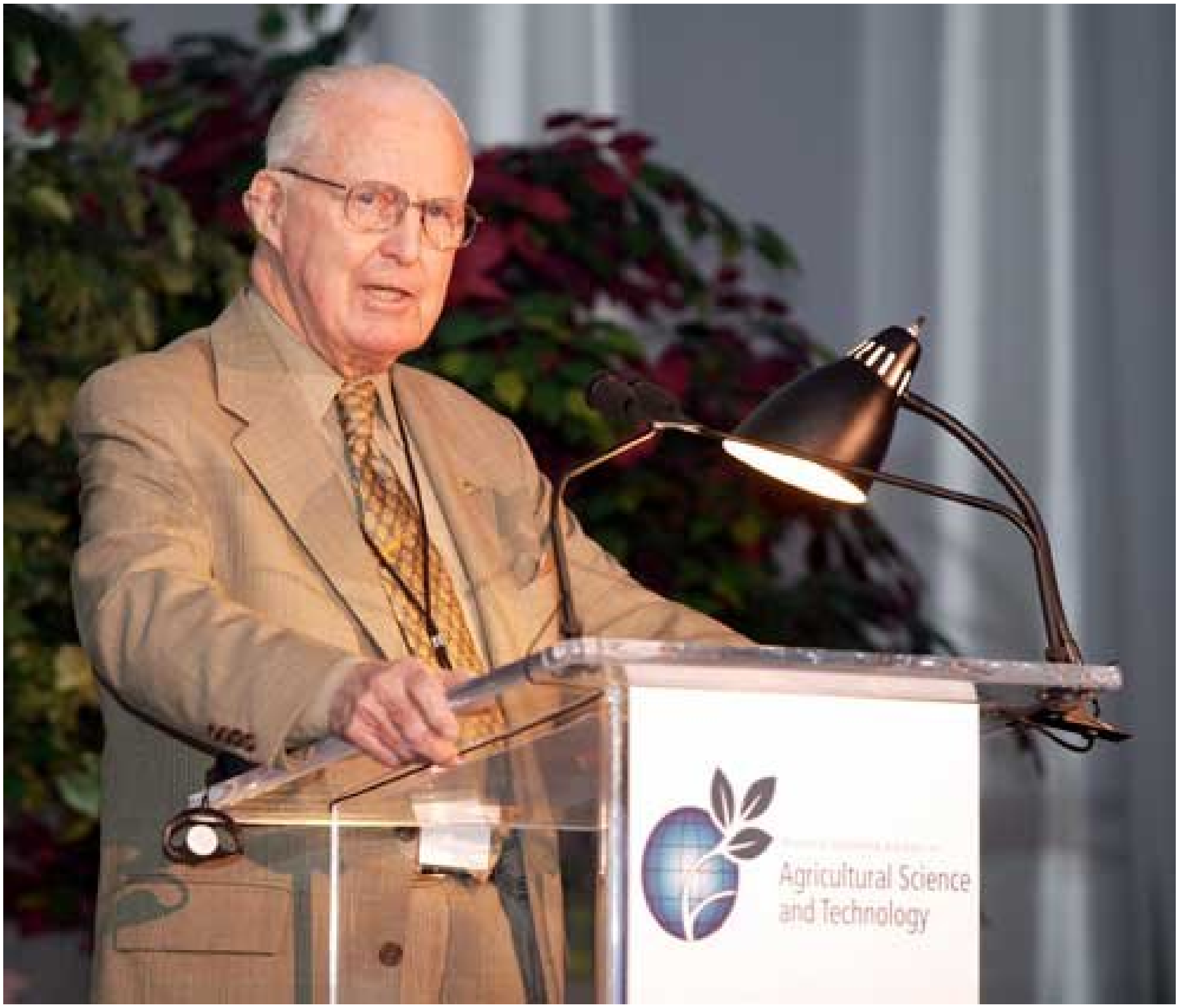
- Tetraploid and hexaploid wheats are *allopolyploids*, **inter-generic hybrids** between diploid wheats and *Aegilops* (goatgrass)!
- Tetraploid wheats have genome AABB (A from diploid wheats, most likely *Triticum urartu*, B from *Aegilops speltoides*)
- Hexaploid wheats have genome AABBDD (D from *Aegilops tauschii*)

Aegilops speltoides



Aegilops tauschii

Norman Borlaug, University of Minnesota, 1914–2009



Father of "green revolution", Nobel Prize (1970)

Norman Borlaug started contemporary wheat selection

- Dwarf wheats (especially in common wheat) are selected with transition from sickle to harvesting machines, they withstand many weather problems and are more drought-resistant
- Wheats with branched spikes (based on tetraploid *Triticum turgidum*, rivet wheat and hybrids)
- Octoploid forms ($2n = 56$) are artificial, typically have bigger grains
- Hybrids with rye, $\times$ *Triticosecale* (*Triticum* $\times$ *Secale*)

Rivet wheat, *Triticum turgidum*

× ***Triticosecale***

5 Other C_3 grains

5.1 Rye

Rye, *Secale*

- Belongs to the same tribe with wheat, Triticeae
- Much "younger" cultivated plant
- Cultivated mostly in temperate regions of Eurasia (Russia, Germany, Sweden) and Canada

Rye features

- Hardy plant, likes sandy soils, survives with a frost, has a short life cycle adapted for long days, however, yield is low, $\approx$ 1 ton/hectare
- Many winter cultivars
- Cross-pollinated
- Rich of proteins, therefore rye bread is growing hard faster than pure wheat bread; typically, rye bread contains wheat additives (sometimes up to 70%)
- Has multiple uses: as a forage plant become available early in the spring, as a source of ethanol, as a source of straw

Rye taxonomy

- Several species, only one is cultivated: *Secale cereale*
- Has two subspecies: one is a cultivated rye, *Secale cereale* subsp. *cereale*, second is a weed (occuring mostly in wheat crops): *Secale cereale* subsp. *segetale*
- Chromosome number is diploid ($2n = 14$), similar to primitive diploid wheats

Rye origin and history

- Weed rye originated from wild species and become annual (other ryes are perennial) in order to correspond with wheat life cycle
- Cultivated rye is a domesticated weed rye
- N. Vavilov stated that rye outperformed wheat on the northern slopes of Caucasus mountains where spring may come two months later than on southern slopes; this competition sometimes resulted in pure rye crops
- Than selection started for bigger grains, since rye is cross-pollinated, selection went faster
- First remains of rye dated 300–400 AD (Black Sea coast)
- Since rye has open flowers, it sensitive to ergot (*Claviceps purpurea* fungus) containing hallucinogenic lysergine acid which was the cause of *ergotism disease* in medieval centuries. In times of the "small ice age" (13–18 centuries), when wheat in most of Europe was replaced with rye, ergotism was probably the reason of the widespread "witch hunting".

Cultivated rye, *Secale cereale* subsp. *cereale*

[Note the dark ergot (*Claviceps purpurea*) fruiting bodies]

Weed rye, *Secale cereale* subsp. *segetale*

For Further Reading

References

[1] P. Stamp. *Virtual cereal cultivar garden* [Electronic resource]. 2008. Mode of access: `http://www.sortengarten.ethz.ch/?content=start`

[2] A. Shipunov. *Ethnobotany* [Electronic resource]. 2011—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_310`

Outline

6 Main food source plants: grains

6.1 Barley

Barley, *Hordeum*

- Belongs to the same tribe Triticeae
- Plant of multiple use: as bread (rarely), as a cereal, for making beer, as a forage plant
- Old West Asian culture, now cultivated mostly in temperate regions of North Hemisphere

Barley features

- Grains are not fully appropriate for bread, they have too high amount of proteins ($> 7\%$), resulted in bread which is crumbling too much
- Hardy plant, survives easily in winter (there are many winter cultivars), has extremely fast life cycle and therefore cultivated on high altitudes in mountain areas (as Tibet)

Barley taxonomy

- Almost 40 species, only two are widely cultivated
- *Hordeum distichon*, two-rowed barley, is cultivated mostly for beer production; spike has two rows of spikelets
- *Hordeum vulgare*, six-rowed barley, cultivated for multiple purposes; six rows of spikelets
- These species are sometimes treated as one

Hordeum distichon, two-rowed barley

- Old culture (7,000 BC) from West Asia and Egypt, originated from wild *Hordeum spontaneum*
- Annual, with flat spikes
- Only spring forms
- Now cultivated mostly in West and Middle Asia and Europe

Hordeum vulgare, six-rowed barley

- Newer culture, 4–5,000 BC, originated from East Asia
- China and Japan are still centers of diversity (and probably, centers of origin)
- Goes very high on mountains, up to 6,000 m above sea level
- Widely cultivated, the yield is comparable to the contemporary wheats ($\approx$ 2 ton/ha)
- Unfortunately, sensitive to drowning and to fungal diseases, especially to powdery mildew (*Erysiphe* spp.)

Role in brewing

- For brewing, barley grains are malted: germinated by soaking in water and then sharply drying by hot air
- Consequently, enzymes started to modify starch into mono- and disaccharides, such as fructose, glucose, sucrose and maltose
- There saccharides are using for making wort (mixture of malted barley with water); wort is then fermented with brewer yeasts (*Saccharomyces cerevisiae* fungus)

Two-rowed barley, *Hordeum distichon*

Six-rowed barley, *Hordeum vulgaris*

Ancestor of barley, *Hordeum spontaneum*

6.2 Oat

Oat (*Avena*)

- Belongs to different tribe, Aveneae
- Morphology is also different: oats have branched inflorescence, panicle
- Several species in cultivation, as a forage plants (especially for horses) and as cereals

Oat features

- Hardy culture, cultivated mostly in temperate regions, yield relatively low, is ≈ 1 ton/hectare
- Grains contain high amounts of proteins and lipids

- Mostly spring forms (winter cultivars also exist); life cycle longer than in barley (should be planted earlier in a spring)
- Not sensitive to many fungal diseases

Oat taxonomy

- Several dozens species, only two are widely cultivated
- *Avena byzantina*, red oat, is more hardy and also better adapted to dry climates, has long grains
- *Avena sativa*, common oat, main cultivated oat, has shorter grains

Origin of oats

- Red oat is a domesticated form of wild oat, *Avena sterilis*. Cultivation started with invention of big cavalry armies ($\approx$ 400 BC) of Alexander the Great
- Common oat was the weed of emmer wheat (*Triticum dicoccum*), and became pure culture when crops went northward (similar to rye)

Red oat, *Avena byzantina*

Common oat, *Avena sativa*

Oat ancestor, *Avena sterilis*

6.3 "European" grains: summary

Summary: "European" grains

- Wheats (*Triticum*) are ancient cultivated plants, originated in West Asia
- Tetraploid and hexaploid wheats are intergeneric hybrids
- **Barley** is an ancient culture well adapted to agriculture in mountain regions
- **Rye** and **common oat** were originated from weeds

6.4 Rice

Rice (*Oryza sativa*)

- Belong to the tribe Oryzeae
- Has panicle as an inflorescence, flowers with 6 stamens (uncommon in grasses)
- More than half of human population use rice as a main food source
- Cultivated mostly in tropics and subtropics, below 42° latitudes

Rice features

- High calories (360 cal / 100 g), up to 10% of proteins, including lysine amino acid (!)
- White (polished) rice does not contain embryo and therefore deficient of many vitamins; beriberi disease is a deficiency of vitamin B_1 (tiamine) originated in richer families of Indonesia (because they were wealthy enough to buy a "better" rice)
- Rice is not used for bread, if cooked it become extremely brittle
- Yield is much higher than wheat, $\approx$ 6 ton/hectare!
- Rice is a coastal plant, requiring water, especially when young; seedlings are often manually planted in the soil covered with water
- Ancestrally, rice requires monsoon climate: first season is wet (rice germinates), second is dry (rice matures)

Summary

- **Rice** is the old culture with extremely complicated agriculture but extremely high yield

Summary

- **Barley** is an ancient culture well adapted to agriculture in mountain regions
- **Rye** and **common oat** were originated from weeds

For Further Reading

References

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Outline

7 Main food source plants: grains

7.1 Rice

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- Ancestrally, rice requires monsoon climate: first season is wet (rice germinates), second is dry (rice matures)

Rice taxonomy

- 28 species, only one is widely cultivated: *Oryza sativa*, common rice
- Several main varieties, including Japanese (short-grain) and Indian (long-grain) rice. Japanese variety has sticking (high proteins) and non-sticking forms.

Rice origin and history

- First remains (Thailand) are 7,000 BC; mass cultivation started in East Asia 4–5,000 BC
- Most probably, perennial *Oryza perennis* is a wild relative of cultivated rice
- Came to Europe with Arabs in first millennium
- From 1865, is cultivated in U.S. (first plantations in North Carolina)
- After the "Green Revolution" in 1960s, genetically modified rice cultivars allow to finish hunger in India and China

Rice agriculture

- Seeds are germinated in nurseries
- After several weeks, seedling are transplanted (often manually) to flooded fields
- Water should be removed after 1–2 month from transplanting
- There are also "mountain" rice which does not require flooding (but its yield is less)

Common rice, *Oryza sativa*

Rice flower

Ancestor of rice, *Oryza perennis*

8 Lesser C_3 grasses

8.1 Indian rice, *Zizania*

Indian rice, *Zizania*

- Small (3 species) genus of water grasses distributed in East Asia and North America
- Big (up to 1.5 m), partly submerged grasses with unisexual flowers
- Inflorescences are panicles
- Long grains

Zizania aquatica, or manoomin

- Only one species was used by Native Americans
- Odjibwe name “manoomin”, Dakota name “psi”
- Half-cultivated (supported but not planted)
- Stems tied (precaution against birds), then harvested from canoe

Ricing, step 1

Ricing, step 2

Ricing, step 3

Ricing, step 4

Ricing, step 5: threshing

Ricing, step 6

Summary

- **Rice** is the old culture with extremely complicated agriculture but high yield

Summary

- **Barley** is an ancient culture well adapted to agriculture in mountain regions
- **Rye** and **common oat** were originated from weeds

For Further Reading

References

[1] P. Stamp. *Virtual cereal cultivar garden* [Electronic resource]. 2008. Mode of access: `http://www.sortengarten.ethz.ch/?content=start`

[2] A. Shipunov. *Ethnobotany* [Electronic resource]. 2011—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_310`

Outline

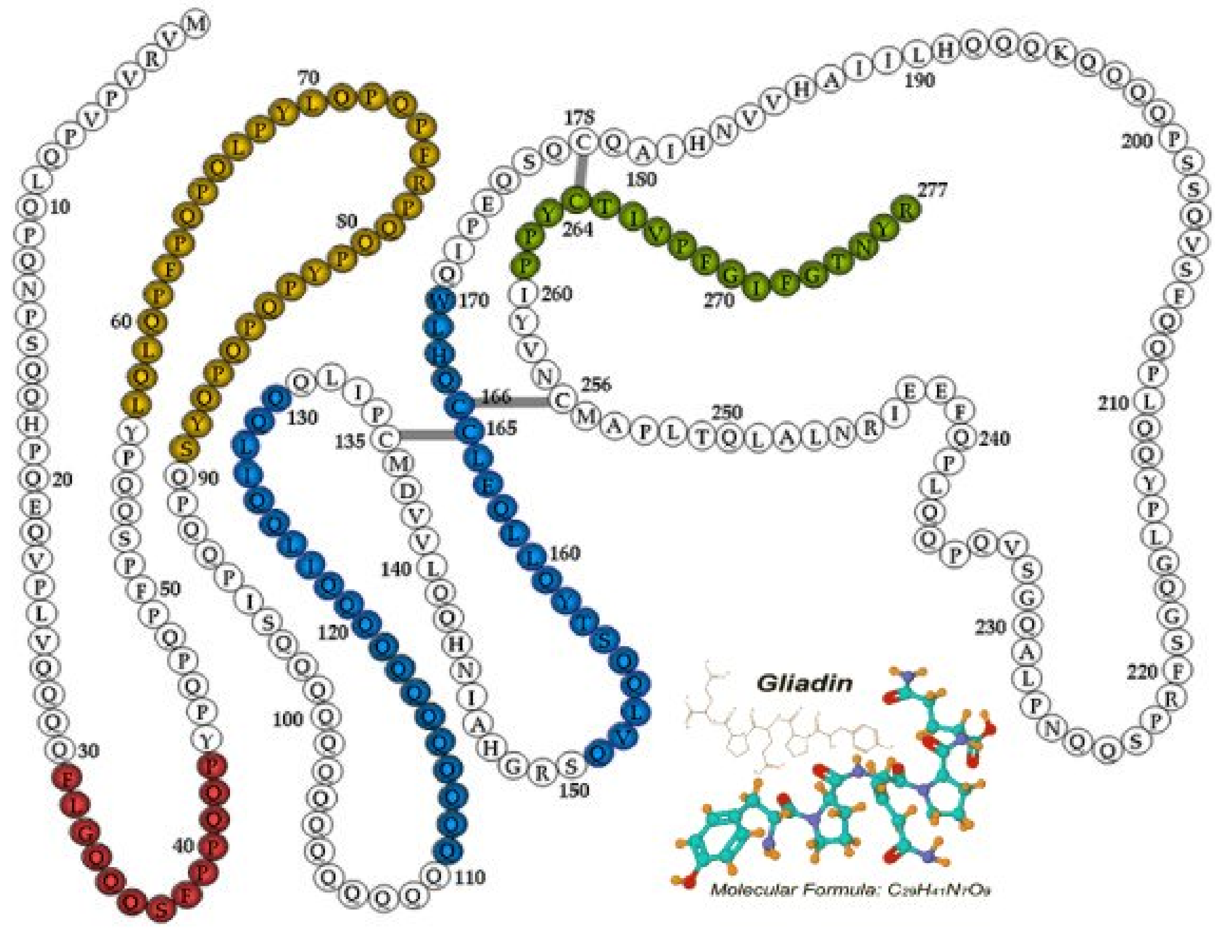
9 Main food source plants: grains

10 African C_3 and C_4 grains

Gluten and celiac disease

- Gluten (grain proteins) of Triticeae includes prolamines—storage proteins
- They work against insect alpha-amilases making seeds virtually inedible for insects
- They also weaken tight junctions in the gut epithelial cells and cause celiac disease, auto-immune inflammation of gut epithelium
- However, the last also suppress bacterial infections so there is a positive selection for gluten sensitivity
- Finally, it is impossible to knead dough without glutens...

Gliadin motifs which cause celiac disease



10.1 *Digitaria exilis*, fonio

Digitaria exilis, fonio

- Main crop of West Africa

- The only cultivated species of big (≈ 300 species) genus *Digitaria*
- Low, heavily branched grasses
- Grains are extremely small (2–3 mm); however, the yield is comparable with primitive wheats (0.6–1 ton/ha)

Fonio agriculture

- Well adapted to short days, high temperatures and low precipitation
- Needs only surface development of soil, planted by scattering
- Manual harvesting and threshing

Fonio

Fonio threshing

Fonio grains

10.2 *Eragrostis tef*, tef

Eragrostis tef, or tef

- One of the main cultures of East Africa
- Used for making bread
- Small, branching plants with small spikelets and grains
- Grains are rich of iron (used also for medical purposed, for treating anemia)
- Well adapted to high altitudes
- Yield is comparable with rye ($\approx$ 1 ton/ha)

Tef

Tef grains

For Further Reading

References

[1] P. Stamp. *Virtual cereal cultivar garden* [Electronic resource]. 2008. Mode of access: `http://www.sortengarten.ethz.ch/?content=start`

[2] A. Shipunov. *Ethnobotany* [Electronic resource]. 2011—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_310`

Outline

11 C_4 grains

11.1 *Zea mays*, corn

***Zea mays*, corn, maize**

- The most important world grain (after wheat and rice)
- Mostly tropical, subtropical and warm temperate culture
- U.S. is a main corn producer (almost 50% of world production)

- Has a high yield: up to 8 tons/hectare
- Grains are rich of proteins (up to 20%) and oil (4–8%)
- Using for bread-like products, for making starch, sugar, as a forage plant, for making different secondary production (coal, ethanol, paper)

Zea mays **morphology and taxonomy**

- Unique grass, the sole member of genus *Zea*
- High (up to 6 m) annual with relatively small root system
- Has a highly modified inflorescences: terminal male are panicles whereas axillary female inflorescences have inflated axis and densely packed flowers
- Female flowers have extremely long styles (sometimes $\approx$ 1 m)
- Cross-pollinated
- Caryopsis big, round-shaped, with soft or glossy endosperm

Zea mays **diversity**

- Four most common varietes:
- var. *microsperma*: small grains and corns, endosperm has two layers and used for popcorn
- var. *amylacea*: grains a rich of starch
- var. *dentiformis*: 70% of cultivated corn
- var. *saccharata*: rich of sugars, used for canned corn

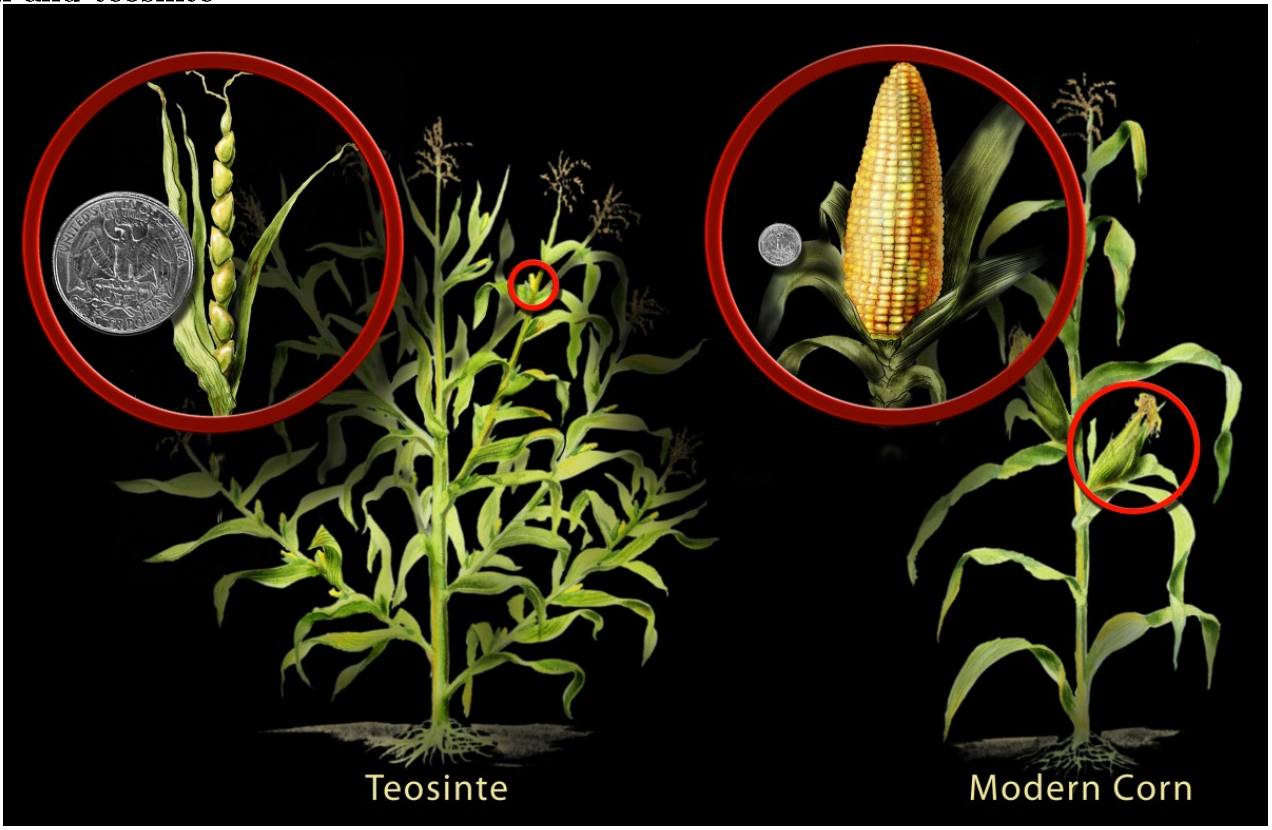
Zea mays **agriculture**

- Optimal temperatures are 25–30° C
- Needs a constant water supply and rich (especially with nitrogen and phosphorous) soil
- Most effective with crop rotation
- Likes short days, vegetation period up to 200 days

Zea mays **origin**

- No close relatives exist (!)
- Two related genera are *Teosinte* (teosinte) (now frequently included in *Zea*) and *Tripsacum* (gama grass) which could cross with corn
- Most probably, wild ancestor became extinct $\approx$ 5,000 years ago

Corn and teosinte



Teosinte

Tripsacum

***Zea mays* history**

- First remains from Mexico dated 3,400 years BC
- Most probably domestication started in Mexico and Central America independently
- All varieties already exist in pre-Colombian era, corn became widely cultivated from Canada to southern South America
- In 1492, Columbus wrote first notes about corn cultivation
- From XVI century, cultivation started in Africa, then in Europe and finally in Asia

11.2 *Sorghum*

***Sorghum*, sorghum**

- More than 30 species, many of them are cultivated
- Ancient culture (3,000 BC), started in Africa
- Now cultivated mostly in Asia and Africa, preferably in most dry and hot places
- Yield is around 3 tons/hectare

Sorghum morphology and agriculture

- Tall (up to 1.5 m) grasses
- Inflorescences are dense panicles
- Small grains
- Requires high temperatures and short days
- Drought-tolerant, allows most kinds of soils
- Long growth period: 200 or more days
- Came to Asia $\approx$ 2,000 years ago, but cultivated in Europe and U.S. only for last 100 years

Sorghum diversity

- *Sorghum bicolor*—grain sorghum, Africa
- *Sorghum durra*—white sorghum, India
- *Sorghum chinensis*—red sorghum, or gao liang, China

Sorghum

Gao liang

11.3 Pearl millet, *Pennisetum*

Pearl millet, *Pennisetum*

- One cultivated African species, *Pennisetum glaucum*
- Forage and cereal culture, mostly in Africa and Asia
- Tall plant with compact cylindric panicle
- Undemanding culture, requires only warm temperatures and short days

Pearl millet

11.4 Finger millet, dagusa, *Eleusine*

Finger millet, dagusa, *Eleusine coracana*

- Indian ancient crop (now cultivated also in Africa), sole species of genus
- Used as cereal
- Yield is comparable with wheat (2 ton/hectare)
- Requires aerated, humid soils and short days
- Resistant to fungal and bacterial diseases

Finger millet

11.5 Common, or proso millet, *Panicum*

Common, or proso millet, *Panicum miliaceum*

- Initially, ancient Chinese culture (2,500 BC)
- Grains are rich of proteins (14%)
- Requires short days but also has short cultivation time therefore cultivated up to 56° latitude
- Now cultivated mostly in East Europe, in U.S. only as a birdseed

Proso millet

Proso millet in Russian grocery store

Barley, buckwheat and proso cereals

Proso millet broom

12 Non-grass grains, or pseudocereals

12.1 Buckwheat, *Fagopyrum esculentum*

Buckwheat, *Fagopyrum esculentum*

- Pseudocereals are not grasses but are using in similar ways, e.g., for flour, as "true" cereals, sometimes even for breads
- Buckwheat (*Fagopyrum esculentum* from Polygonaceae family) is one of the most important and old (6,000 BC) pseudocereal
- Green buckwheat (*Fagopyrum tataricum*) in the another cultivated species
- Yield is relatively low ($\approx$ 1 ton/hectare)

- In addition to grain production, one of the best nectar producers
- As C_4 grasses are low of gluten and pseudocereals are *free of gluten*, they now became main components of gluten-free diet

Buckwheat features

- Hardy plant (mountain origin!), but requires rich and relatively wet soils
- Two forms of flowers, with long and short styles: **heterostyly**. Therefore, strict cross-pollinator. Main pollinators are bees: minimum two hives per hectare required.
- Grains are rich of proteins and micro-elements (especially iron)

Buckwheat, *Fagopyrum esculentum*

Buckweed pollination and fruits

Buckwheat history

- Domesticated probably in Nepal (where is still used as nut) and spread across most of Eurasia
- Cultivated in Europe (especially Russia and France), China, Canada and northern U.S. (e.g., North Dakota)

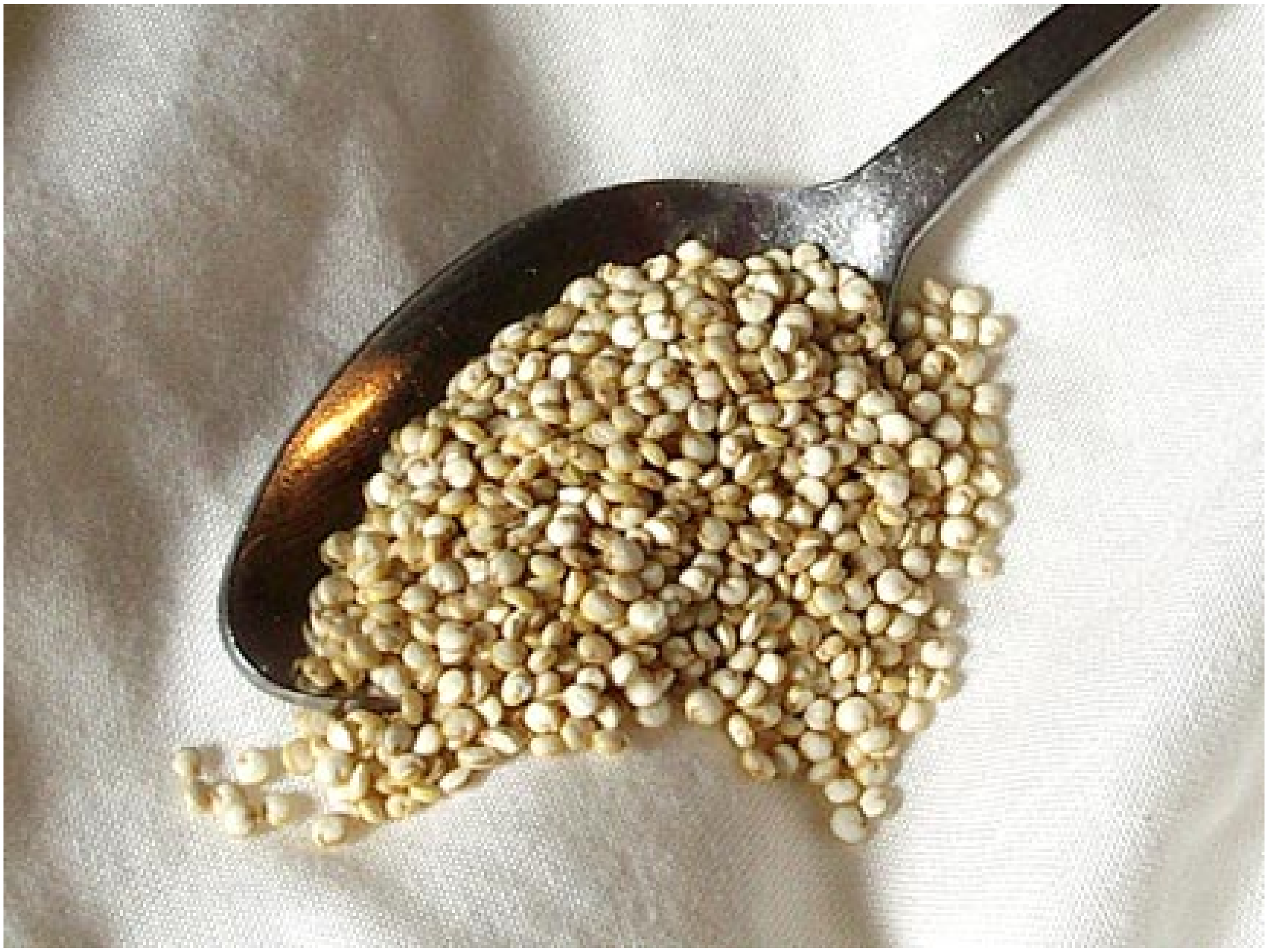
12.2 Quinoa (*Chenopodium*) and other pseudocereals

Quinoa (*Chenopodium quinoa*)

- Belong to Amaranthaceae family (close to buckwheat family)
- Originated in Andean region, used from 2,000 BC and was plant of main importance (more than corn, secondary only to potato) in Inca civilization
- Adapted to high altitudes, easily cultivated above 4,000 meters
- Yield is $\approx$ 2 ton/hectare
- Contain balanced sets of useful amino acids and microelements; could be used as a sole food even for long journeys
- Unfortunately, seeds contain weakly toxic and bitter *saponin* which should be removed before cooking (usually by soaking in water)

Quinoa, *Chenopodium quinoa*

Quinoa grains



Other important pseudocereals

- South American qaniwa (*Chenopodium pallidicaule*) and North American (native for North Dakota!) pitseed goosefood (*Chenopodium berlandieri*) are both similar to quinoa
- Amaranth (*Amaranthus* spp. from Amaranthaceae): cultivated mostly in Europe and America, originated from Central America. Grains are highly diverse in microelements and rich of proteins
- Chia (*Salvia hispanica* from Labiatae): domesticated in Mexico, used by Aztecs. Grains are rich of diverse lipids and slime polysaccharides. Used also to make drinks. From 2008, recommended as "novel food" in Eropean Union
- Whattleseed (*Acacia* spp. from Leguminosae): original grains of Australian Aborigines

Amaranth, *Amaranthus* sp.

Chia, ***Salvia hispanica***

Whattleseed, *Acacia* spp.

Australian millstone

Summary

- Widely cultivated C_4 grasses are mostly ancient American (corn) or African (sorghum) cultures
- **Pseudocereals** are non-grass grains, plants from families other than Gramineae but used for same purposes

For Further Reading

References

[1] A. Shipunov. *Ethnobotany* [Electronic resource]. 2011—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_310`

[2] P. M. Zhukovskij. *Cultivated plants and their wild relatives* [Electronic resource]. Commonwealth Agricultural Bureaux, 1962. Abridged translation from Russian. Mode of access: `http://ashipunov.info/shipunov/school/biol_310/zhukovskij1962_cultivated_plants.pdf`.

Outline

13 Starch-containing plants

13.1 Potatoes, tuber species of genus Solanum

Potatoes, tuber species of genus *Solanum*

- *Starch* and *inulin*—polymers of glucose or fructose monosaccharides, respectively. Plants accumulate them mostly in underground parts: roots, rhizomes, tubers
- *Solanum* is one of the largest plant genera (up to 2,000 species!) and includes several important plants (tomatoes and eggplants) and potatoes—species from section **Petota** ($\approx$ 15 species, all produce "potatoes').

Morphology and other features of potatoes

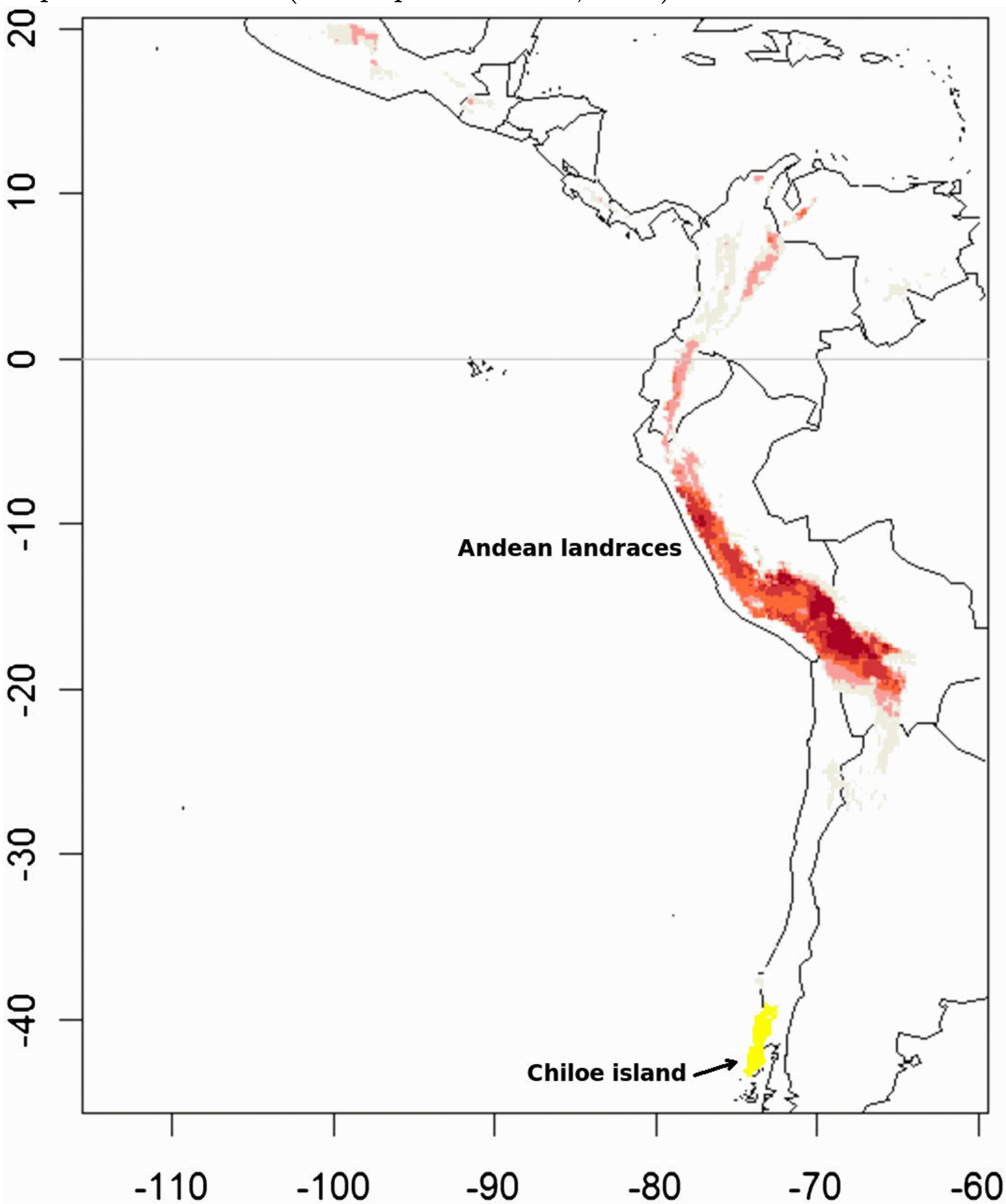
- Potatoes are **tubers**, enlarged parts of specialized rhizomes; buds grow into tubers in darkness
- Main function of tubers is vegetative propagation
- Yield of tubers is high, $\approx$ 15 ton/hectare, but 70–80% of it is a water
- Still, in calories yield is higher than rice or corn: every 100 g contain 15 g of carbohydrates
- There are almost no fats and low amounts (2%) of proteins
- Plants are cross-pollinated; fruits are toxic (contain *solanin*)

Diversity of potatoes

- All species from Petota section may form tubers
- The biggest yield is from tetraploid forms ($2n = 48$) growing in Central Andes and island Chiloe

Potatoes of Ecuador

Richness of potato landraces (from Spooner et al., 2010)



Agriculture of potatoes

- The best is extremely simple agriculture plus high energetic yield
- Planting is from potato buds, not from seeds
- Critical stage of cultivation is "hilling", increasing the soil level around stems
- Harvesting is still not mechanized well
- Storage requires more stable conditions than seed storage

Summary

- **Starch-containing plants** are accumulating starch or inulin in underground parts

Summary

- Widely cultivated C_4 grasses are mostly ancient American (corn) or African (sorghum) cultures
- **Pseudocereals** are non-grass grains, plants from families other than Gramineae but used for same purposes

For Further Reading

References

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Results of the first exam

Results of the first exam

Outline

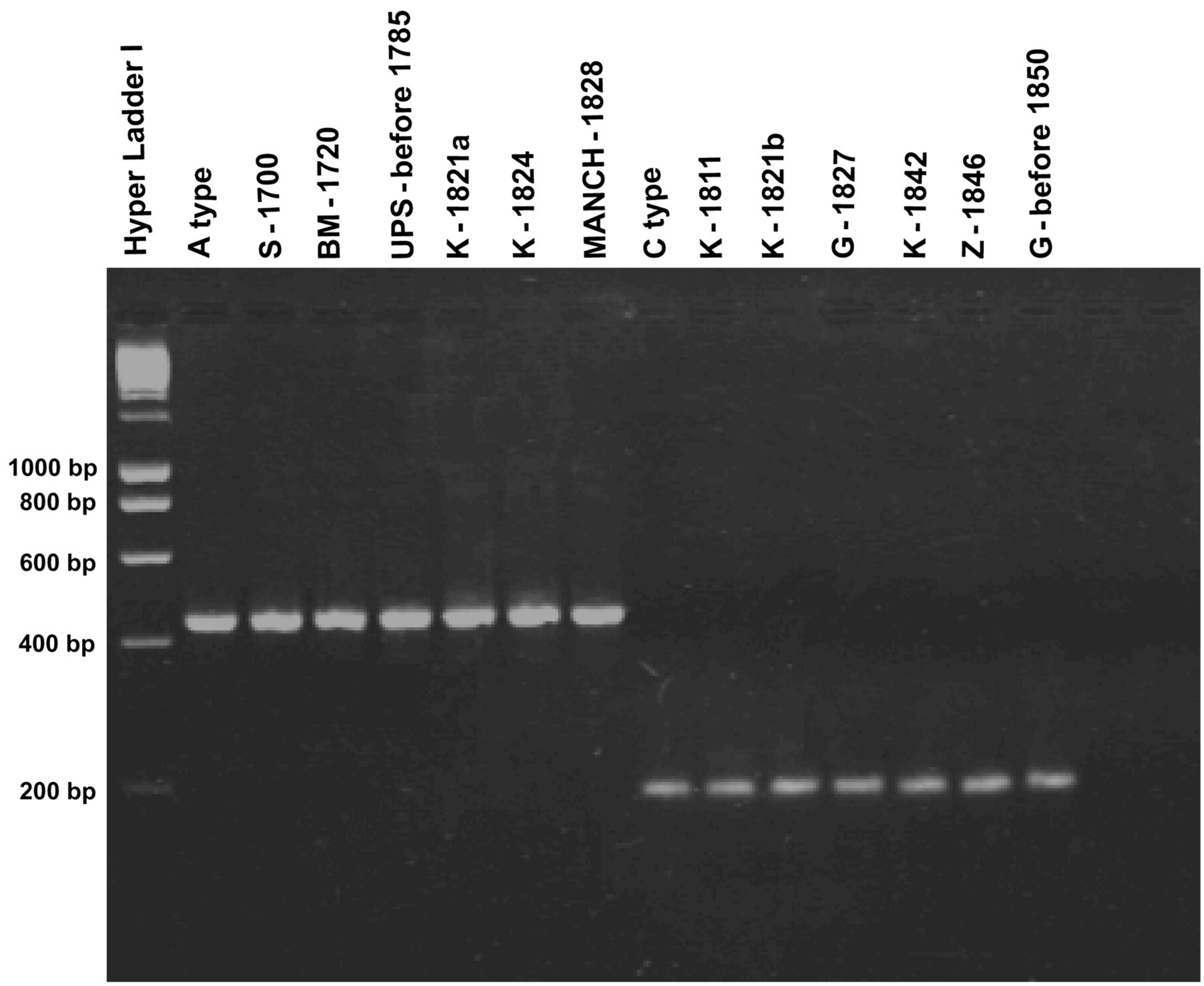
14 Starch-containing plants

14.1 Potato

History of potatoes

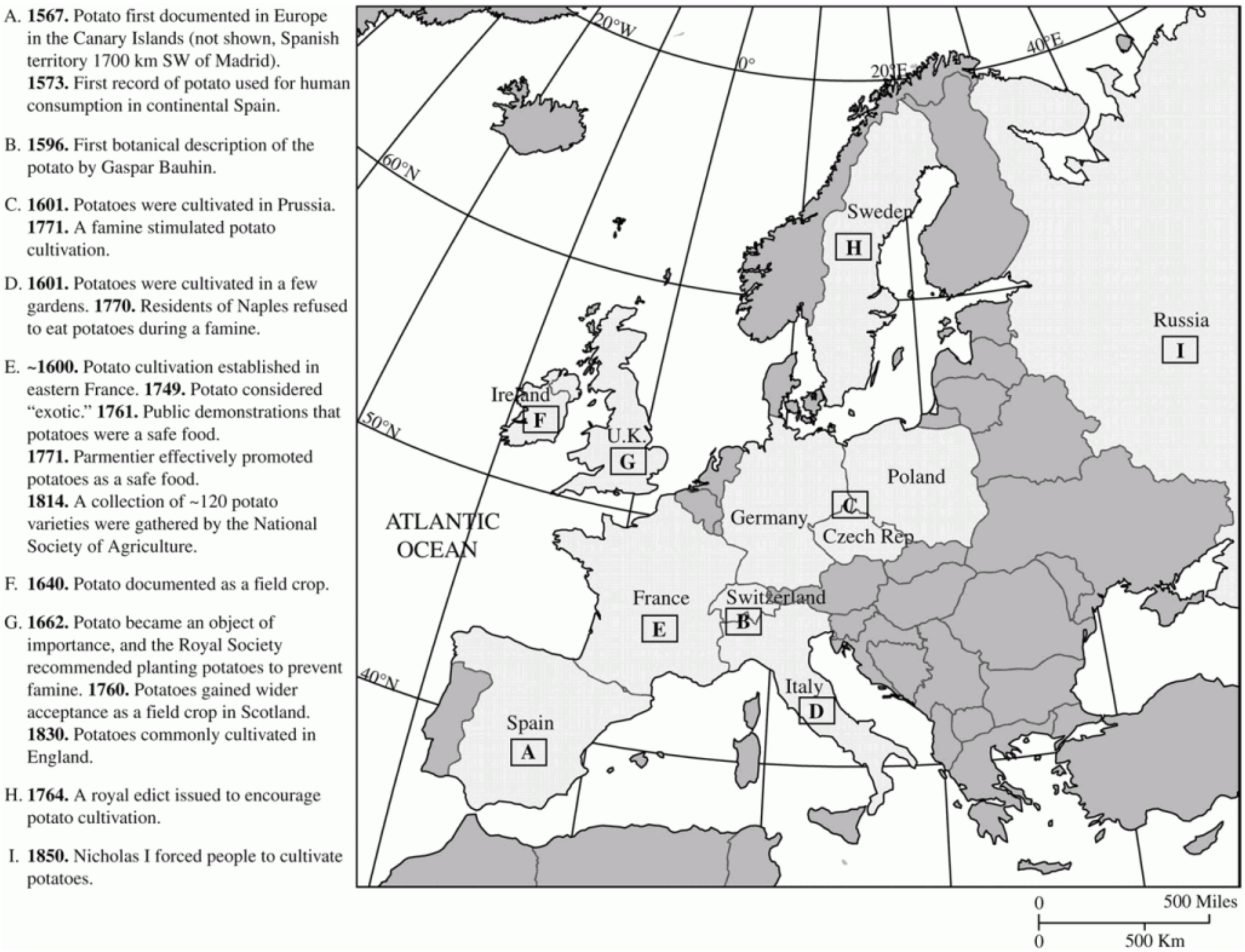
- Domesticated around 3,000 BC and together with quinoa became the main food of Inca empire
- Initially, used mostly as a freeze-dry "chunjo"
- Is known in Europe since 1601
- In XVIII century, was forcedly introduced into culture by many European monarchs and then became widely adopted
- Now, the main producers are China, Russia, India and U.S.

DNA test of European potato cultivars



Amplified PCR products of the plastid trnV-UAC/ndhC intergenic spacer region of 12 pre-1850 Solanum tuberosum specimens (Ames & Spooner, 2008)

Main dates of potato introduction (from Ames & Spooner, 2008)



Great Irish famine and ***Phytophthora infestans***

- Potato occured to be susceptible for several dangerous pathogens, e.g., potato blight "fungus" (*Phytpophtora infestans*)
- Pandemic of potato blight covered Europe in the middle of XIX century (1845–1852), when potato became the main food in many northern European countries including Ireland
- In Ireland, it resulted in 1 million deaths and decreasing of population to 25% due to emigration

Potato blight, ***Phytophtora infestans***

One of Irish famine monuments

Colorado beetle (*Leptinotarsa decemlineata*)

- One of the most dramatical example of American invasive species in Europe
- In Colorado Rocky Mountains, these beetles were feeding on *Solanum rostratum* plants but not on potato
- During World War I and then especially World War II, it became spreading across all Western Europe and then eastward
- Distribution is now covered all North Hemisphere (except China)

Colorado potato beetle...

... and its first host, *Solanum rostratum*

14.2 Sweet potato, Ipomoea batatos

Sweet potato, *Ipomoea batatos*

- Belongs to morning glory genus *Ipomoea* from Convolvulaceae family
- Cultivated for thickened secondary roots (tuberous roots, not tubers!)
- Contain 12% of starch, 5% of sugars, little proteins and almost no fat
- Rich of vitamins, especially vitamin A precursor beta-carotene

Sweet potato morphology

- Herbaceous vine, perennial plant cultivated as annual
- Tuberous roots are large, up to 25 kg
- Reproduction is both from seeds and vegetative, from root and stem parts (cuttings)
- Large, trumpeting, insect-pollinated flowers

Ipomoea batatas, sweet potato

Sweet potato agriculture

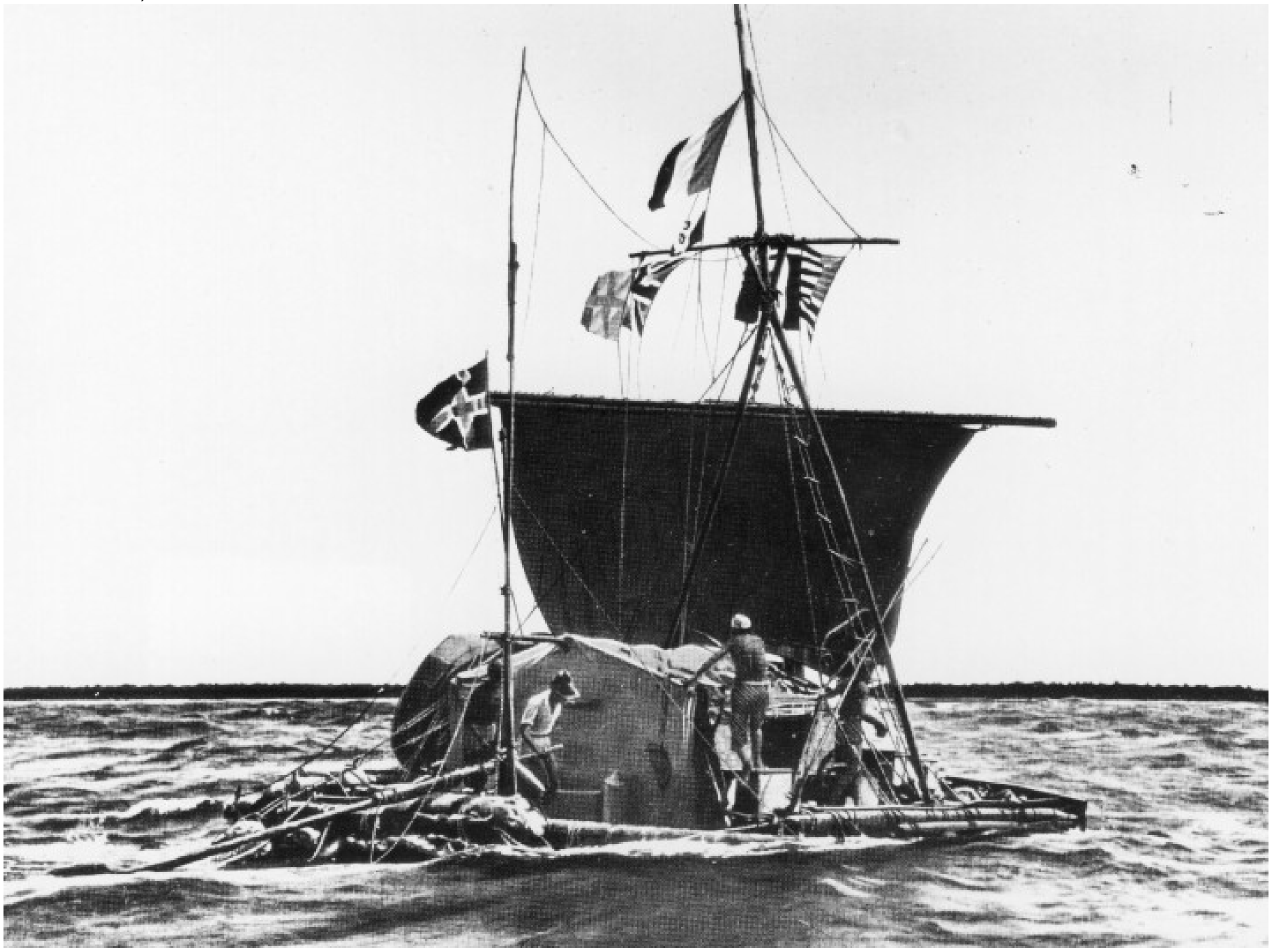
- Pure tropical culture, does not tolerate frost
- Requires short days, full sun, light soil
- Planting as cuttings, this increases the number and weight of tuberous roots (subsidiary roots)
- Green part is used as a forage for animals

Planting of sweet potato

History of sweet potato

- Domesticated in Central America almost 3,000 BC and spread to Polynesia before European colonization
- In Polynesia, it is called the "kumara", remarkably similar to the Quechua "kumar" in Peru: that is one of reasons for Thor Heyerdahl Kon-Tiki expedition
- Now two main producers are China and Nigeria

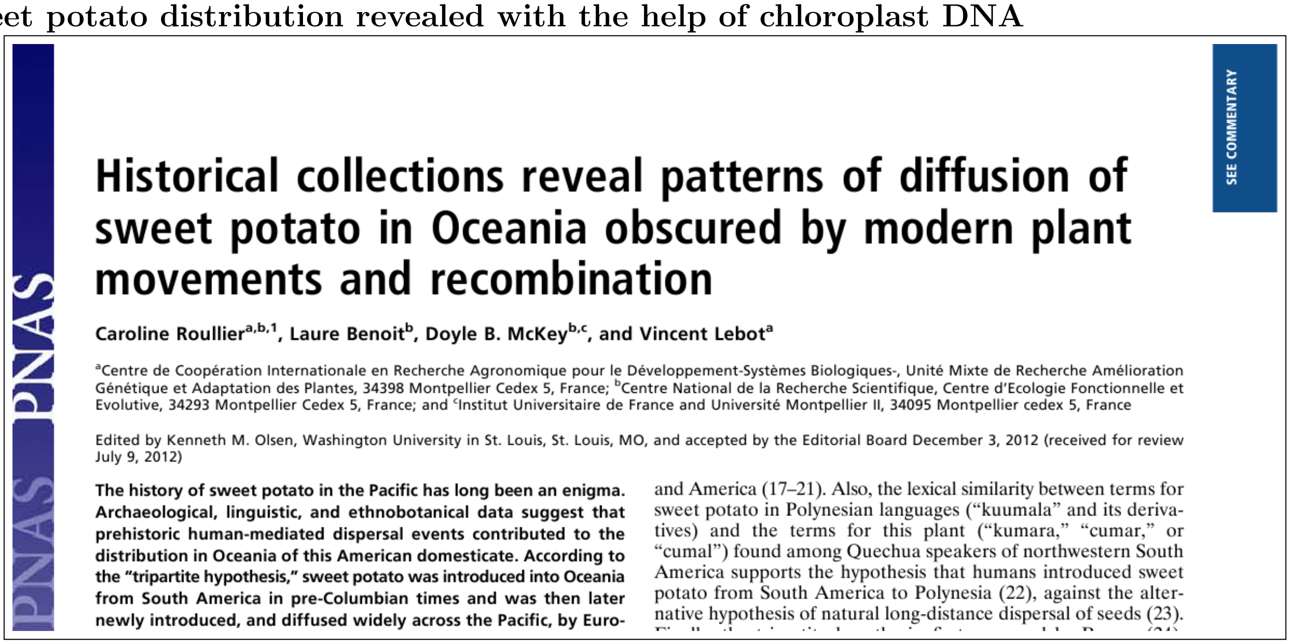
Kot-Tiki raft, 1947



15 Starch-containing plants

15.1 Sweet potato, Ipomoea batatos

Sweet potato distribution revealed with the help of chloroplast DNA



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SEE COMMENTARY

Historical collections reveal patterns of diffusion of sweet potato in Oceania obscured by modern plant movements and recombination

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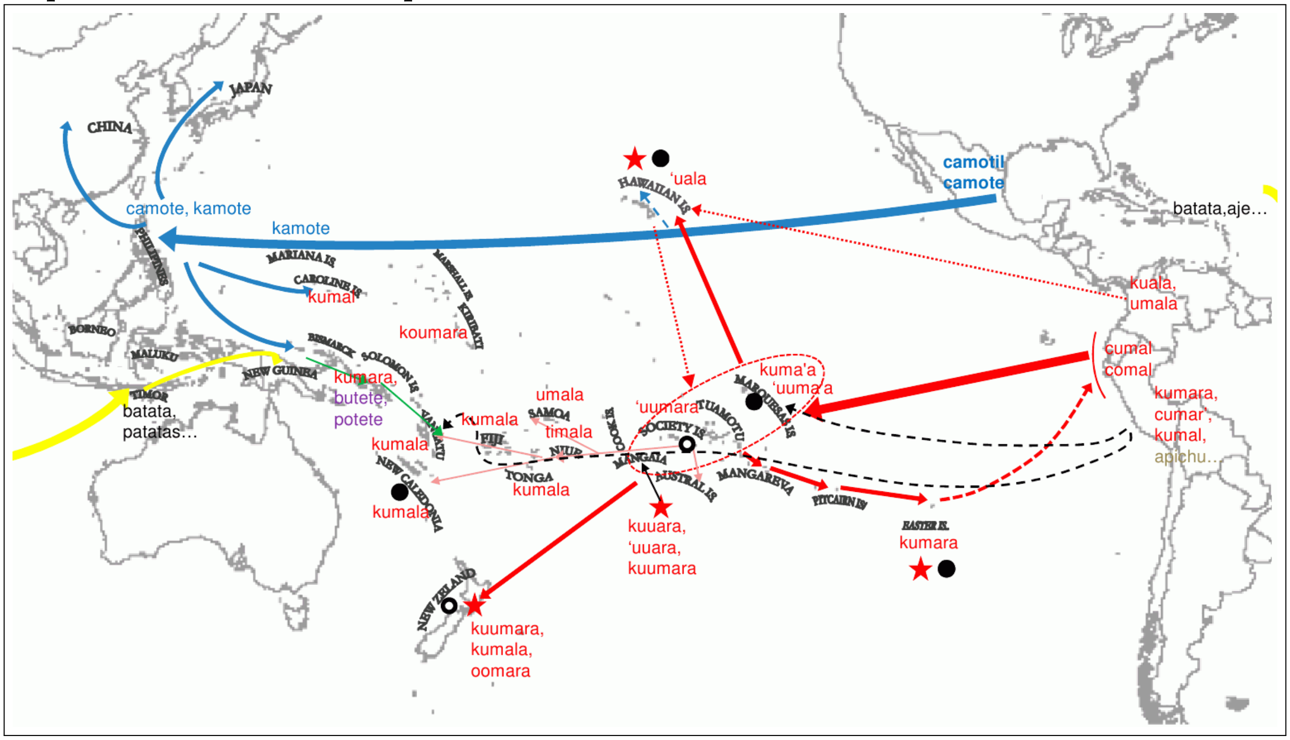
The history of sweet potato in the Pacific has long been an enigma. Archaeological, linguistic, and ethnobotanical data suggest that prehistoric human-mediated dispersal events contributed to the distribution in Oceania of this American domesticate. According to the "tripartite hypothesis," sweet potato was introduced into Oceania from South America in pre-Columbian times and was then later newly introduced, and diffused widely across the Pacific, by Euro-

and America (17–21). Also, the lexical similarity between terms for sweet potato in Polynesian languages ("kuumala" and its derivatives) and the terms for this plant ("kumara," "cumar," or "cumal") found among Quechua speakers of northwestern South America supports the hypothesis that humans introduced sweet potato from South America to Polynesia (22), against the alternative hypothesis of natural long-distance dispersal of seeds (23).

Sweet potato distribution map



15.2 Cassava, Manihot esculenta

Cassava, manioc, *Manihot esculenta*

- Belongs to the tree genus *Manihot* from spurge family Euphorbiaceae
- Third largest source of carbohydrates in the world
- It is a shrub cultivated as annual (!)
- Secondary roots (not stems!) are thickening and form tuberous parts

In Spanish, called "yuca" (do not mix with aloe-like *Yucca* plant).

Cassava plantation

Cassava features

- Tuberous roots have high amount of dry mass (30%), high in starch, phosphorous and vitamin C but poor in proteins and essential amino acids
- **Toxic**, contain cyanogenic compounds which are liberating hydrogen cyanide (HCN). Consequently, should be pressed, soaked, cooked or fermented before use. Without preparation caused a *konzo* disease.
- Harvesting is manual; roots are deteriorated fast and should be processed as soon as possible

Cassava preparation: peeling

Cassava preparation: grinding

Cassava preparation: pressing

Cassava preparation: drying

Cassava history

- Domesticated in Brazil around 6,000 BC
- Went to Africa with Portuguese trades and then to south-west Asia
- Now, Nigeria and Thailand are biggest producers

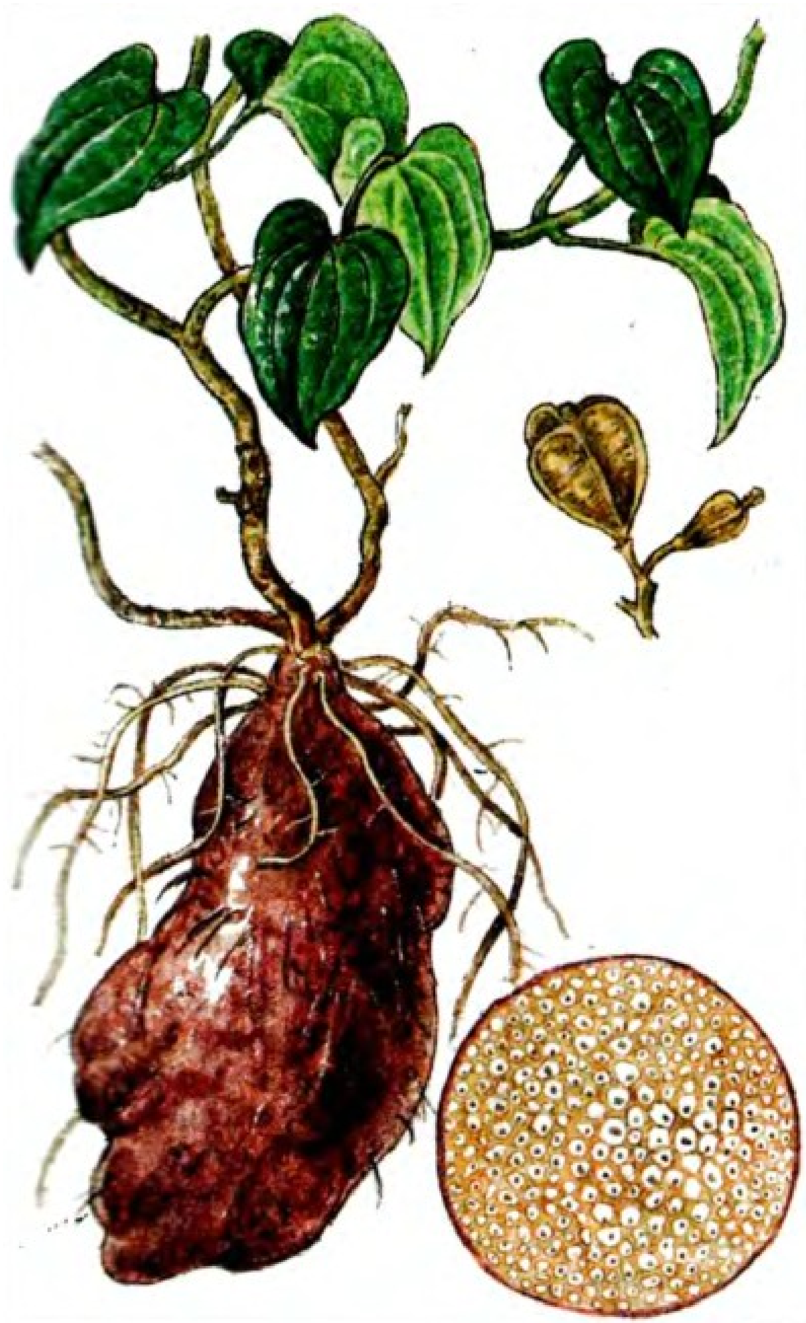
15.3 Yam (tropical yam), Dioscorea spp.

Yam, *Dioscorea* spp.

- Several species of large genus *Dioscorea* and Dioscoreaceae family
- Cultivated for tubers (morphologically similar to potato tubers)
- Frequently used as a flour
- Could be stored up to half-year, even in tropical climate

Sweet potato is sometimes called “yam” in U.S.

Yam, *Dioscorea*



Yam features

- Tubers could be huge: up to 2.5 m and 70 kg
- Contain starch, significant amounts of vitamin C, and several microelements
- Hilling is an important stage of cultivation
- Long vegetation period (up to 1 year)
- Due to the size of tubers, harvesting is only manual

Yam plantation

Yam history

- Three most cultivated species: *Dioscorea rotundata*, yellow yam of Africa; *D. alata*, water yam of Polynesia; and *D. opposita*, Chinese yam
- These species were separately domesticated, most probably prehistorically
- During potato pandemic, *Dioscorea alata* cultivation started in Europe, still cultivated in France
- Now the biggest producer is Nigeria

Water yam of Tonga

Summary

- **Starch-containing plants** are accumulating starch or inulin in underground parts
- Sweet potatoes and cassava (manioc) are two largest starch sources after potato

For Further Reading

References

[1] A. Shipunov. *Ethnobotany* [Electronic resource]. 2011—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_310`

[2] P. M. Zhukovskij. *Cultivated plants and their wild relatives* [Electronic resource]. Commonwealth Agricultural Bureaux, 1962. Abridged translation from Russian. Mode of access: `http://ashipunov.info/shipunov/school/biol_310/zhukovskij1962_cultivated_plants.pdf`.

Outline

16 Starch-contained plants

16.1 Taro

Taro, *Colocasia esculenta* and *Xanthosoma sagittifolium*

- Belong to arum family, Araceae
- African and South American origin, respectively
- Large semi-aquatic herbs with thickened underground stem (rhizome)
- Rhizome is inedible because of calcium oxalate which must be removed by cooking

Colocasia is "malanga" in Puerto-Rico whereas *Xanthosoma* is "yautia"

Colocasia esculenta

Xanthosoma sagittifolium

Taro harvesting

Walmart vegetables in Puerto Rico

16.2 Lesser starch-containing plants

Bread tree, *Artocarpus integer*

- Large tree of mulberry family, Moraceae
- Polynesian origin
- Has a compound "fruit"—ripe inflorescence
- A common product is a cooked or **fermented** breadfruit mash
- It is normally kept for the very long time as a sour dough which helps for Polynesian traditional life style, involving long travels from island to island.

Breadfruit

Breadfruit fermentation place, Marshall islands

Related: Obesity and Type II diabetes in Polynesians

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Obesity in Samoans and a perspective on its etiology in Polynesians.

S T McGarvey

+ Author Affiliations

Abstract

For Samoans, modernization produces obesity and adiposity and concomitant increases in cardiovascular disease risk factors and outcomes. Massive adiposity and high prevalence of obesity characterizes modernizing adult Samoans. Mean body mass index (in kg/m2) at ages 25-54 y is 30-32 for males and 32-36 for females. Prevalence of overweight in female adults is 46% in traditional Western Samoans and 80% in migrants in Hawaii. Five-year longitudinal data show striking weight and fat gain, especially in younger adults and females. An evolutionary perspective on Polynesian adiposity is based on scenarios of the fates of sailors on the voyages of discovery and of settlers in the pioneer island villages. Efficient metabolisms producing rapid adipose-tissue growth could have increased survival among the first Polynesians. Rapid dietary and physical activity changes caused by modernization interacting with such population genetic predispositions may lead to the documented massive adiposity.

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Am J Clin Nutr June 1991
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16.3 Lesser starch-containing plants

Sago palm, *Metroxylon saghu*

- Belongs to palm family, Palmae
- Tree of Indonesian origin
- Stem (!) is used for starch (sago) production

Sago palm

Sago harvesting

Sago filtering

Andean starch tuber plants

- Oca, *Oxalis tuberosus*, from Oxalidaceae, wood sorrel family
- Ulluco, *Ullucus tuberosus*, from Basellaceae family
- Mashua, *Tropaeolum tuberosum* from Tropaeolaceae, nasturtium family

Oca, *Oxalis tuberosus*

Ulluco, ***Ullucus tuberosus***

Mashua, ***Tropaeolum tuberosum***

16.4 Starch plants of native use in North Dakota

Arrowhead, duck potato, *Sagittaria latifolia*

- "Pshitola" (Dakota), "mujotabuk" (Ojibwe)
- Aquatic plant from Alismataceae family
- Corms and rhizomes are used as a source of starch

Arrowhead, *Sagittaria latifolia* plant

Sagittaria latifolia corm

Quamash (_Camassia quamash_)

- Famous “Quamash”, important food source of Native Americans in the West
- Belongs to lily family, Liliaceae
- Bulbs are edible and highly nutritious

Quamash, *Camassia quamash*

Quamash roots

Potato bean, groundnut, *Apios americana*

- “Mdo” in Dakota language; *Apios americana* belongs to legume family (Leguminosae)
- Grow across all eastern part of U.S.
- Used by Native Americans as a main starch source, tubers also contain significant amounts of proteins; beans are also edible

Potato bean, *Apios americana*

Prairie turnip, breadroot, *Psoralea esculenta*

- "Tipsi" in Dakota language, again, *Psoralea esculenta* is a legume
- Common plant of North Dakota
- Thick main root is edible after cooking or making flour

Breadroot, *Psoralea esculenta*

16.5 Inulin plants

Jerusalem artichoke, *Helianthus tuberosus*

- *Helianthus tuberosus* belongs to Compositae (sunflower) family
- Tubers are rich of inulin, fructose polymer, useful dietary fiber
- Plant was used by eastern Indian tribes and now spread to Eurasia

Jerusalem artichoke

Jerusalem artichoke tubers

Yacon, *Smallanthus sonchifolius*

- Belongs to aster family, Compositae
- Roots are rich of inulin, and also fructose and fructo-oligosaccharides (FOS) such as kestose (F2)—“alternative sweeteners”
- Traditional Andean culture; had ceremonial importance in times of Mochica culture (Peru, 100–800 AD)

Yacon roots

Yacon plant

Some other inulin plants

- Common chicory, or *Cichorium intybus* from the same family Compositae; this European plant became invasive in North America
- Chicory is cultivated sporadically as vegetable and as a source of chicory drink—coffee supplement; 68% of inulin in dry weight
- Dandelion, *Taraxacum officinale* is again an invasive plant; inulin-containing root is edible after cooking
- Many other Compositae (e.g., thistles) also have edible roots rich of inulin

Chichory

One of thistles, *Arctium*

Arctium roots are edible

16.6 Starch plants from sedge family: starch + silicon

Water chestnut, *Eleocharis dulcis*, Cyperaceae, China

- Rich of dietary fibers, vitamins B, copper and manganese
- Cell walls contain phenolic compounds which are not damaged when boiling

Water chestnut

Chufa, *Cyperus esculentus*, Cyperaceae, Africa

- Tubers are rich of potassium, phosphorous and oils (20–36%!)
- Traditional food in Africa, also cultivated in Spain and California

Chufa

Summary

- **Starch-containing plants** are accumulating starch or inulin in their underground parts
- Sweet potatoes and cassava (manioc) are two largest starch sources after potato
- Multiple unrelated tuber starch-bearing species grow in Andes

For Further Reading

References

[1] A. Shipunov. *Ethnobotany* [Electronic resource]. 2011—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_310`

[2] P. M. Zhukovskij. *Cultivated plants and their wild relatives* [Electronic resource]. Commonwealth Agricultural Bureaux, 1962. Abridged translation from Russian. Mode of access: `http://ashipunov.info/shipunov/school/biol_310/zhukovskij1962_cultivated_plants.pdf`.

Outline

17 Centers of cultivated plants origin

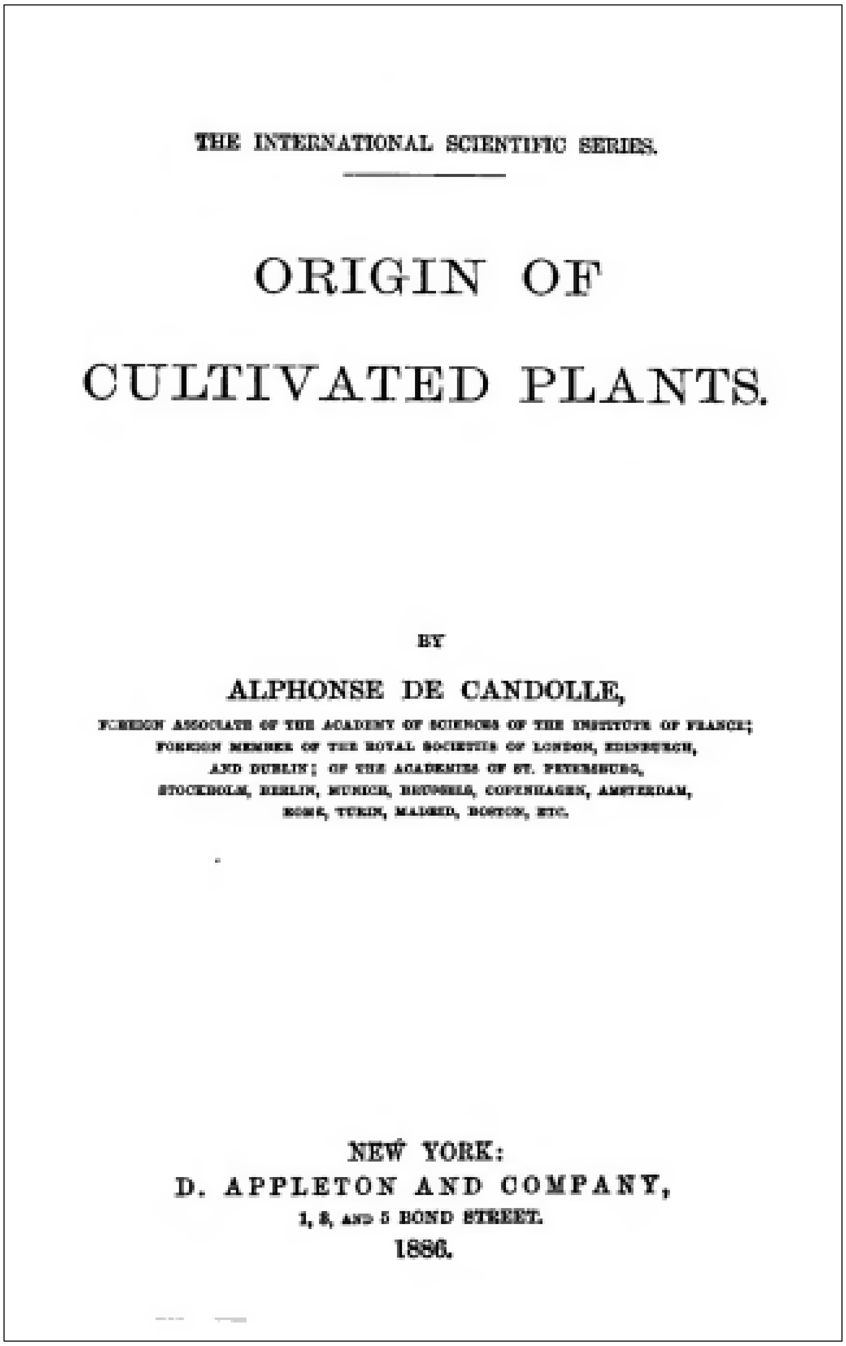
Why knowing centers of origin is important

- Allows to trace history of civilizations alongside with history of plant cultivation
- Allows for historical discoveries
- Helps to find new landraces and wild relatives useful for selection

Initial hypotheses: De Candolle (1882)

- Mentioned that distribution of ancient cultivated plants was very unequal
- Found thee centers of plant origin: China, West Asia/Egypt and tropical Asia

De Candolle's "Origin"


THE INTERNATIONAL SCIENTIFIC SERIES.

ORIGIN OF

CULTIVATED PLANTS.

BY

ALPHONSE DE CANDOLLE,

FOREIGN ASSOCIATE OF THE ACADEMY OF SCIENCES OF THE INSTITUTE OF FRANCE; FOREIGN MEMBER OF THE ROYAL SOCIETIES OF LONDON, EDINBURGH, AND DUBLIN; OF THE ACADEMIES OF ST. PETERSBURG, STOCKHOLM, BERLIN, MUNICH, BRUSSELS, COPENHAGEN, AMSTERDAM, ROME, TURIN, MADRID, BOSTON, ETC.

NEW YORK:
D. APPLETON AND COMPANY,
1, 3, AND 5 BOND STREET.
1886.

Nikolai Vavilov work (1926)

- On the 5th International Genetics Congress, he presented his new classification of centers based on field and collection research
- Differential method: studying density of distribution on a level of varietes. Places where biggest densities were intersected become "centers candidates"
- In 1930s, he establishes "passports" of multiple territories which show ecological, economical and geographic traits

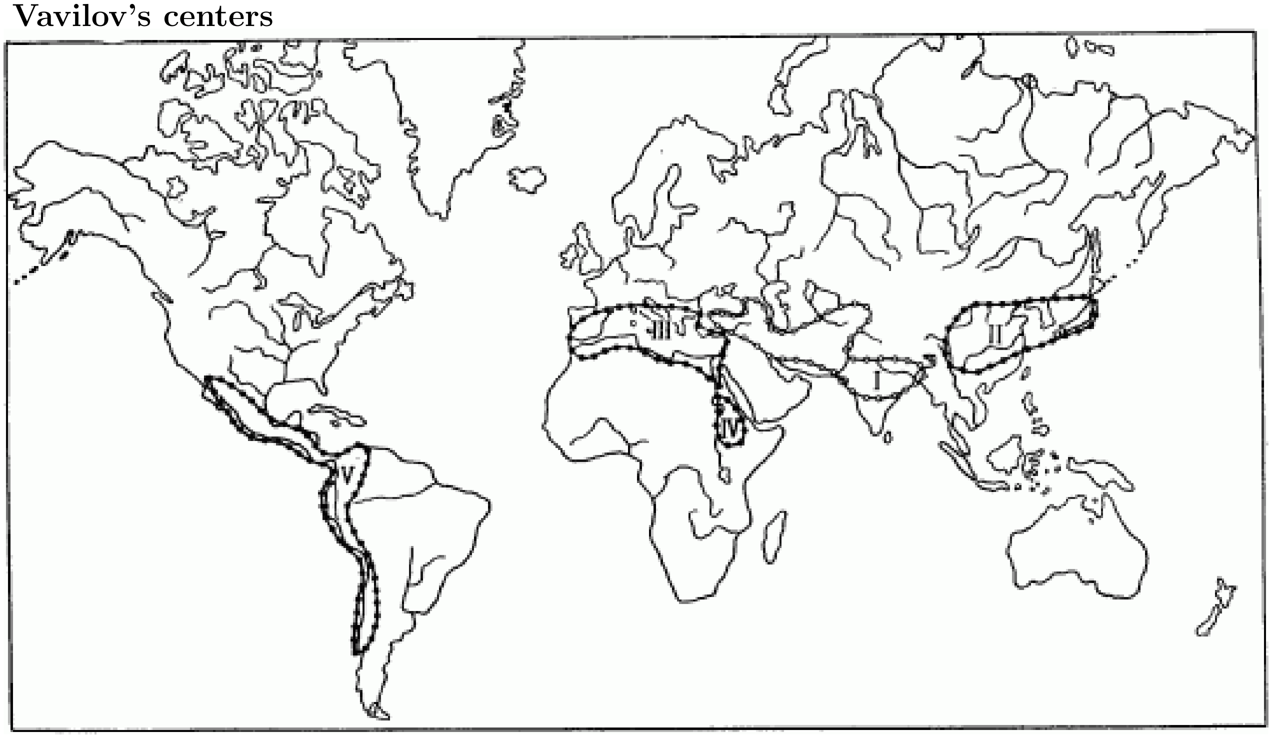
Vavilov's centers (1926)

In 1926, he designated five centers of origin:

1. India
2. China
3. Mediterranean region
4. Ethiopia
5. South and Central America

   Later, he added some (Central Asia) and split some of them

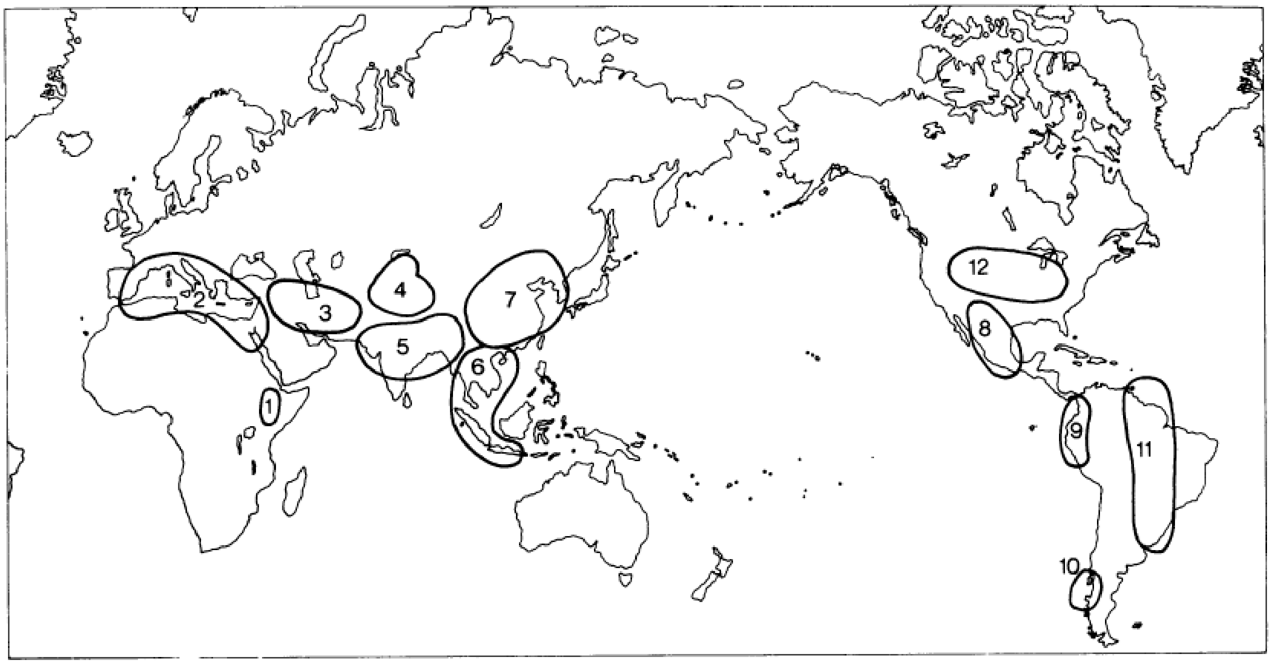
Five Vavilov's centers



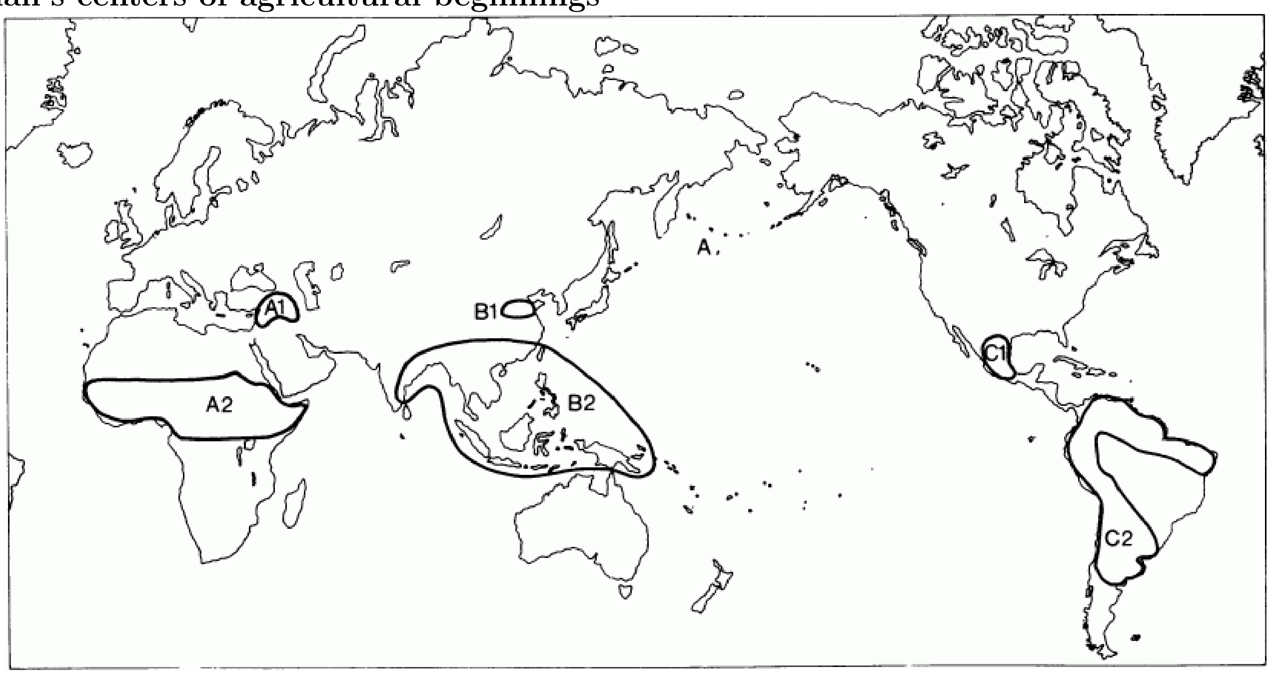
More recent hypotheses

- Darlington (1952): several American centers, twelve centers in total
- Harlan (1971): "centers of agricultural beginnings": only six
- Zhukovskij (1965–1982): 12 "megacenters" (regions). All Vavilov's centers listed, plus several which do not produce substantial amounts of cultivated plants but still separate

Darlington's centers



Harlan's centers of agricultural beginnings

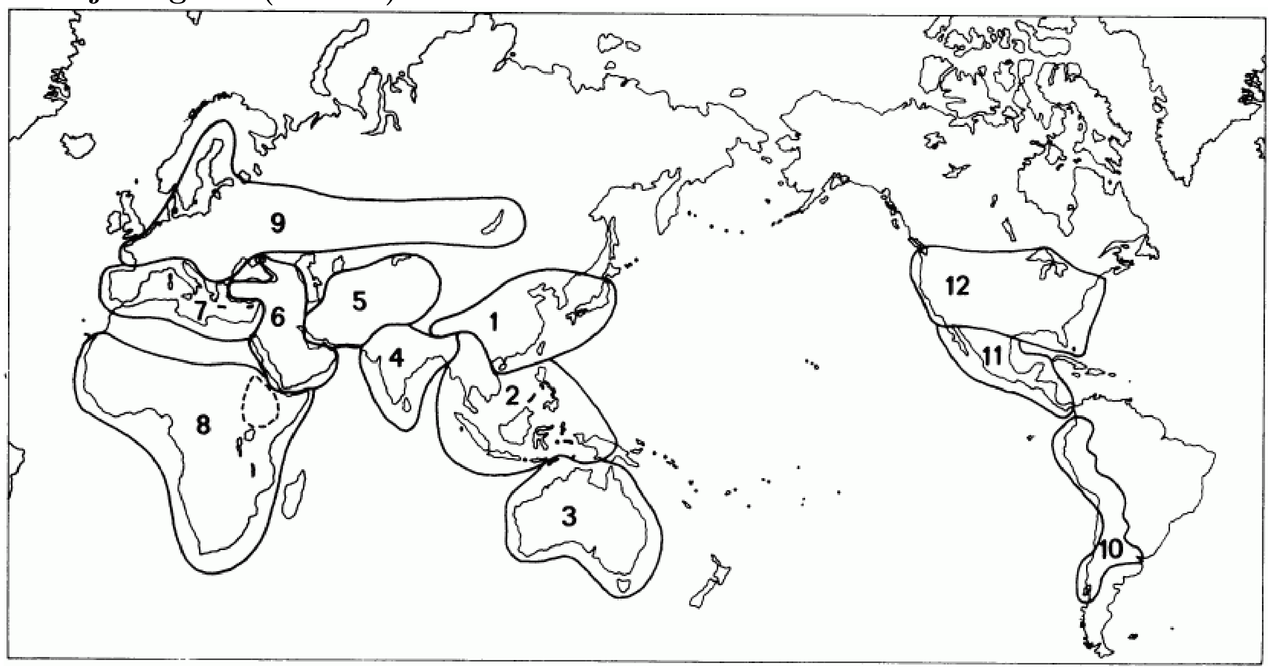


Centers of origin from Zhukovskij

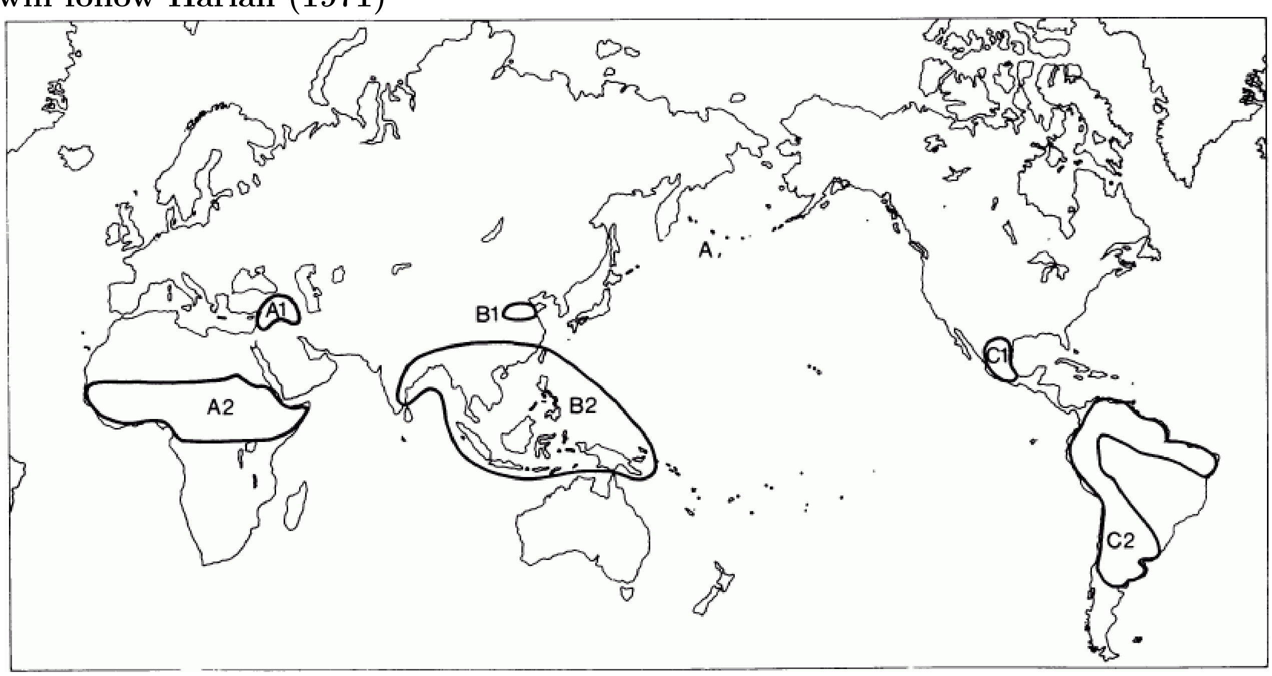
- China
- Indochina—Indonesia
- Australia—New Zealand
- India
- Central Asia
- West Asia

- Mediterranean
- Africa
- Europe—Siberia
- Central America
- Bolivia—Peru—Chile
- North America

Zhukovskij's regions (centers)



We will follow Harlan (1971)



Summary

- According to Harlan (1971), there are 6 centers (regions) of initial plant cultivation

For Further Reading

References

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Outline

18 Centers of cultivated plants origin

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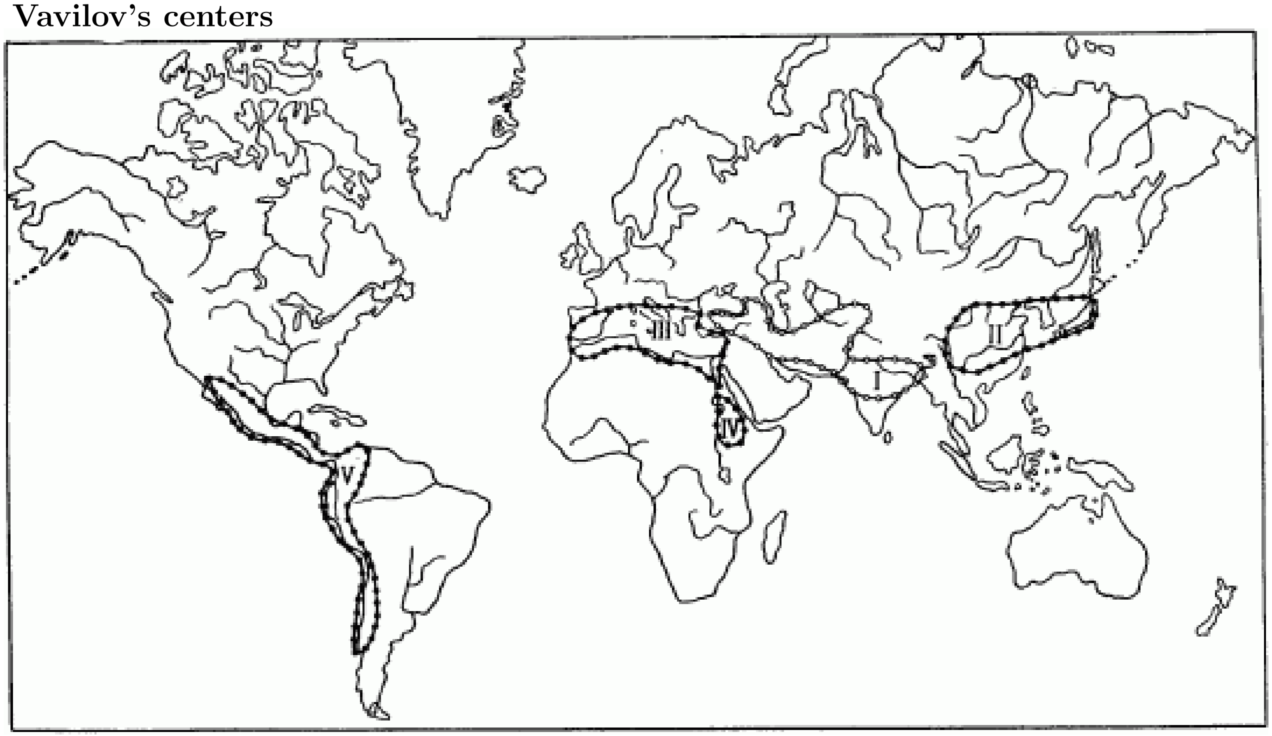
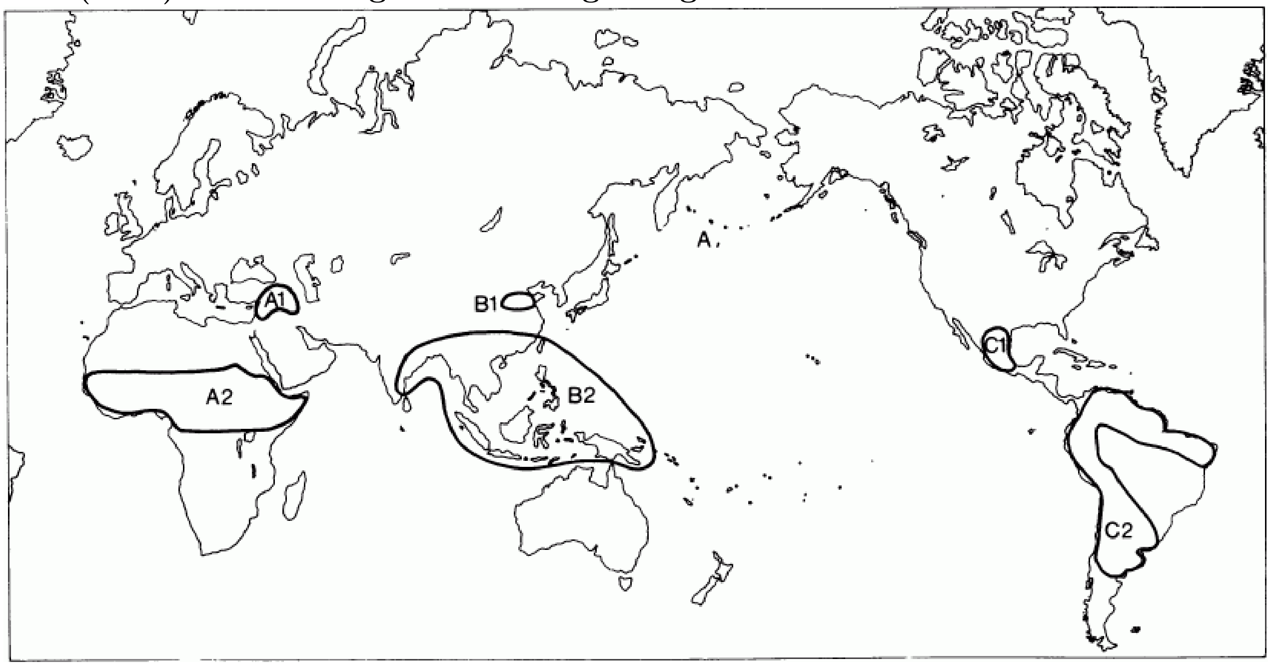
Five Vavilov's centers



Harlan's (1971) centers of agricultural beginnings



West Asian center (A1)

- Xerophytes, plants relatively small, stiff stems and leaves, drought-tolerant
- Some wheats, two-rowed barley, oats, lentils
- Ancient Egypt and Mesopotamia

Indian center (B2)

- Xerophytes, small leaves, rapid development and filling-out of seeds, small seeds, extremely susceprible to European fungal and bacterial diseases
- Some wheats, six-rowed barley, finger millet, chickpea
- Ancient Indus Valley Civilization

African/Ethiopian center (A2)

- Adapted to poor soils, starting to grow in the beginning or in the end of rain season
- Fonio, tef, sorghum, pearl millet
- Ancient African civilizations: Aksum, Yoruba, Benin

China center (B1)

- Mesophytes and even hydrophytes, short development, small and medium-sized seeds, relatively big leaves
- Rice, soybeans
- Ancient Chinese kingdoms

Central American center (C1)

- Xerophytes and mesophytes, slow growing, big seeds, drought- and hot-tolerant
- Corn, common bean, sweet potatoes
- Ancient Aztec and Mayan empires

South American center (C2)

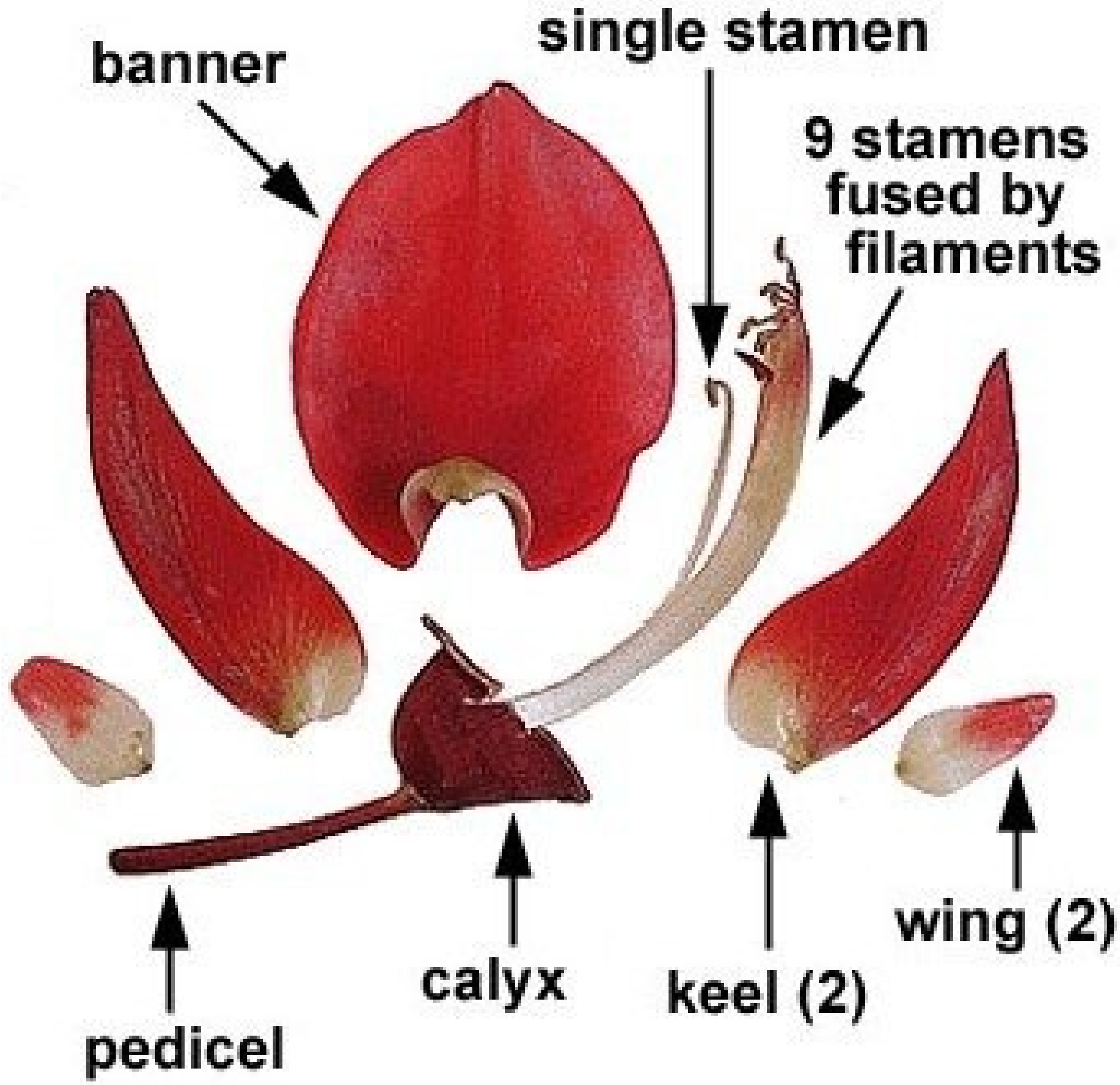
- Mesophytes, many are tolerant to low temperatures, big leaves, developed underground parts
- Cassava, potatoes, oca etc.
- Ancient Andean civilization

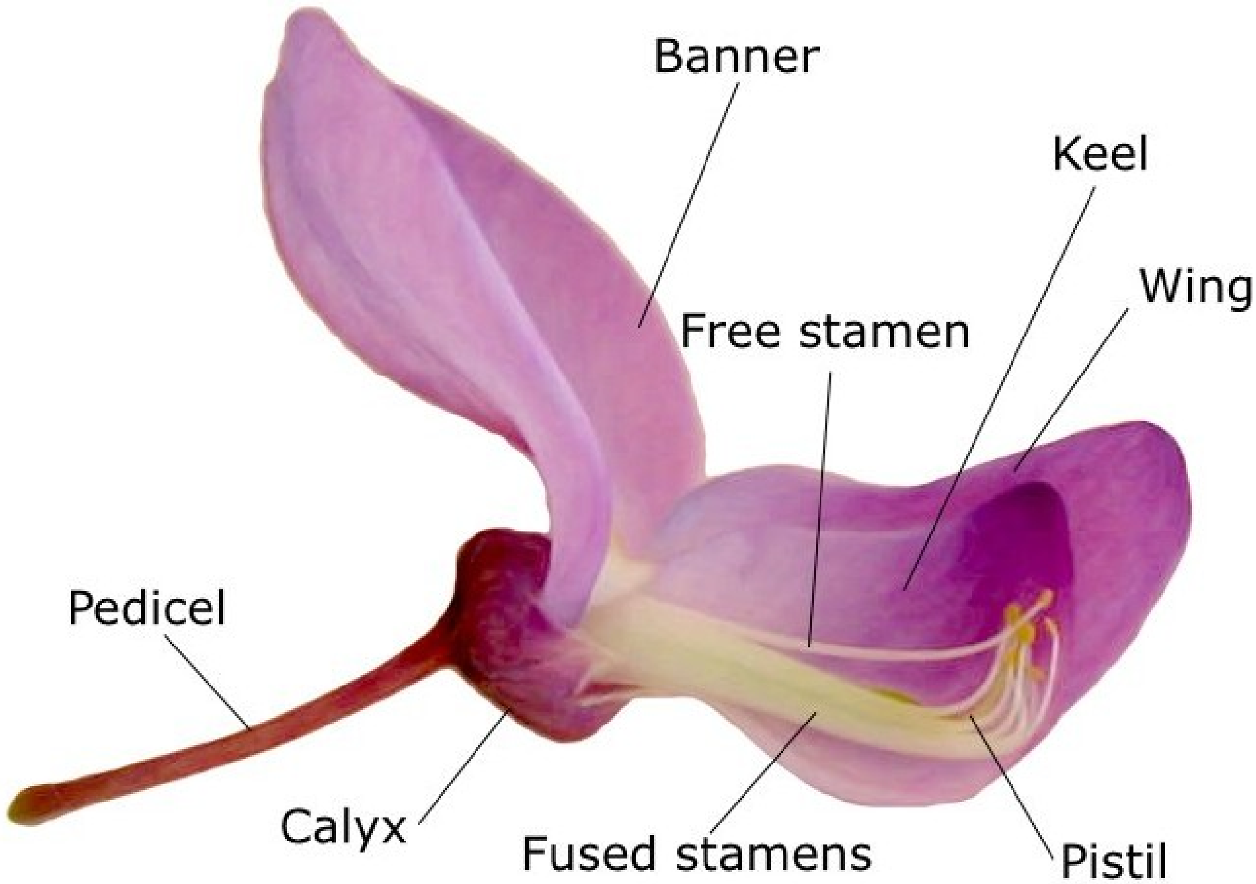
19 Legumes

Main characteristics of legumes

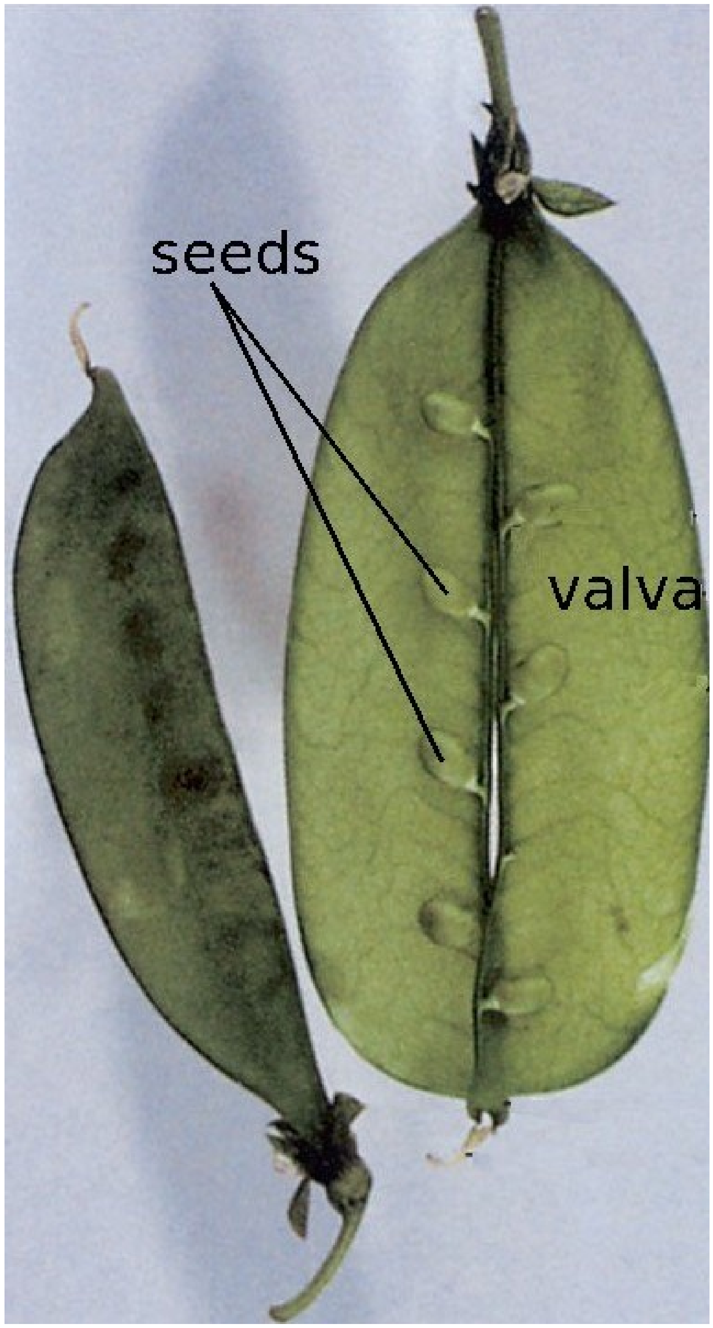
- One of the biggest plant families, more than 15,000 species
- Two most important characters: monosymmetric flowers with banner and keel; and monomerous legume fruit
- Nitrogen-fixing bacteria form root nodules (for cultivation, there are special *nitragines*)
- Consequently, all parts of legumes are rich of proteins, 2–4 times more than in cereals

Monosymmetric flower of legumes


single stamen
banner
9 stamens
fused by
filaments
wing (2)
calyx
keel (2)
pedicel



Legume: the fruit of Leguminosae



Root nodules

19.1 Soya beans, soybeans, Glycine max

Soya beans, *Glycine max*

- The most cultivated legume
- Seeds contain 42% of proteins including essential amino acids lysine, methionine and tryptophan; plus 20% of non-saturated oils
- Nearly universal culture: used as food, as technical culture, as oil culture and for the forage

Soya flowers

Soya features

- Cultivated mostly to the south from 50° latitude
- Nitrogen assimilation is slow at the beginning of season and reach the pike when plants start to flower
- Yield is ≈ 2 ton/hectare
- Main producer is United States, than Brazil

Soya agriculture

- Requires warm, wet and shiny climates; tolerates small frosts
- Easily grow on different soils but needs crop rotation
- Relatively fast growing: 120–150 days
- The biggest problem is harvesting: early harvesting leads to decaying of seeds whereas late harvesting results in legume cracking

Soya beans

Soya history

- Prehistoric crop in East Asia (B1)
- Introduced in Europe and North America about the end of XVIII century
- In U.S., considered as technical and did not used for food until late 1920s

19.2 Beans (Phaseolus vulgaris)

Beans (*Phaseolus vulgaris*)

- The second most cultivated legume

- “Beans” is the name of multiple cultivated legumes (more then 10 genera), but in strict sense, there are common beans, *Phaseolus vulgaris* and similar species
- Seeds are rich of carbohydrates and proteins
- Green legumes are also used as vegetables

Beans features

- Herbaceous annual vines with deep roots
- High diversity of cultivars
- Beans should be cooked for at least 10 min at 100° C to destroy weakly poisonous *phytohaemagglutinins*

Beans

Diversity of common beans

- Navy beans (*Phaseolus vulgaris*, multiple cultivars
- Lima beans (*Phaseolus lunatus*)
- kidney beans (*Phaseolus vulgaris* cv. 'Red Kidney')
- Pinto beans (*Phaseolus vulgaris* cv. 'Pinto')
  and many others...

Beans agriculture

- Extremely heat tolerant, requires average watering
- Does not grow well in colder climates
- Require short days; soil type is not critical
- Often cultivated inside mixed crops (with corn, rice, safflower)

Beans history

- Native culture of Central America and Mexico (C1); important plant for Aztec civilization
- Spread around the world in XIX century
- Top producers now are Brazil and India

19.3 Pea (Pisum sativum)

Pea (*Pisum sativum*)

- Old culture of Old World, one of most hardy legumes
- Food and forage plant
- Seeds are high of carbohydrates (14%, and 1/3 of them are sugars) and proteins (5%)

Pea flowers

Pea features

- Annual herb which is able to climb up to 2 m with tendrils

- Comparing with other legumes, has an extremely short vegetation period, from 65 days (!)
- The northern line of cultivation is 68° latitude
- Long-day culture, also requires wet soils

Pea history

- Domesticated prehistorically in West Asia (A1); wild landraces of same species are still exist
- Spread to both Western Europe and Eastern Asia (common culture in Japan)
- Self-pollinated, and became a famous model plant of first genetic experiments made by Gregor Mendel

Summary

- Legumes are rich of proteins including essential amino-acids
- They mostly require humid climates and do not need specific soils

For Further Reading

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Outline

20 Legumes

20.1 Lentils, Lens culinaris

Lentils (*Lens culinaris*)

- One of the oldest cultivated plats, has been part of human diet since Neolitic times
- Rich of proteins (26%) and especially carbohydrates (60%)

Lentil

Lentils features

- Annual herbaceous vine up to 1 m high
- Less hardy than pea, requires warm season, vegetation period is often more than 100 days
- Long-day plant, drought tolerant (this is rare among cultivated legumes)
- Has relatively low yield (0.8 ton/hectare)

Lentils history

- Was domesticated in West Asia (A1) even before first civilizations appear

- Mentioned in Old Testament since it was a common food for Palestinian nations
- The word "lens" originated from Latin name of lentils
- Biggest producers are now Canada and India

Red and brown lentils

20.2 Chickpea (Cicer arietinum)

Chickpea (Cicer arietinum)

- One of primary Indian (B2) food plants
- Composition and yield is similar to lentils ($\approx$ 23% proteins and 64% carbohydrates, 0.8 ton/hectare)
- Has big seeds, requiring more boiling time than other legumes (up to 2 hours)
- Green parts are not edible as forage

Chickpea

Chickpea features

- Drought tolerant and therefore cultivated in arid climates
- Does not require specific soils
- Prefer long-days: does not go far into tropics; biggest producers are India, Pakistan and Turkey

Chana masala: Indian cousine

Some other legumes

- Pigeon pea (*Cajanus cajan*) perennial legume, originated in India (B2)
- Hyacinth bean (*Lablab purpureus*) has the African origin (A2), it is frequently grown also as ornamental
- Winged bean (*Psophocarpus tetragonolobus*) from South-West Asia (B2), multi-use food crop, all parts are edible

21 Sugar plants

21.1 Sugars

Sugars and their role

- Mono- and polysaccharides
- Glucose, fructose, sucrose, cellobiose
- Starch (amylose + amylopectin) and glycogen

Sugars and civilizations (speculation!)

- High level of glucose uptake by nervous cells
- Increasing use of sugars in human history
- "Unsuccessful" civilizations which did not find a reliable source of sugars

Ethanol

- Immediate product of yeast fermentation of glucose
- Pre-adaptation to alcohol from frugivores
- Bind to GABA (gamma-aminobutyric acid) receptors
- Converted into acetaldehyde (toxic!) by alcohol dehydrogenase and then into acetic acid by acetaldehyde dehydrogenase
- Asian flush and alcoholism are related to the genetic diversity of alcohol dehydrogenases

Downsides of sugars

- Obesity, because sugars are easy to convert into fats
- Diabetes, because insulin cannot deal with large quantities of sugars
- Dental diseases, especially dental caries (caused by lactobacteria taking sugars for their growth)
- Multiple synthetic sweeteners have been developed to avoid side-effects of sugars: heterocyclic saccharine (in "Sweet'N Low"), amino acid derivative aspartame (in "Equal"), chlorine hexose sucralose (in "Splenda", "Altern"). All have some associated problems.

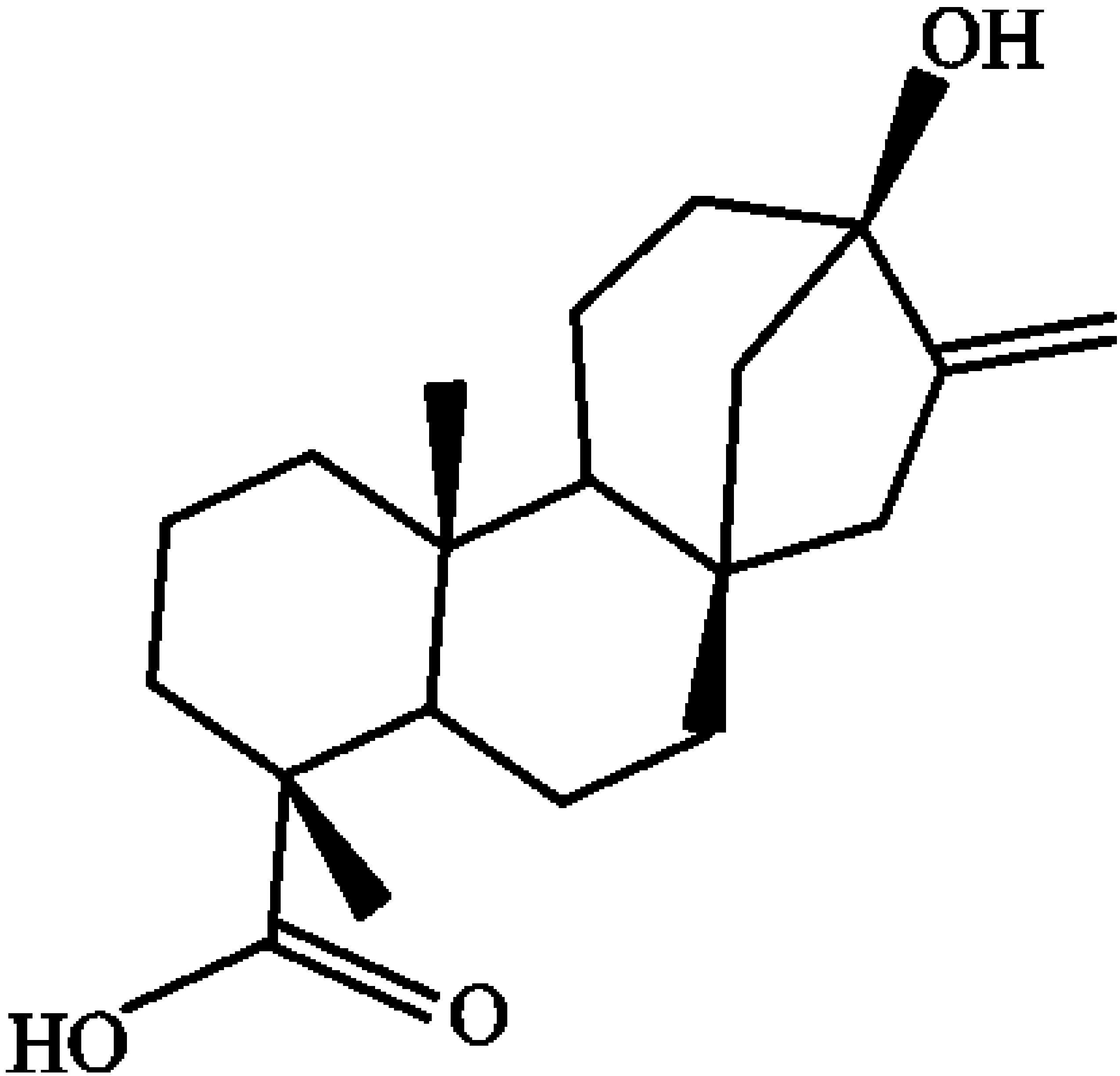
21.2 Sweeteners

***Stevia rebauldiana*, the natural sweetener**

- Belongs to aster family, Compositae
- Originated in South America (C2)
- Leaves contain the group of sweet glycosides, derivatives of steviol
- They are 100–150 times sweeter than sucrose (on the weight concentration basis)
- Despite of multiple controversies (not approved in EU, banned in Norway and Singapore) used by Coca-Cola and PepsiCo in their "zero calories" drinks

***Stevia* flowers**

Steviol

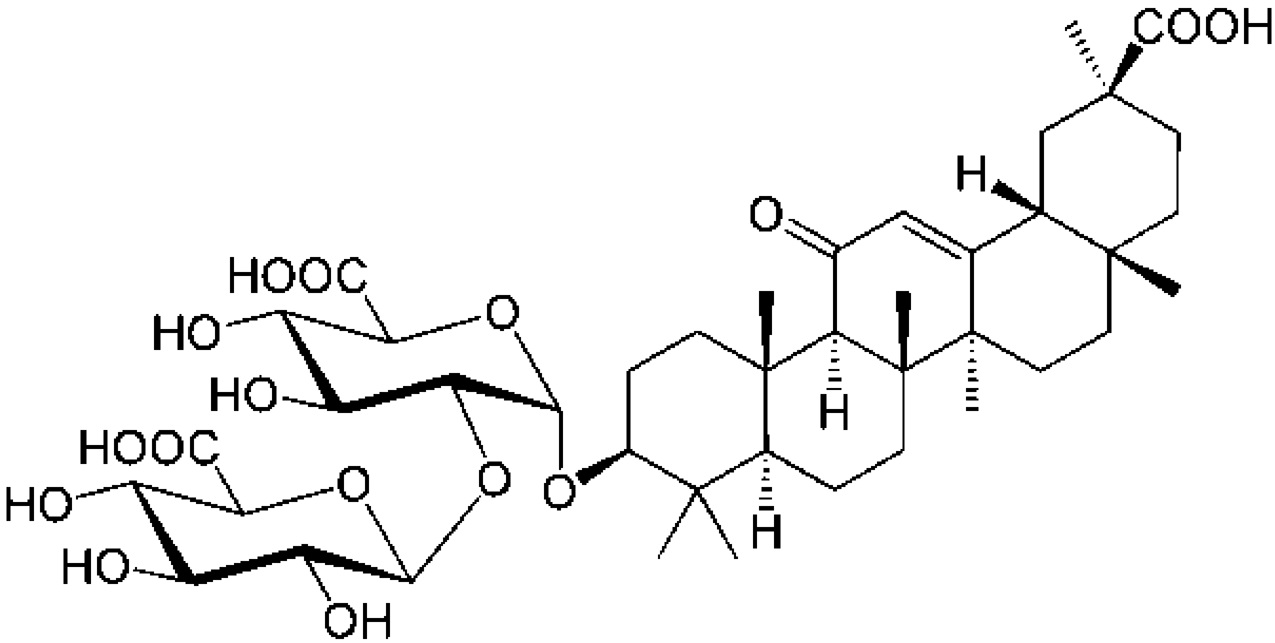


Our native natural sweeteners

- North Dakotan wild licorice (*Glycyrrhiza lepidota*) belongs to legume family, Leguminosae
- Contains natural sweetener **glycyrrhizin**, about 50 time sweeter than sucrose
- Side-effects are hypertension and lowering of testosterone level in males

American licorice, *Glycyrrhiza lepidota*

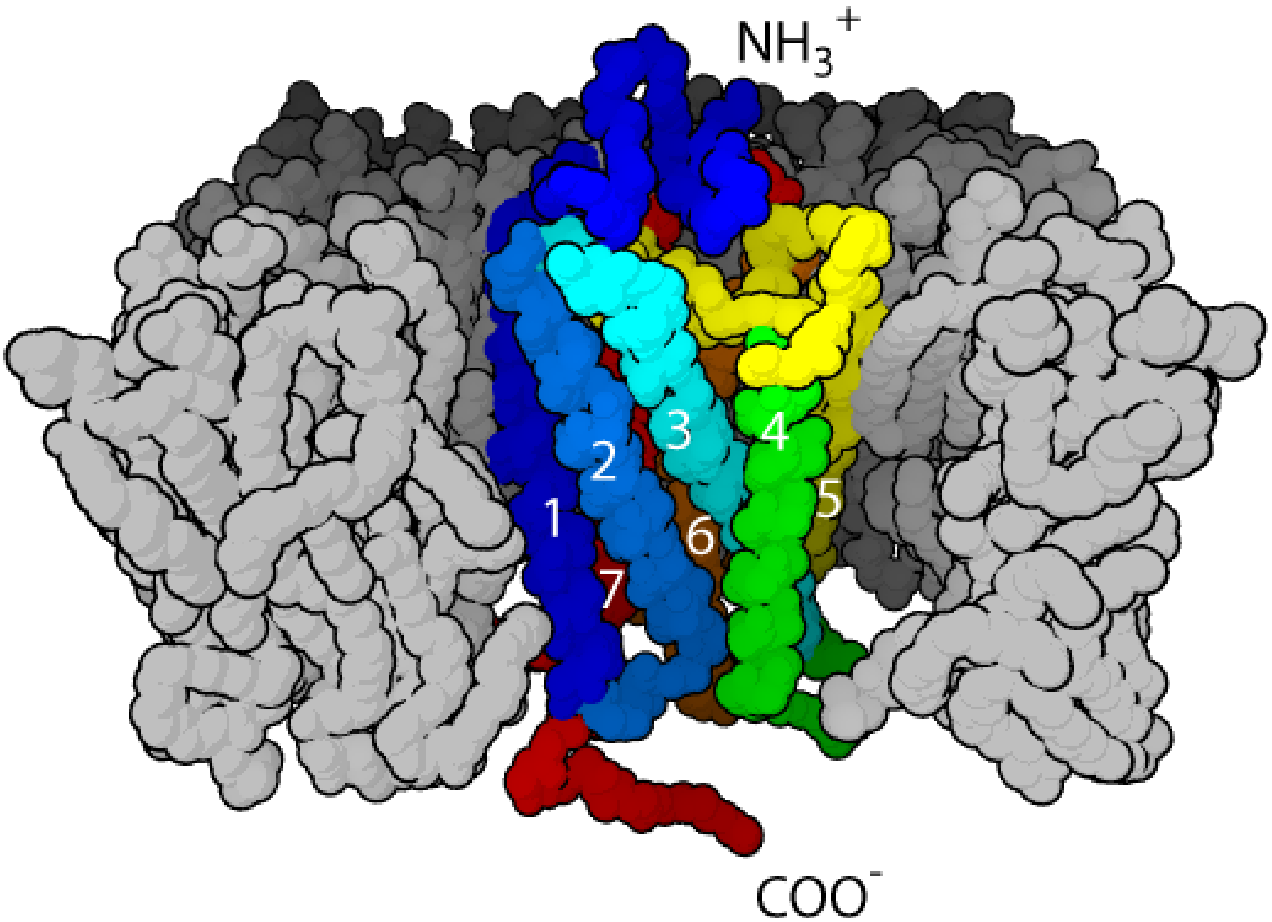
Glycyrrhizin



What is sweetness?

- Nature of sweetness is not yet fully discovered
- Probably due to specific Van der Waals forces occurring in variety of molecules
- These molecules have an effect on sweet receptors—large proteins from G protein-coupled receptors (GPCRs) group

GPCR, sweetness receptor



Miracle fruit, *Synsepalum dulcificum*, the super-sweetener

- West African (A2) small tree, belongs to tropical Sapotaceae family
- Berries convert sour tastes into sweet tastes (!), effect lasts for ≈ 1 hour
- The effect is due to glycoprotein miraculin which is binding to sweet receptors
- Cultivation is now starting in Florida, approval as food additive is pending—it is heat-resistant and may be used as a “sweetener”; there are genetically modified lettuce plants which produce miraculin

Miracle fruit

Miraculin glycoprotein

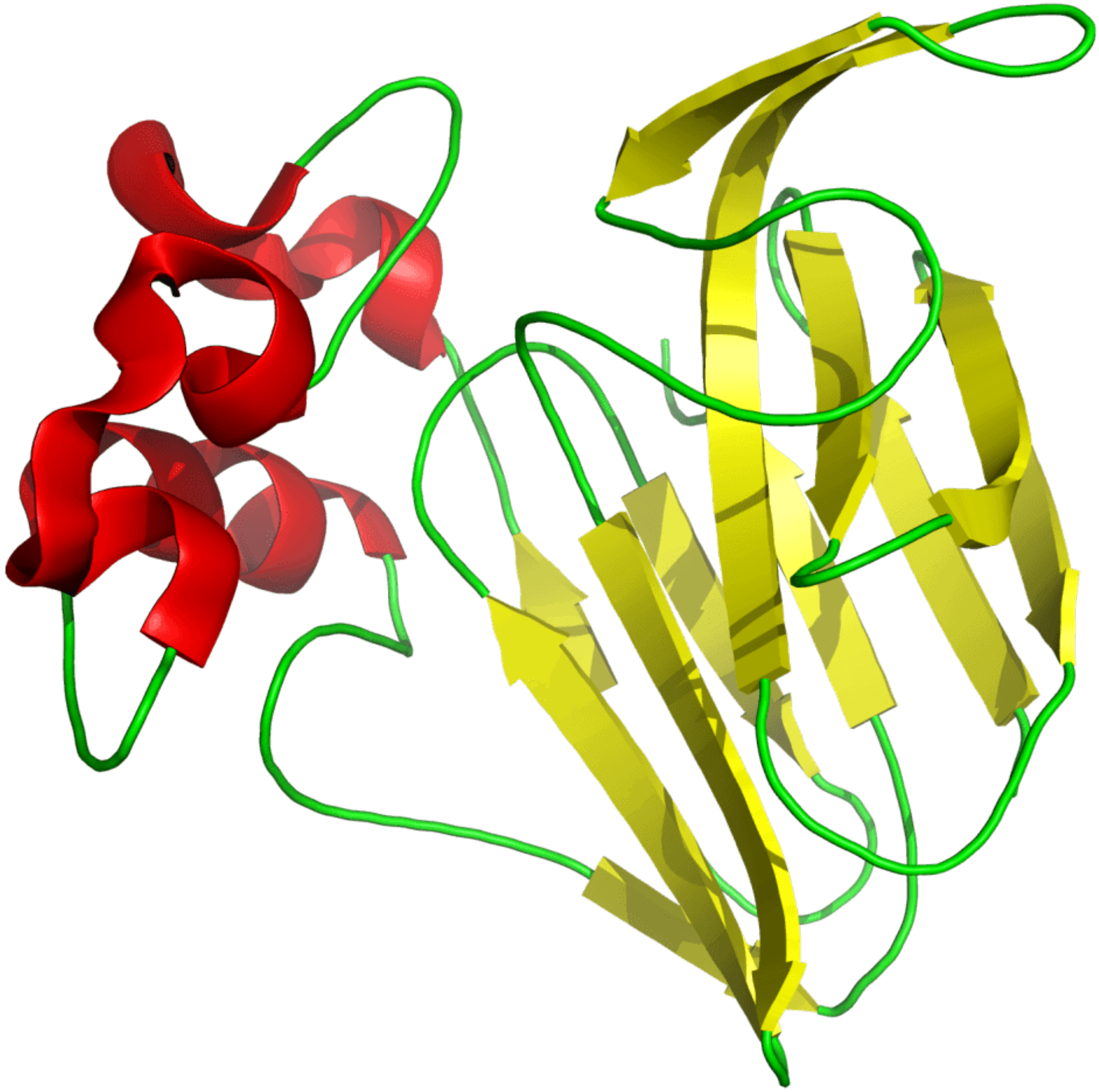
Other plants super-sweeteners

- Curculin from *Curculigo latifolia* ("lumbah-lumbah"), Malaysian (B2) herb from Hypoxidaceae family, has the same effect + it is also super-sweet by itself (500–2000 times sweeter on weight basis than sucrose).
- Thaumatin from *Thaumatococcus daniellii* ("miracle berry"), West African herb from Marantaceae, is 3000 times sweeter than sucrose.
- Monellin from *Dioscoreophyllum volkensii* ("serendipity berry"), West African Menispermaceae vine, is 800–2000 times sweeter than sucrose but only to Old World monkeys including humans.

Lumbah-lumbah

Miracle berry (not "miracle fruit"!)

Thaumatin, the most sweet protein



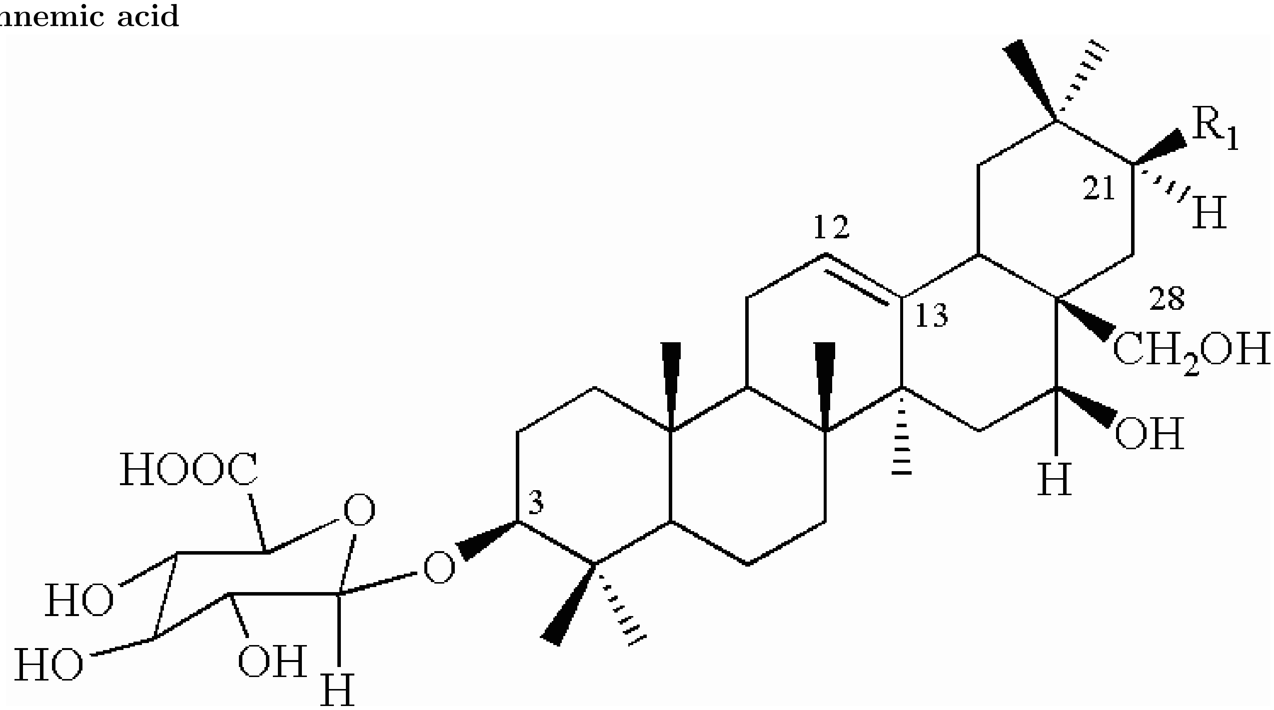
Serendipity berry, *Dioscoreophyllum volkensii*

Anti-sweeteners

- Several plants contain chemicals which are able to suppress sweet receptors
- Indian herbaceous vine *Gymnema sylvestris* from a dogbane family (Apocynaceae) contain gymnemic acids which suppress sweet taste for ≈ 10 min
- In addition, plant has an unrelated (?) effect in lowering blood sugars
- Used as a drug for curing Type 2 diabetes and different forms of metabolic disorders

Gymnema sylvestre

Gymnemic acid



21.3 Sugar cane

Sugar cane, *Saccharum officinarum*

- Belongs to grass family, Gramineae; it is a C_4 grass
- The oldest cultivated sugar plant
- Contains sugars in stem

Sugar cane

Sugar cane biology

- Extremely tall grass, up to 6 m tall (!)
- Stem phloem juice contains 12–20% of sucrose in lower parts of stem
- Juice is pressed, filtrated, evaporated, centrifuged (to separate syrup from sugar crystals) and dried

Sugar cane agriculture

- Grafted culture, it is not recommended to wait until flowering
- Short-day, sun-loving plant, optimal temperatures should be > 20° C
- Requires irrigation even in humid tropics (!) and significant amounts of phosphorous
- Vegetation period is up to 250 days

Sugar cane history

- The culture started in Indian center, then moved to China and with Arabs—to Europe (Spain, 1150 AD)
- Arabs first invented white, filtrated sugar
- Went to Central and South America in XVI century (Europe needs sugar but it was not growing well there!).
- Now cultivated in tropical America, Africa and Asia (top producers are Brazil and India) but culture is declining under the pressure of competition with sugar beet
- Etymological dictionary says that:

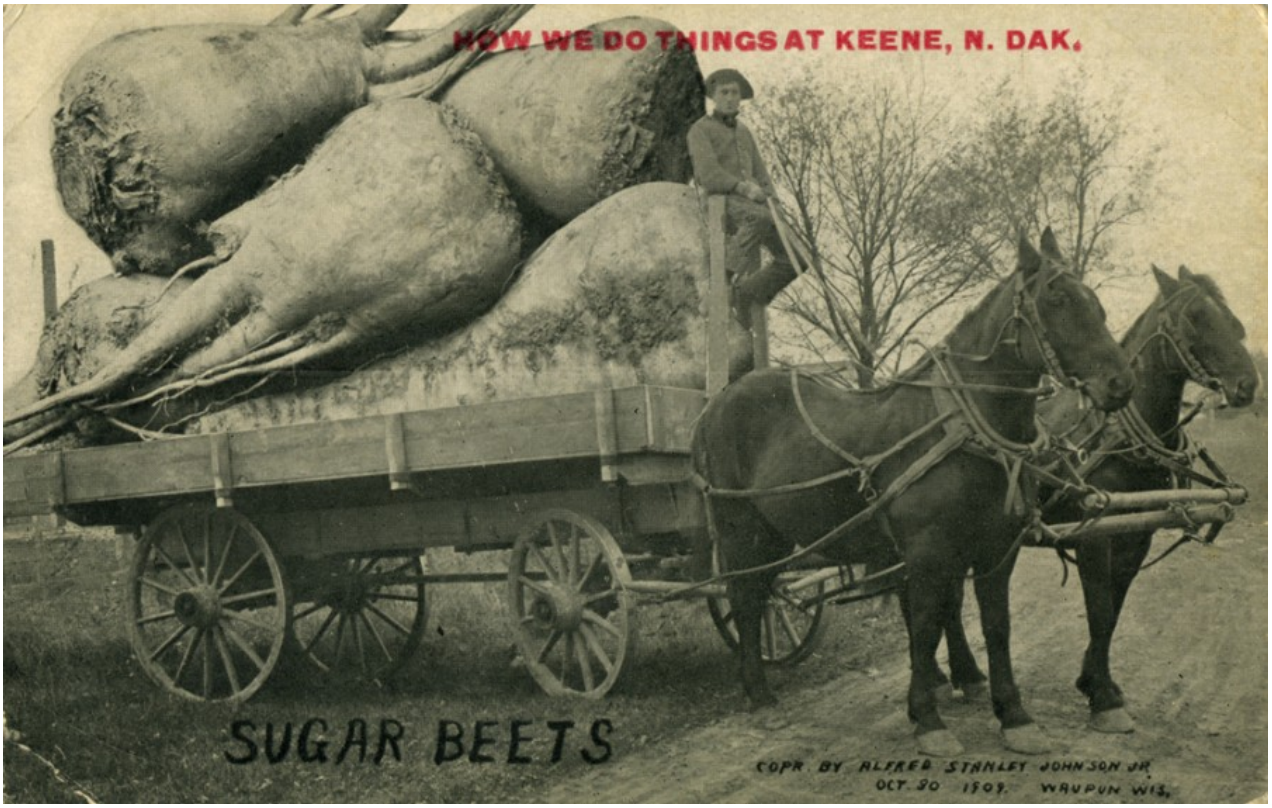
  sugar: late 13c., from O.Fr. sucre "sugar" (12c.), from M.L. succarum, from Arabic sukkar, from Pers. shakar, from Sanskrit sharkara "ground or candied sugar," originally "grit, gravel"

21.4 Sugar beet

Sugar beet, *Beta vulgaris* var. *saccharifera*

- Amaranth family, Amaranthaceae (or Chenopodicaceae in older classifications)
- Same species with vegetable beet
- Has been selected from leaf and root beets for only 300 years: one of the youngest cultures
- Root contains up to 20% of sucrose

Sugar beet from North Dakota! (that's a joke photo)



Sugar beet biology

- Biennial plant: first year with rosellate leaves, second year forms stem with non-showy flowers
- The "root" is actually intermediate structure between stem and root in strict sense—hypocotyl
- Has anomalous secondary growth (layers of tissues)
- Roots are "white": do not contain betalain (red pigment which probably helps red beet to protect tissues from fungi and animals)

Sugar beet agriculture

- Hardy plant: North Dakota is one of the leading states in sugar beet cultivation
- Yield is typically ≈70 ton/hectare (wet mass), and 12 ton/hectare (pure sugar): compare with ≈100 and ≈10 for sugar cane
- Some plants should be left for seeds (second year)
- Susceptible for weeds (needs herbicides)

Sugar beet history

- In 1747, the sucrose content was discovered
- In 1810s, due to continental blockade of France, sugar mills were established across all Europe
- In XX century, sugar production was almost doubled
- Leading countries now are France, Germany and U.S.; one of biggest research centers is NDSU

21.5 Sugar maple

Sugar maple, *Acer saccharum*

- Tree from Sapindaceae (Aceraceae in older classifications) family
- Old semi-cultivated plant of eastern tribes of Native Americans
- Spring sap is the main source of sugar

Sugar maple

Native sugar-making

Sugar maple features and history

- Sap contains 2–5 % of sucrose, the season starts in early spring and continues 4–8 weeks
- In total one tree could produce up to 50 liters of sap per season for 60–70 years (from 30–40 to 100 years old)
- Production increased during Civil War
- Leading producer is Canada (Quebec)
- One can use boxelder (*Acer negundo*) for syrup
- Analogous birch syrup from *Betula* is more poor, only 1–2% of sugars

Sugar collection

Sugar evaporation

Summary

- Legumes are rich of proteins including essential amino-acids
- They mostly require humid climates and do not need specific soils
- Sugar is highly used but controversial source of energy
- Sweet taste still has undiscovered nature

For Further Reading

References

[1] A. Shipunov. *Ethnobotany* [Electronic resource]. 2011—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_310`

[2] P. M. Zhukovskij. *Cultivated plants and their wild relatives* [Electronic resource]. Commonwealth Agricultural Bureaux, 1962. Abridged translation from Russian. Mode of access: `http://ashipunov.info/shipunov/school/biol_310/zhukovskij1962_cultivated_plants.pdf`.

Outline

22 Sugar plants

22.1 Sugar palms

Arenga sugar palm, *Arenga pinnata*

- Belongs to palm family, Palmae
- The source of "gur" sugar and also wine
- Inflorescences are used for taking sap (17–20% of sucrose)

Arenga sugar palm

Arenga sugar palm features and history

- Syrup are very easily inverted (hydrolyzed into glucose and fructose) and should be evaporated as soon as possible
- Every day, palm tree gives 5–7 liters of sap; the season is up to 8 weeks
- Old Indian culture spread into south-east Asia

Collection of palm sap

Toddy, *Caryota urens*

- African sugar palm, one of the largest palms
- Monocarpic tree, dies after flowering
- Since the sap is fermented fast, it mostly used as a source of palm vine (≈1% of alcohol)
- Starred in groundbreaking novel “The Palm Wine Drinkard” by Nigerian author Amos Tutuola

Toddy palm

Toddy palm on flowering stage

Palm-wine drinkard

For Further Reading

References

[1] A. Shipunov. *Ethnobotany* [Electronic resource]. 2011—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_310`

[2] P. M. Zhukovskij. *Cultivated plants and their wild relatives* [Electronic resource]. Commonwealth Agricultural Bureaux, 1962. Abridged translation from Russian. Mode of access: `http://ashipunov.info/shipunov/school/biol_310/zhukovskij1962_cultivated_plants.pdf`.

Outline

23 Sugar plants

23.1 Lesser sugar plants

Sweet sorghum, *Sorghum saccharatum*

- Grass, selection started in 1940s
- Similar in agriculture, but much less demanding plant than sugar cane

- 10–20% of sucrose in stems
- Now cultivated mostly in U.S. and Argentine

Sweet sorghum

Mezcal, tequila agave, *Agave tequilana*

- Monocarpic Mexican plant from asparagus family (Asparagaceae)
- The sap is rich of sugars, mostly fructose
- Used mostly for alcohols like mezcal, pulque and tequila

Mezcal

Japanese raisin tree, *Hovenia dulcis*

- Large East Asian tree from buckthorn family, Rhamnaceae
- Large fruit stalks ("subsidiary fruits") may be used as replacement for honey
- Has several medicinal properties (e.g., helps recovery from alcoholism)
- Many other fruits were and are used as sugar sources: most notable are Mediterranean **grapes**, **apricots**, **melons** and **figs**.

Japanese raisin tree

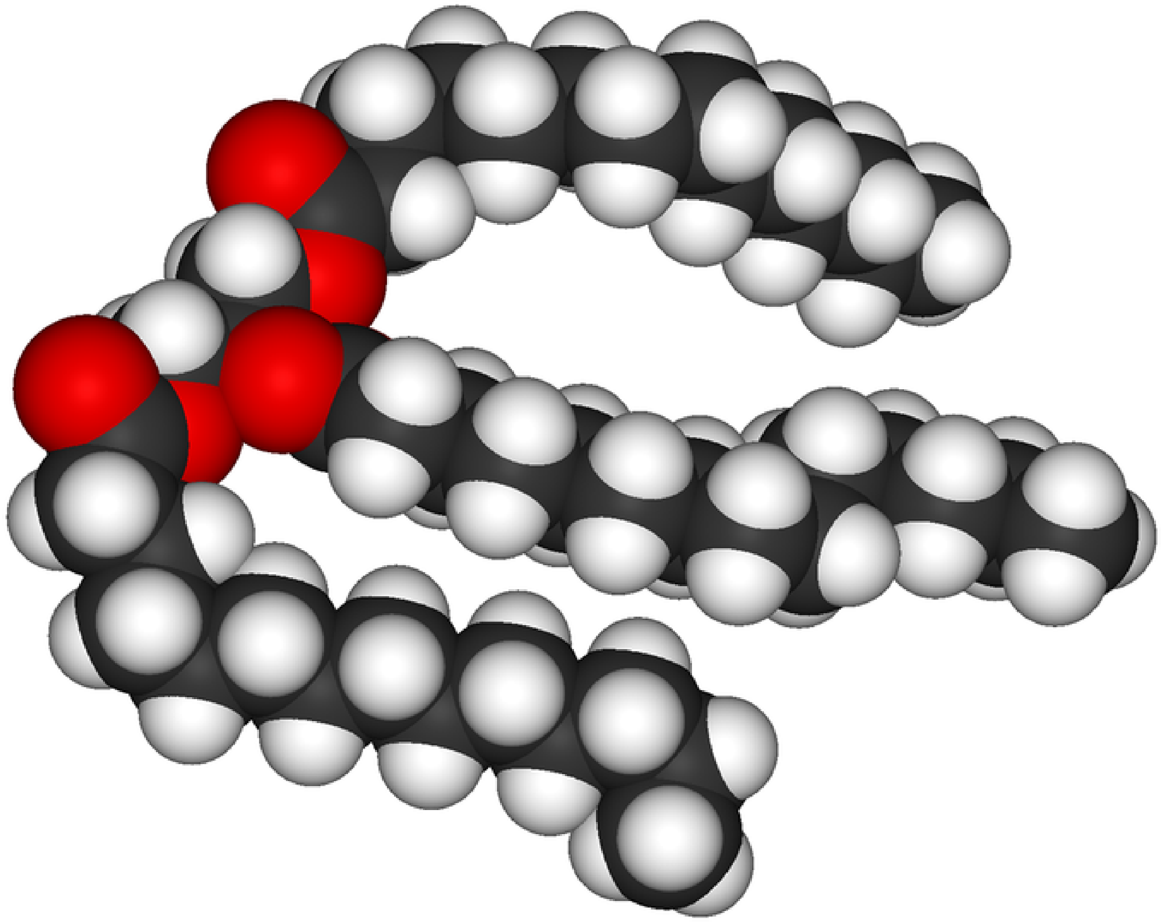
24 Oil plants

24.1 Introduction to oils

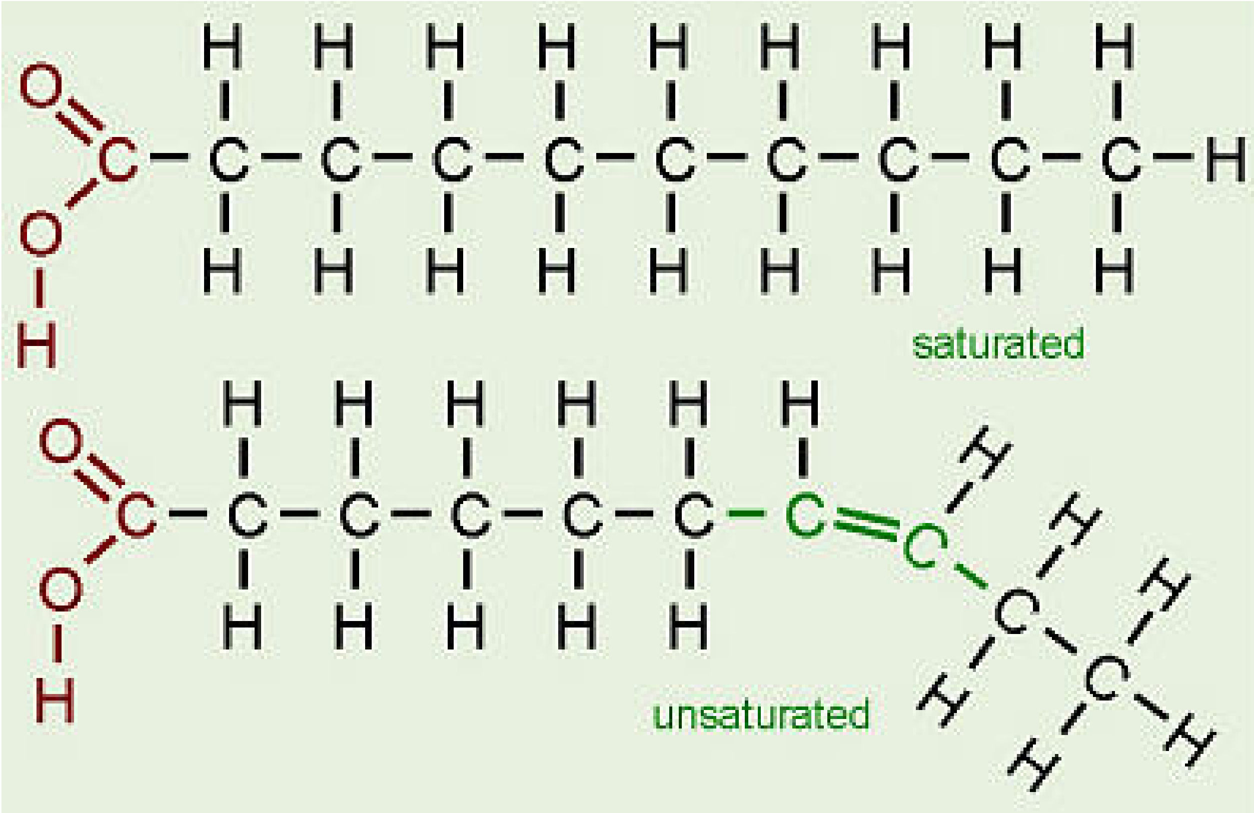
What are oils

- Triglycerides: triesters of glycerol and saturated or non-saturated fatty acids
- Liquid triglycerides are **oils** whereas hard are **fats**
- *Hydrogenated* oils are hard derivatives of liquid plant oils

Triglycerides



Fatty acids



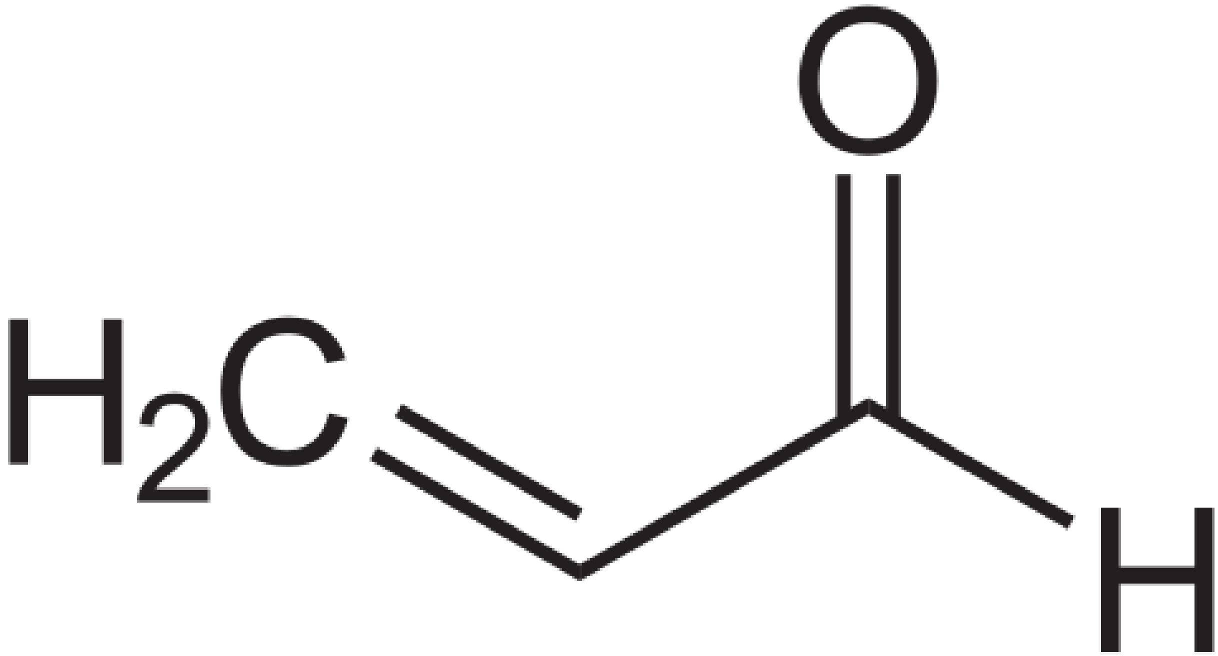
Oils' features

- High energy: 9 calories (0.009 Cal) per gram, two times more than carbohydrates or proteins
- Slow metabolism, several times slower than of carbohydrates
- Many mammals (including humans) use fats also as a source of water

Smoke temperatures

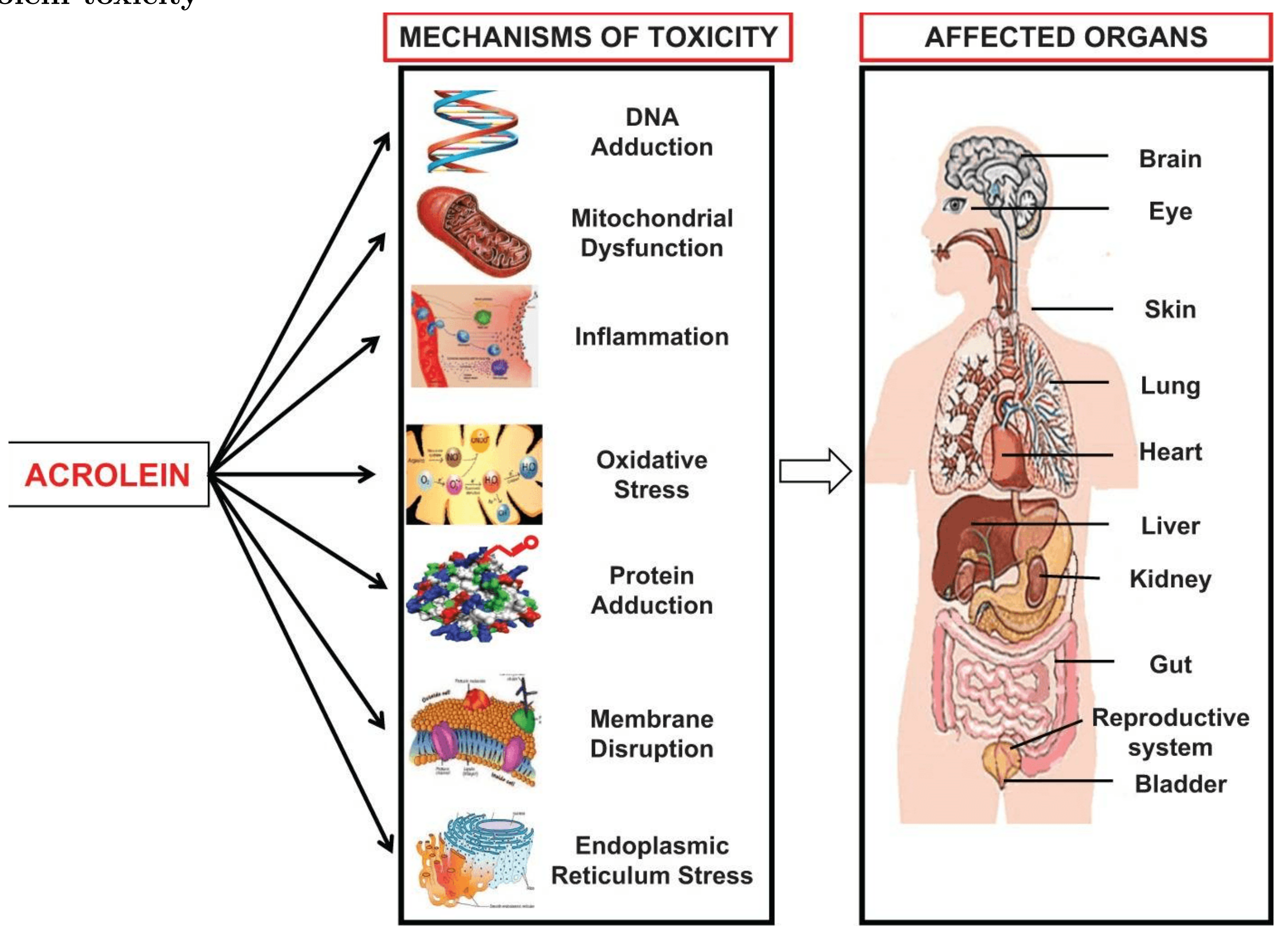
- Under high temperatures, oils start to smoke: this is due to acrolein
- Acrolein is highly toxic (even used as chemical weapon in World War I)
- Cream butter has ≈175°C smoke point whereas many plant oils like peanut have ≈232°C smoke point; flax oil is an exception (≈107°C)

Acrolein



Multiple, probably unrelated (Moghe et al, 2015) toxic effects

Acrolein toxicity

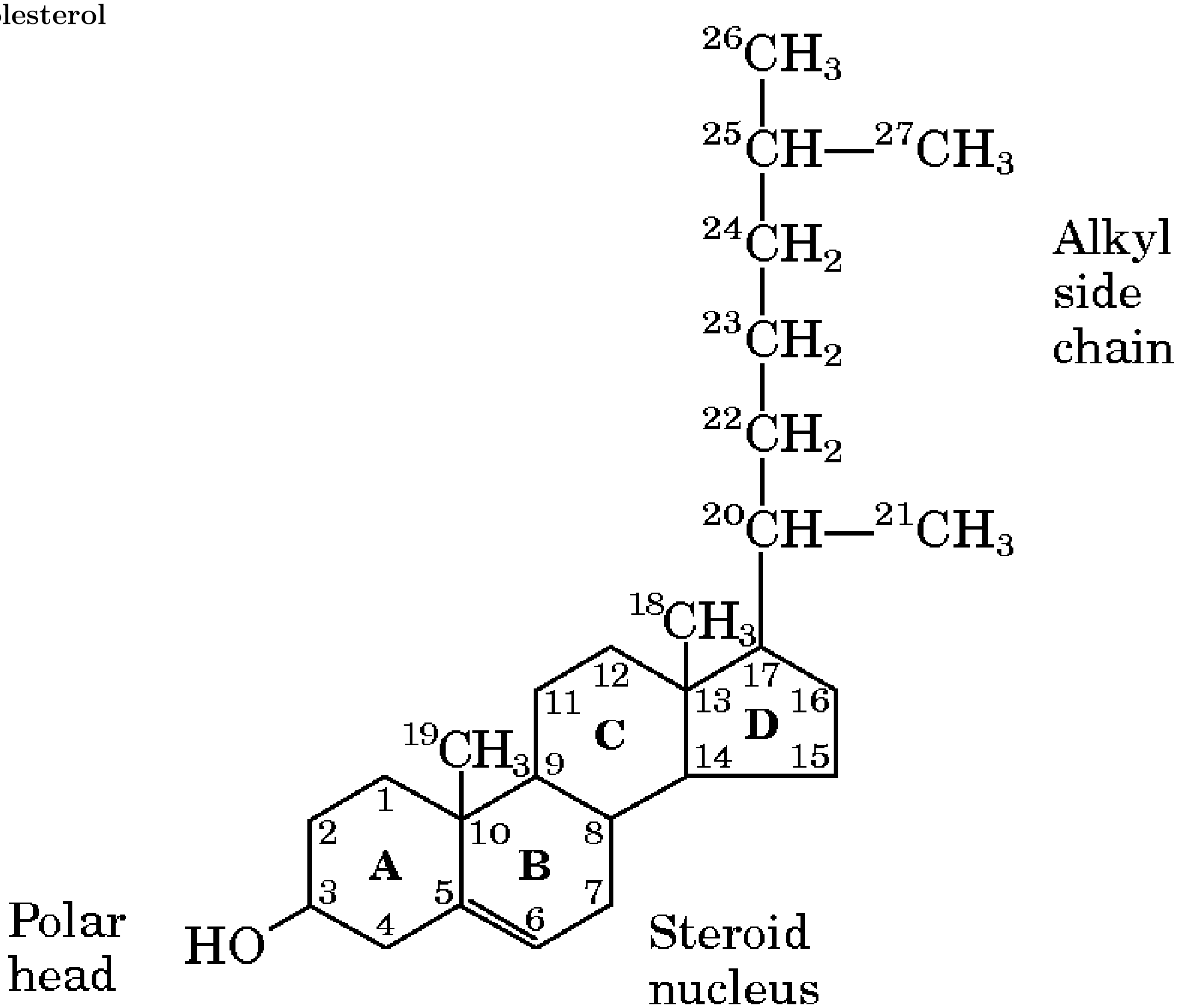


From `https://www.ncbi.nlm.nih.gov/pubmed/25628402`

Cholesterol

- Cholesterol is a main component of animal cell membranes and predecessor of steroid hormones
- However, suspicions raised that high level of cholesterol corresponds with atherosclerosis (Ancel Keys' conception of "Mediterranean diet")
- The most risky group are men of age 35–55
- Recent experiments suggest that cholesterol level has **only weak or no relation** with vessel diseases:
  - `http://www.ncbi.nlm.nih.gov/pubmed/16340654`: 70% of human population are hyporesponders to dierary cholesterol
  - `http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3900007`: population and individual differences are more important than diet
- Plant oils do not contain cholesterol

Cholesterol

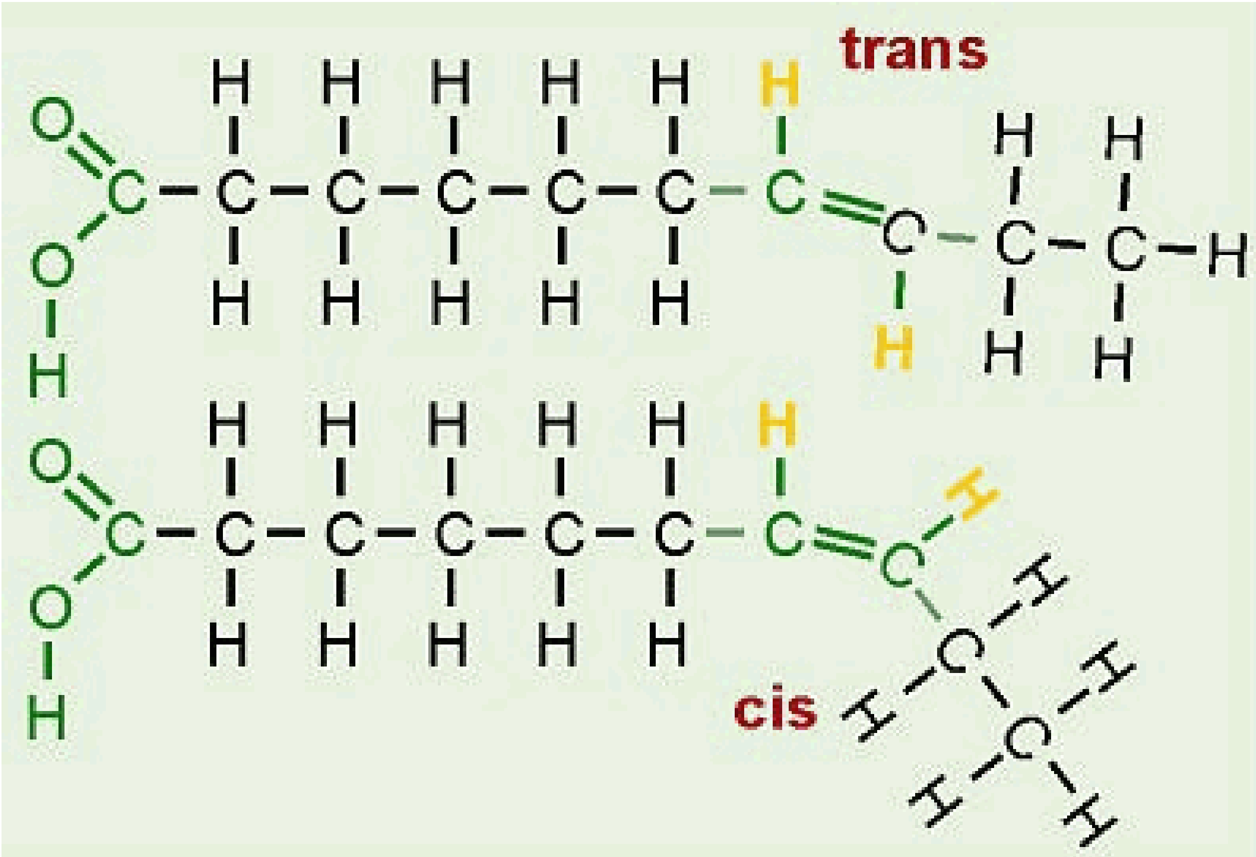


Trans fats

- Trans fats are byproducts of hydrogenation of plant oils, they also may appear in deep fat frying

- Again, *suspicion* is that trans fats are related with heart diseases
- Now most of hydrogenated oils (margarines) are almost free of trans fats

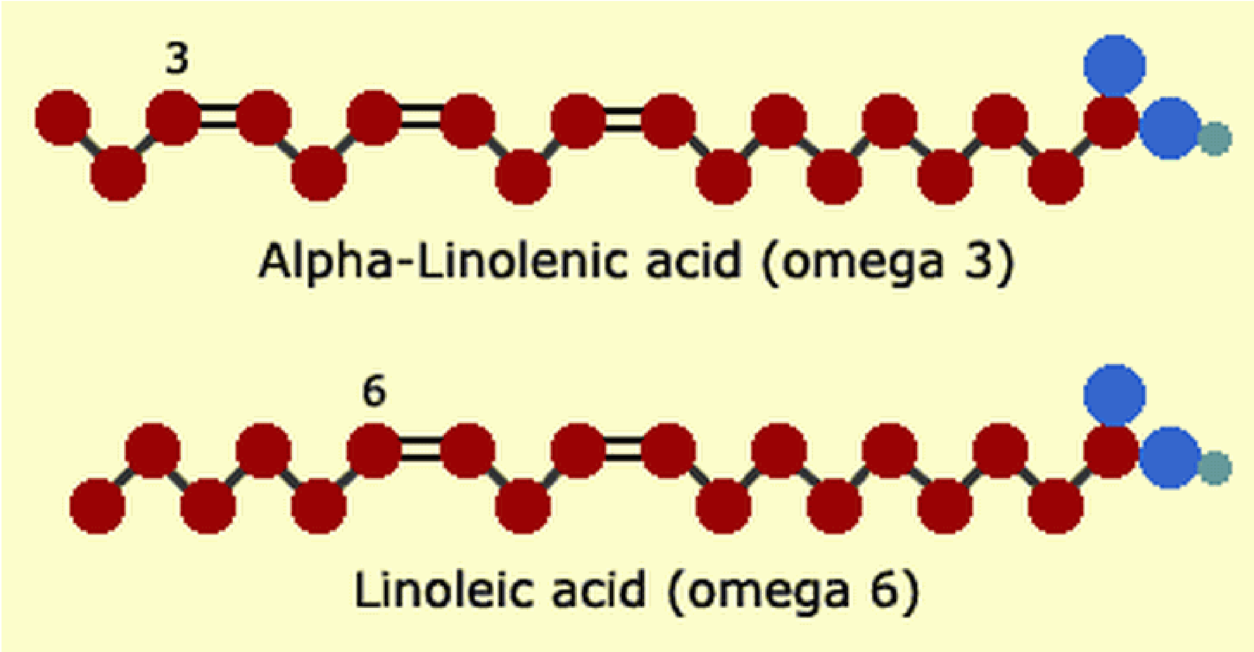
Trans fatty acids



Omega-n-unsaturated fatty acids

- Essential fatty acids that may only be synthesized in plants
- They *probably* related with lowering of cholesterol level, with curing Type 2 diabetes, and with general lowering of cardiovascular mortality
- Canola, flax and soybean oils contain significant amounts of omega-3-unsaturated fatty acids (and also sea fishes)

Omega-n-unsaturated fatty acids



24.2 Sunflower, *Helianthus annuus*

Sunflower, *Helianthus annuus*

- Belongs to aster family, Compositae
- Big genus distributed in North and South (but not Central) Americas
- Only one species, *Helianthus annuus* is cultivated as an oil plant

Sunflower biology

- Annual plant (exception among sunflowers!)
- Young plants are highly heliotropic
- Up to 65% of oils in seeds
- Used also as forage plant, especially in northern regions
- Coordinates of flowers in the head are explained with Vogel's model:

$$r = \sqrt{n}; \quad \theta = n \times 137.5^\circ,$$

  where where θ is angle, r is the distance from the center, n is the index number of the floret, and c is a constant.

Sunflower head

Sunflower agriculture

- Requires light and aerated, rich soils; root system allows to use water from deep layers of soil; requires phosphorus
- Vegetation period 70–140 days
- Wind- and insect-pollinated plant
- Oil is pressed similarly to most oil plants
- There are also nut cultivars

Sunflower history

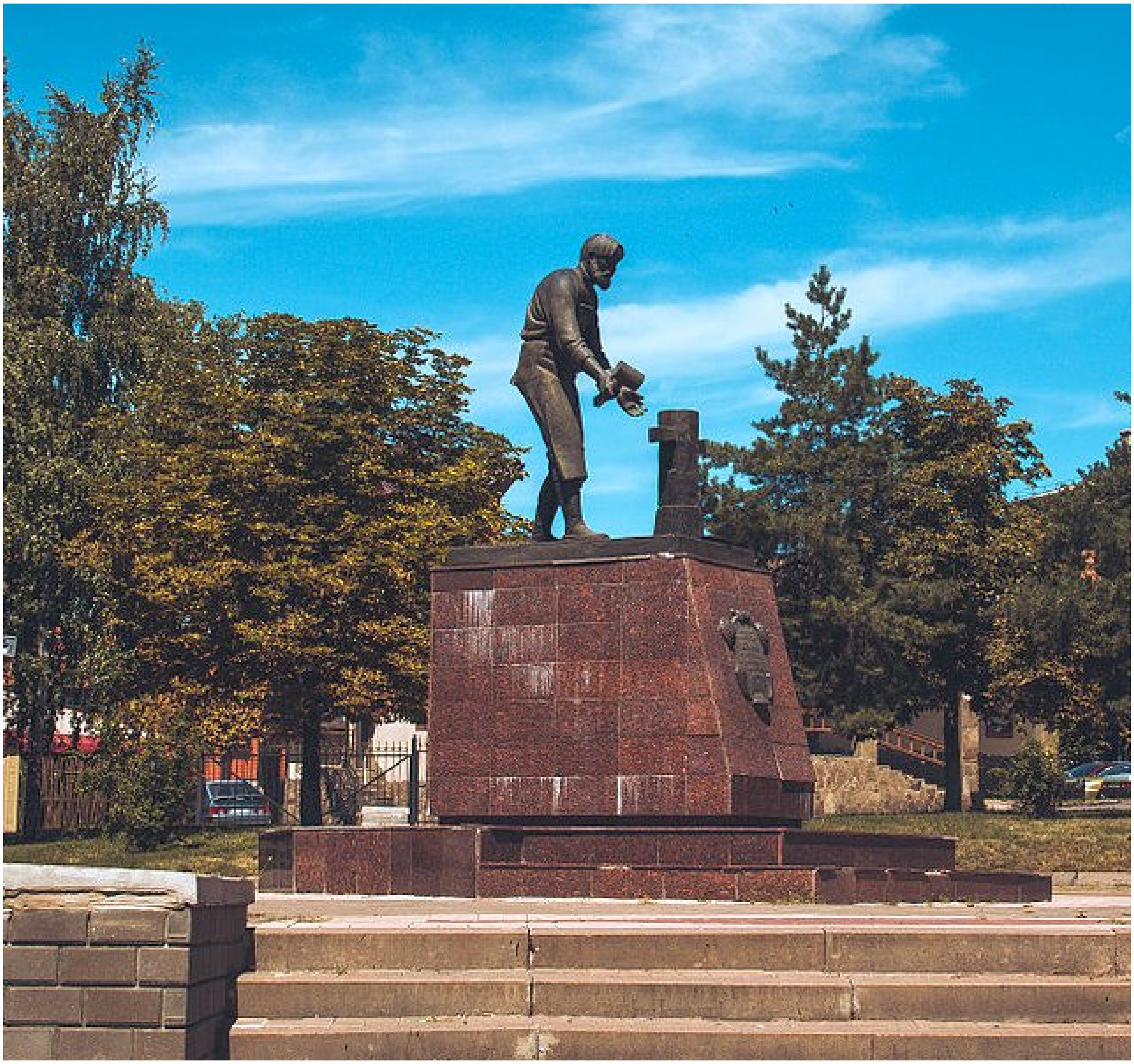
- Domesticated most probably in North America, widely used by native tribes in New Mexico and other southern states
- Went to Europe in 1510, cultivated as ornamental and forage plant and then abandoned
- In Russia, folk selection resulted in fasciated cultivars which have several times more seeds per head
- In 1829, Russian peasant Daniil Bokarjov discovered the high oil content and made first sunflower oil
- Ukraine, Germany and United States are now main producers

- Symbol of Ukraine, state flower of Kansas
- Oil is fragrant, smoke point is about 230° C

Fasciation: elongation of apical meristem

This feature was probably used for the sunflower selection.

Bokarjov memorial in Alekseevka, Belgorod region



24.3 Peanut, *Arachis hypogaea*

Peanut, *Arachis hypogaea*

- Belongs to legume family, Leguminosae
- Geocarpic plants: fruits are burying into the ground
- One of the most protein-rich oil plants (53% oils, 25% proteins)

[We skip here soybeans which were described on previous lectures]

Peanut biology

- Small, self-pollinated plant with flowers positioned nearby soil surface
- Burying structure is a gynophore, part of flower receptacle

- Legumes are indehiscent, contain 2–3 seeds
- 1–2% of human population have peanut allergy to peanuts (consequence of high protein content)
- Smoke point is about 232° C

Peanut

Peanut agriculture

- Vegetation is 3–5 months
- Requires warm temperatures, average precipitation (500–1,000 mm) and light, sandy soils
- As a legume, does not need many fertilizers
- Susceptible to fungus contamination in storage: some fungi produce toxic *aflatoxin*

Peanut history

- Cultivated species is a tetraploid originated from hybridization of two South American wild species
- In valleys of Peru, cultivated from 5,600 BC
- In XVII century, went independently to Africa and Asia

- Biggest producers now are China, India and U.S. Main crop in several West African countries, e.g., Ghana.
- Hundreds of cultivars, in U.S. there are mostly "Runner" and "Virginia" groups

24.4 "Canola", rapeseed, *Brassica napus*

"Canola", rapeseed, *Brassica napus*

- "Canola" stands for "**can**adian oil", name of the group of cultivars of rapeseed, Brassica napus from cabbage family, Cruiferae
- One of the most hardy oil plants
- New culture, only in 1970s started to be used widely

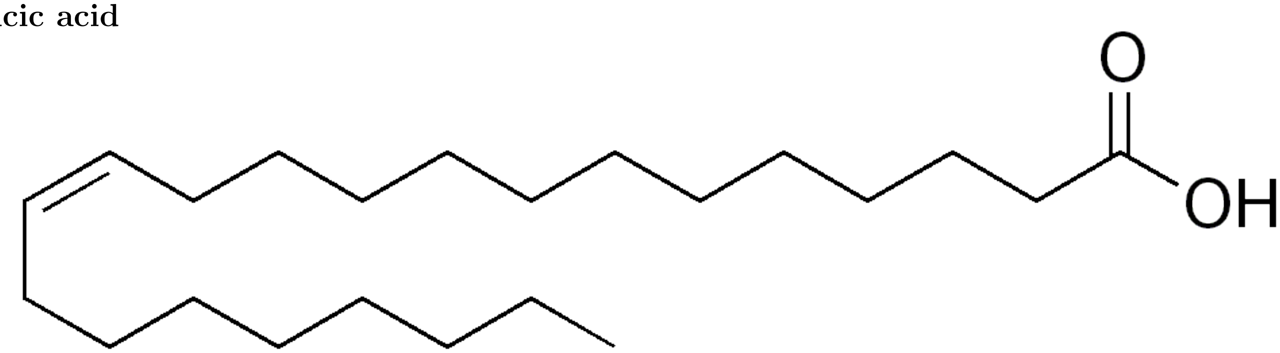
Canola

Canola biology

- Medium-sized (up to 1.5 m tall) herbaceous annual, cultivated as winter or as spring crop
- Seeds contain high amounts of unsaturated oils including omega-3 oils
- 200° C smoke point

- Cross-pollinated, produces significant amounts of nectar
- Non-canola cultivars contain potentionally toxic erucic acid and glucosinolates
- Erucic acid, however, is used as four-to-one mixture with oleic acid and constitutes “Lorenzo’s oil” (there is a movie with same name); an experimental treatment for the rare neurobiology disorder adrenoleukodystrophy

Erucic acid



Canola agriculture

- Relatively easy culture, requires water and cool temperatures, long-day plant
- Needs high amounts of fertilizers
- Harvesting should be fast because siliques are dehiscing fast

Canola siliques

Canola history

- Domesticated in Europe
- Cultivated for a long time but mostly as technical oil plant
- In 1974, zero-rapeseed was selected which contained less than 2% of erucic acid; in 1982, 00-rapeseed which contains almost 0% of erucic acid: canola
- Canola cultivars are susceptible for fungal diseases (erucic acid was a defense agent)
- Canola also susceptible to cross-pollination with technical rapeseed
- Biggest producers now are China, Canada and India

24.5 Olive, *Olea europaea*

Olive, *Olea europaea*

- One of the oldest oil plants, also used as vegetable
- Belongs to olive family, Oleaceae
- Relatively hardy plant despite of evergreen life form

Olive biology

- Evergreen, long-lived (up to 2,000 years), small tree
- Starts to produce fruits from 3–4 year (when grafted)
- Cross-pollinated with wind
- Oil does not contain omega-n-unsaturated fatty acids

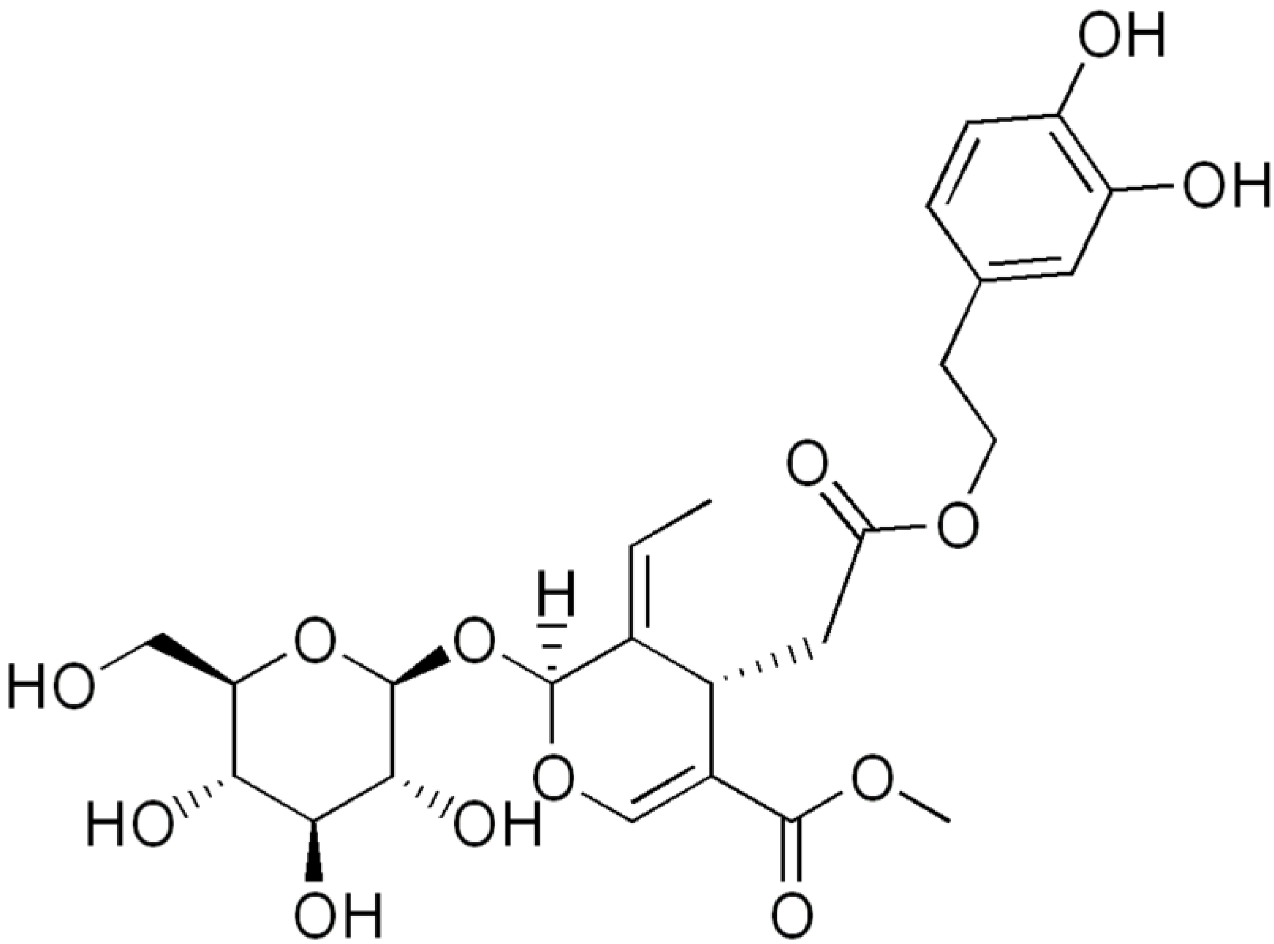
Olives in Greece

Olive agriculture

- Requires dry air and lots of sun, does not particular to soils (but grows better on limestone soils)
- One tree may produce ≈20 kg of fruits per year for 200 years
- Harvested in winter, half-manually, by shaking trees
- Oil is pressed, outer parts are fermented to remove bitter *oleuropein*
- Smoke point 200° C

Olive harvesting

Oleuropein



Olive history

- Large historical and mythological background: from Old Testament and Greek mythology to Quran
- Cultivation started $> 6,000$ BC in Mediterranean
- More than 500 cultivars; top producers are Spain, Italy and Greece
- Olive became invasive in Australia

24.6 Sesame, *Sesamum indicum*

Sesame, *Sesamum indicum*

- Belongs to the tropical genus *Sesamum* (≈20 species) from sesame family, Pedaliaceae
- The oldest cultivated oil plant

Sesame

Sesame features

- Tropical herbaceous annual plant, vegetation 3–4 month, yield is 1–2 tons/hectare
- Seeds contain 50-65% of oil; oil contains phytosterols, vitamin E and significant amounts of microelements, especially iron and magnesium
- Can grow in dry climatic zones
- Used entirely (green mass as a forage, pressed cakes in bakery etc.)
- Smoke point 200° C

Fruits and seeds of sesame

Sesame history

- Cultivation started in India prehistorically, went to ancient Egypt and then to Europe
- Now cultivated mostly in tropics around the world
- Biggest producers are still India and China
- Famous also after Ali-Baba story from "One thousand and one nights"

Ali-Baba (40 thieves are not at home yet)

24.7 Safflower, *Carthamnus tinctorius*

Safflower, *Carthamnus tinctorius*

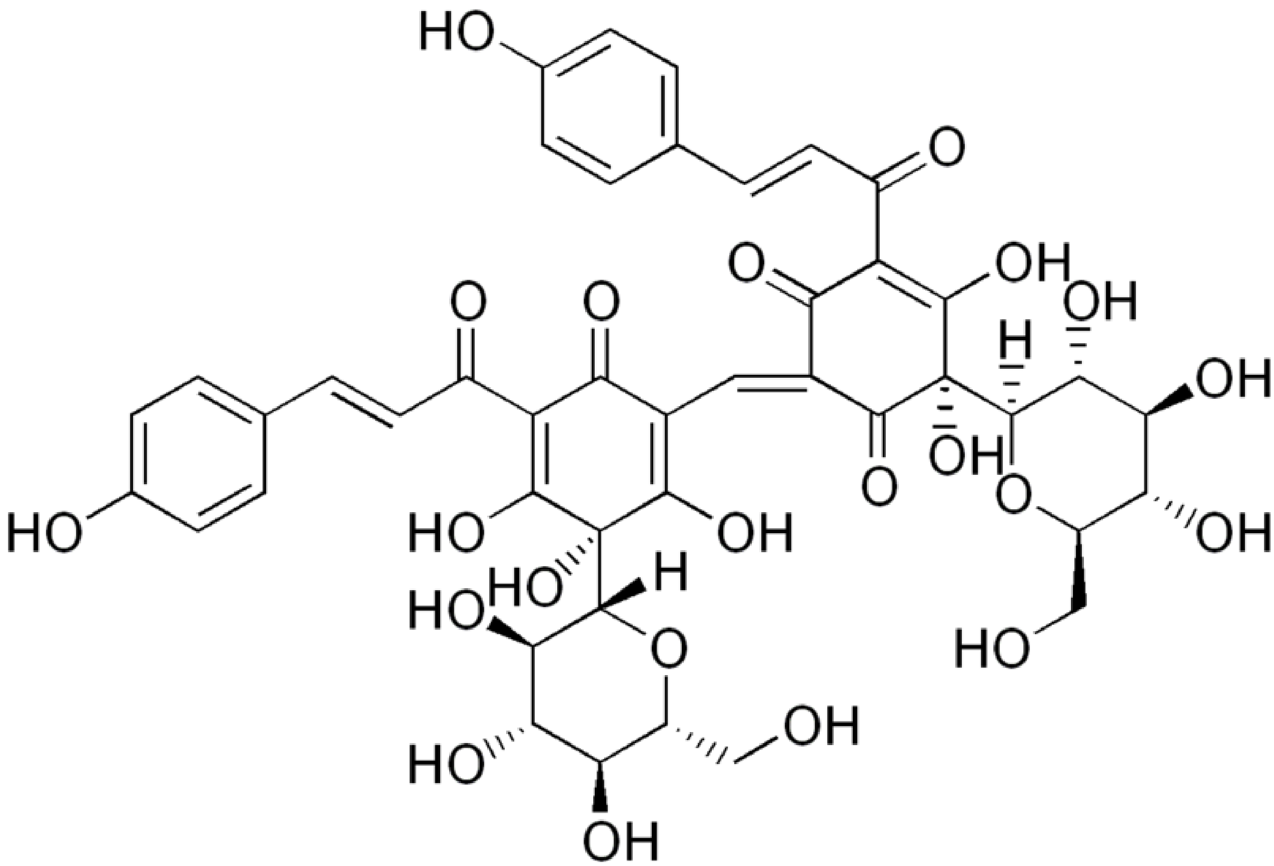
- Belongs to Mediterranean *Carhtamnus* (distaff thistles) genus and atser family, Compositae
- Highly ornamental cultivated plant
- Multiple uses: as oil plant, as medicinal plant and as saffron substitute (red dye)

Safflower field

Safflower features

- Achenes contain 15–35% of oil
- Oil contains mono- and polyunsaturated fatty acids, and therefore may be used for painting (fast-dried oil)
- Flowers contain carthamin which produces a red-brown color, often used in food production
- Rich of tokoferols (vitamin E)
- Smoke point 270° C!

Carthamin



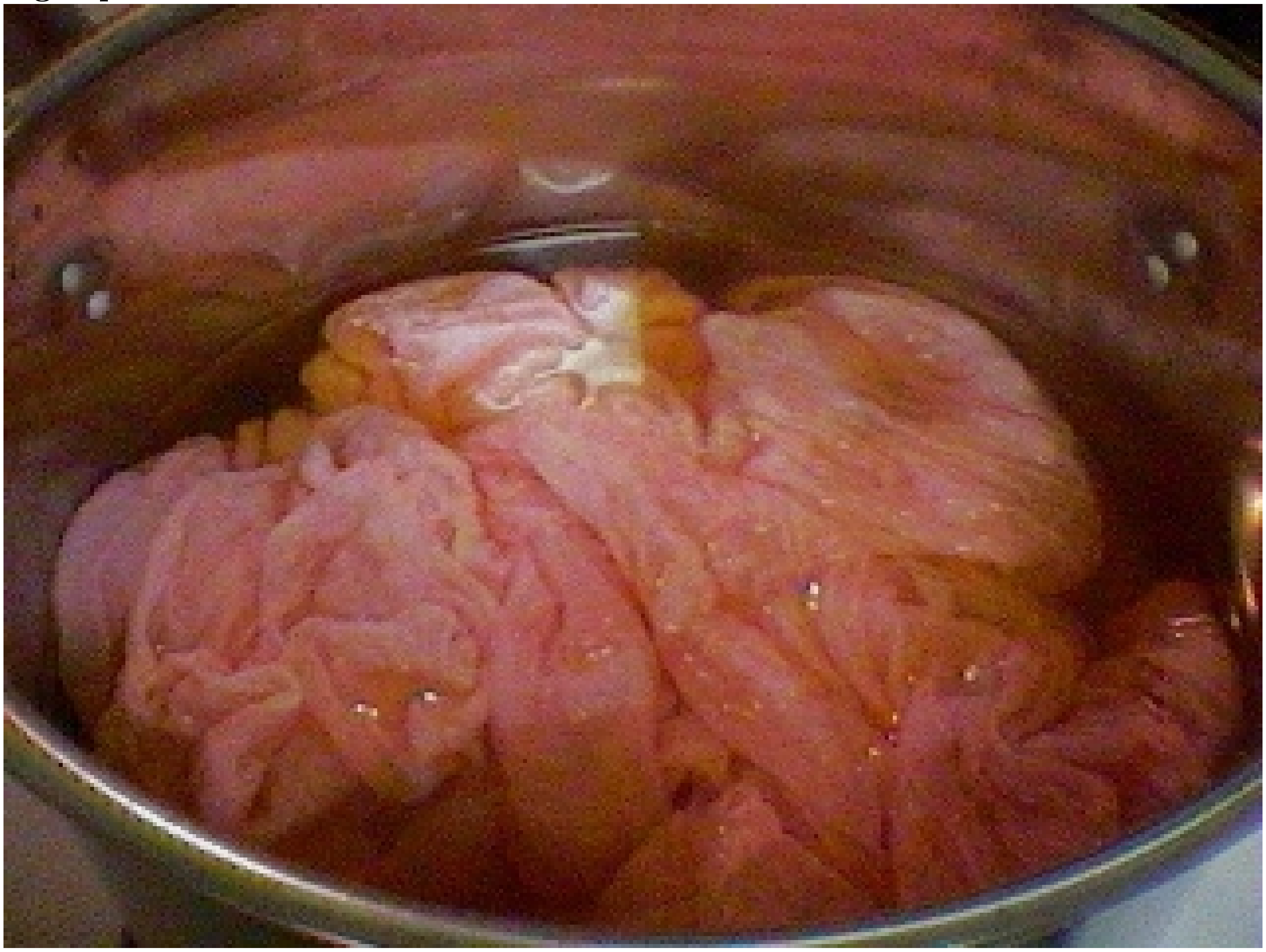
Safflower history

- One of the most ancient cultivated plants, used in Old Egypt
- Went to Japan and used there as a plant which dye had ceremonial meanings

Harvesting safflower

[From Takahata's "Only yesterday" movie]

Making Japanese clothes



Painted with safflower

Shuntei (1898): *Shadow of the Castle*

24.8 Oil palm, Elaeis guineensis

Oil palm, *Elaeis guineensis*

- Used in Africa from prehistorical times, but the mass cultivation started only in the beginning of XX century
- Belongs to palm family, Palmae
- Palm oils are semi-solid at the room temperature: plant fats

Fruits of oil palm

Blocks of palm oil

Oil palm features and history

- Oil is reach of saturated fatty acids, especially palmitic (C_{16}) acid, also rich of carotenes and often has a reddish color
- Yield is high (up to 100 kg of oil from one tree per year), and therefore palm oil is very common in tropics
- Biggest producers are Malaysia and Indonesia
- Also famous as the source of Greek fire and **napalm** (mixture of palmitic acids, several other organic compounds and aluminum)
- Smoke point 230° C

Making of palm oil (Kongo)

Napalm

24.9 New oil cultures

Sacha inchi, *Plunkettia volubilis*—perspective oil plant

- South American, Amazonian tree from spurge family, Euphorbiaceae
- Capsules contain several large seeds, rich of oil (≈60%)
- Sacha inchi oil contains highest amounts of omega-n-unsaturated fatty acids (93%!) and vitamin E
- Cultivation started in 2000s, mostly in Peru

Sacha inchi

Summary

- All oil plants contain oil (non-saturated triglycerides) in seeds
- The most important oil characteristics are smoke temperature, amount of cholesterol, amount of trans fats and amount of omega-n-unsaturated fatty acids
- Oil palm and cocoa tree produce high amounts of plant "fats"
- The most promising contemporary oil cultures are canola and sacha inchi

For Further Reading

References

[1] A. Shipunov. *Ethnobotany* [Electronic resource]. 2011—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_310`

[2] P. M. Zhukovskij. *Cultivated plants and their wild relatives* [Electronic resource]. Commonwealth Agricultural Bureaux, 1962. Abridged translation from Russian. Mode of access: `http://ashipunov.info/shipunov/school/biol_310/zhukovskij1962_cultivated_plants.pdf`.

Outline

25 Oil plants

25.1 Lesser oil plants

Coconut, *Cocos nucifera*

- Belong to Palmae, cultivated around the world as technical and nut plant
- Oil is similar to Africal oil palm: rich of saturated fatty acids, especially lauric acid (48%)
- Oil extracted from either coconut milk (wet process), or copra (dry process)
- Apart from food, has a wide technical use (lubricant, fuel, cosmetics)

[Coconut palm will be covered in more detail later]

Driyng coconut copra for oil making

Soybeans, *Glycine max*

[The plant was covered earlier]

- Apart from protein food, soybeans produce one of most widely used cooking oil ("vegetable oil"), with high smoke point (232°C)
- Soybean oil is rich of poly-unsaturated fatty acids (especially 2-unsaturated linoleic, 51%)
- Soybean oil may also be used for painting (because it is drying slowly), as insect repellent (only in combination with geranium oil like like "Bite Blocker"), as fuel, and as fixative to essential oils

Soybean oil

Soybean oil as biofuel

Flax, *Linum usitatissimum*

- Obtained from flax (*Linum usitatissimum* from Linaceae family) which is also used as technical plant
- Bright yellow, very fast drying oil because it is rich of triply unsaturated fatty acid, α-linolenic acid (up to 55%), smoke point is low (107°C)
- Normally, used as a technical substance for painting, for finishing wood, for linoleum (one of the first half-synthetic floor covering) and also as rich and useful food supplement (α-linolenic acid = ω-unsaturated acid, EFA)

[The plant will be covered in more details later]

Wood finishing with flaxseed oil

Cottonseed, *Gossypium* spp.

- Extracted from seeds of cotton (several species of *Gossypium* from Malvaceae family)
- Oil contains up to 52% stearic (monounsaturated) fatty acid, very stable (does not dry) and with good smoke point (232°C)
- Used in many foods, especially for salad dressings and chips, for deep frying
- High of tokoferols (vitamin E)
- Contain amounts of *gossypol*—biologically active phenolic compound which may be used in medicine (e.g., as contraceptive, for curing viral infections etc.) but should be removed from food oil

[Mostly known as a fiber plant, will be covered later]

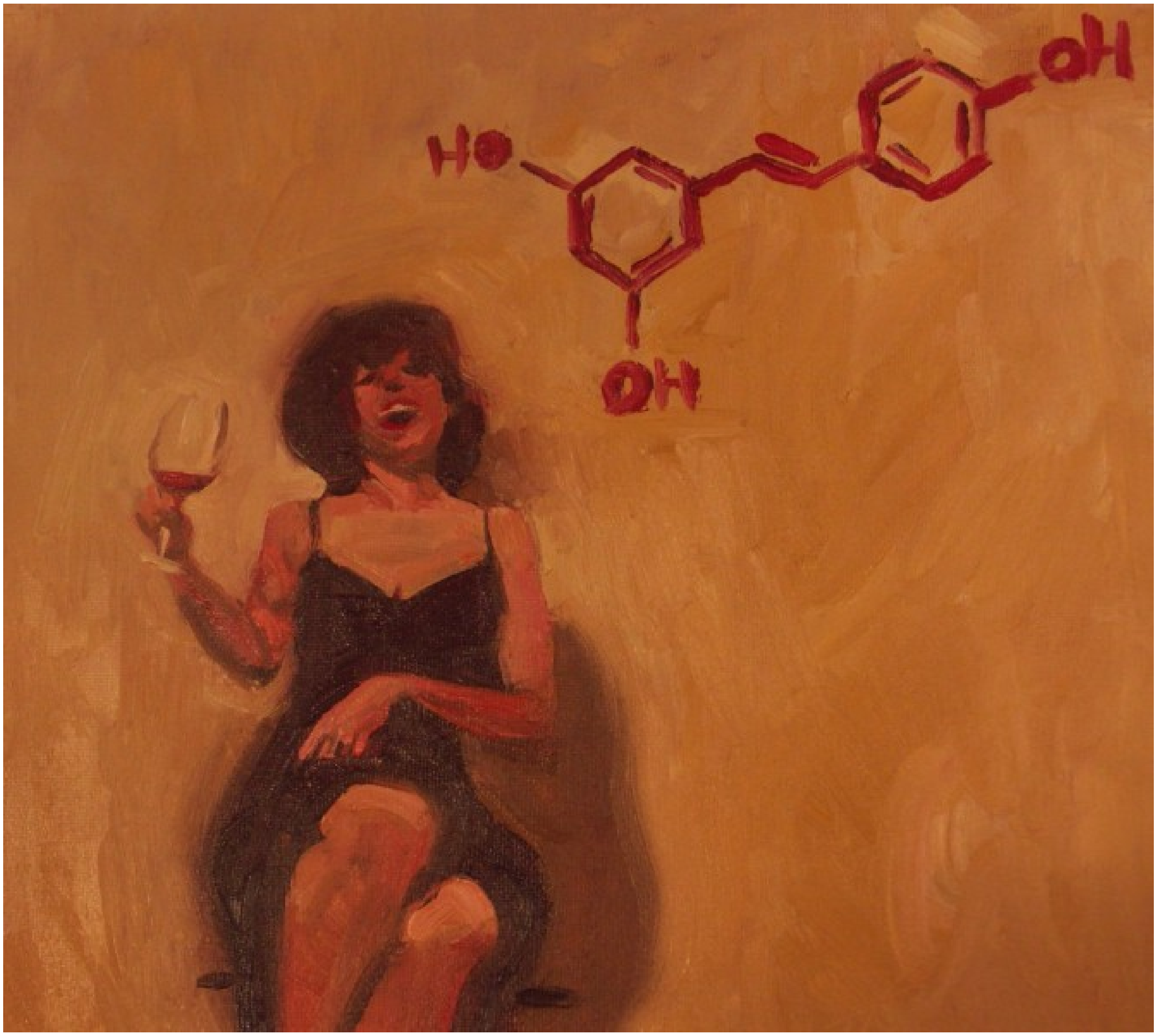
Cottonseed oil

Grapeseed, *Vitis vinifera*

- By-product of winemaking, extracted from grape (*Vitis vinifera* from Vitaceae family)
- Similarly to soybean oil, rich of 2-unsaturated linoleic acid (72%)
- Smoke point 220° C
- Used similarly to cottonseed oil: salad dressings and deep frying
- Has high medicinal value: contains *phytoalexin* (plant non-specific immune chemical) **resveratrol** (also component of red wine) which is anti-cancer and anti-hypertensive drug

[Mostly known as fruit, will be covered later]

Resveratrol



Cocoa butter, from *Theobroma cacao*

- Cocoa butter from *Theobroma cacao* (Malvaceae family) is plant fat, rich on non-saturated fatty acids (stearic and palmitic together ≈60%)
- Has 37°C melting temperature and therefore used a lot as a subsidiary oil in medicine (e.g., in suppositories) and in cosmetics; also used for making white chocolate
- Normally, does not contain theobromine and caffeine (components of dark chocolate)

[The plant will be covered in more details later]

Cocoa flower

Shea butter, from *Vitellaria paradoxa*

- Shea butter from *Vitellaria paradoxa* (Sapotaceae, you already know miracle fruit from this family) is similar to cocoa butter (with similar melting temperature)
- African tree
- It has a double use as edible and as technical
- Used for cosmetics from Ancient Egypt times

Shea tree

Traditional preparation of the shea butter

25.2 Technical oil plants

Essential oils

- Mixture of hydrophobic components bearing plant odors
- Used for aromatherapy and in cosmetics
- The most famous are probably rose oil, geranium oil and eucalyptus oil

Ylang-ylang, *Cananga odorata*

- Tree from custard apple family (Annonaceae) which is cultivated for perfume oil
- Fast-growing tree from Indonesia
- Has diverse medical applications, used for cosmetics (Chanel No. 5) and in aromatherapy
- Comoros is the biggest exporter of ylang-ylang (29% of its annual export)

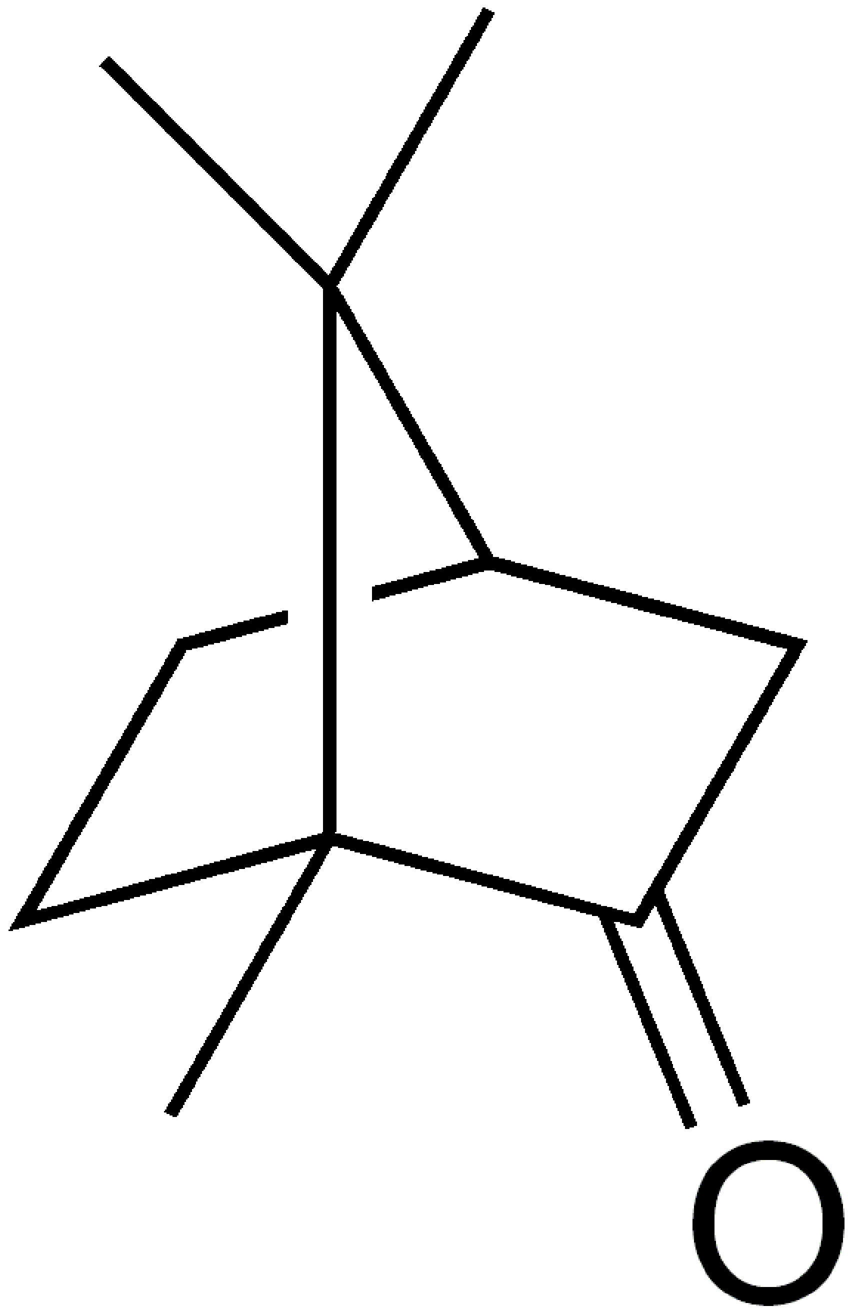
Ylang-ylang

Camphor tree, *Cinnamomum camphora*

- East Asian tree from laurel family, Lauraceae
- Contain multiple aromatic substances, e.g., camphor—unusual hydrophobic molecule
- Camphor use has the old history, it still has a high ceremonial value in Hinduism, used in sweets, for aromatherapy and in fireworks (highly flammable)
- It is a Totoro tree from H. Miyazaki's "My neighbor Totoro" anime film

Camphor tree

Camphor: chair molecule



Totoro on the top of camphor tree

[From Miyazaki's "My Neighbor Totoro"]

Tung, *Vernicia (Aleurites) fordii*

- Small East Asian deciduous tree from spurge family, Euphorbiaceae
- Highly poisonous seeds contain one of the best drying oils, rich (82%) of 3-unsaturated α-eleostearic fatty acid
- Used for finishing wood (especially for musical instruments) and other staining processes

Tung fruits

Castor oil plant, *Ricinus communis*

- African and Indian shrub from spurge family, Euphorbiaceae
- Cultivated as annual in temperate regions
- Seeds are poisonous, but contain (95%) unique castor oil containing hydroxylated ricinoleic oil (unsaturated oil with –OH group)
- Widely used in traditional medicine as laxative, now used in many modern drugs as a component, and also as technical oil for lubrication, making plastics etc.
- In fascist Italy, was widely used for intimidation of Mussolini opponents (oil is not poisonous but in large quantity may be harmful)

Castor plant

Jojoba, *Simmondsia sinensis*

- Shrub of its own family (Simmondsiaceae) native to southern North America
- Name is a result of botanical mistake: botanist J. Link misread label “Calif” as “China”
- Seeds contain unique liquid wax (10°C is a melting point): combination of long-chained fatty acids and fatty alcohols
- Jojoba “oil” is odorless, colorless and oxidatively stable, used a a substitute for sperm whale oil: cosmetics, as stable lubricant (it is not digested for most organisms); and now also as biofuel
- Widely cultivated in Arizona, California and Mexico

Jojoba male flowers

Summary

- Oil palm and cocoa tree produce high amounts of plant "fats"

For Further Reading

References

[1] A. Shipunov. *Ethnobotany* [Electronic resource]. 2011—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_310`

[2] P. M. Zhukovskij. *Cultivated plants and their wild relatives* [Electronic resource]. Commonwealth Agricultural Bureaux, 1962. Abridged translation from Russian. Mode of access: `http://ashipunov.info/shipunov/school/biol_310/zhukovskij1962_cultivated_plants.pdf`.

Outline

26 From food to medicine

26.1 Spices

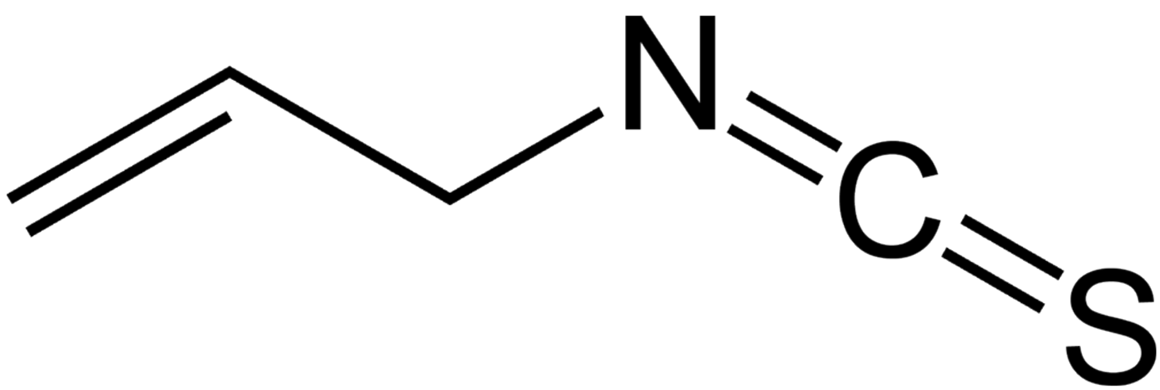
Spicy hot taste

- Caused from several different secondary metabolites which make a burning sensation
- These metabolites work with pain receptors, nociceptors
- One of proposed effects is the stimulation of endorphin and serotonin production in brain

Allyl isothiocyanate plants

- Main component of mustard oils, with formula CH_2–CH–CH_2–NCS
- Anti-herbivore chemical, stored in glucosinolate form and released by myrosinase when cells are broken
- Toxic, strong lachrymator, stimulates nasal and eye receptors
- Plants of Brassicales order (Cruciferae and also Moringaceae like papaya and horseradish tree) are rich of allyl isothiocyanates.

Allyl isothiocyanate



Horseradish, *Armoracia rusticana*

- Perennial plant from cabbage family (Cruciferae) with European origin
- Roots are using as a spice

Wasabi, *Wasabia japonica*

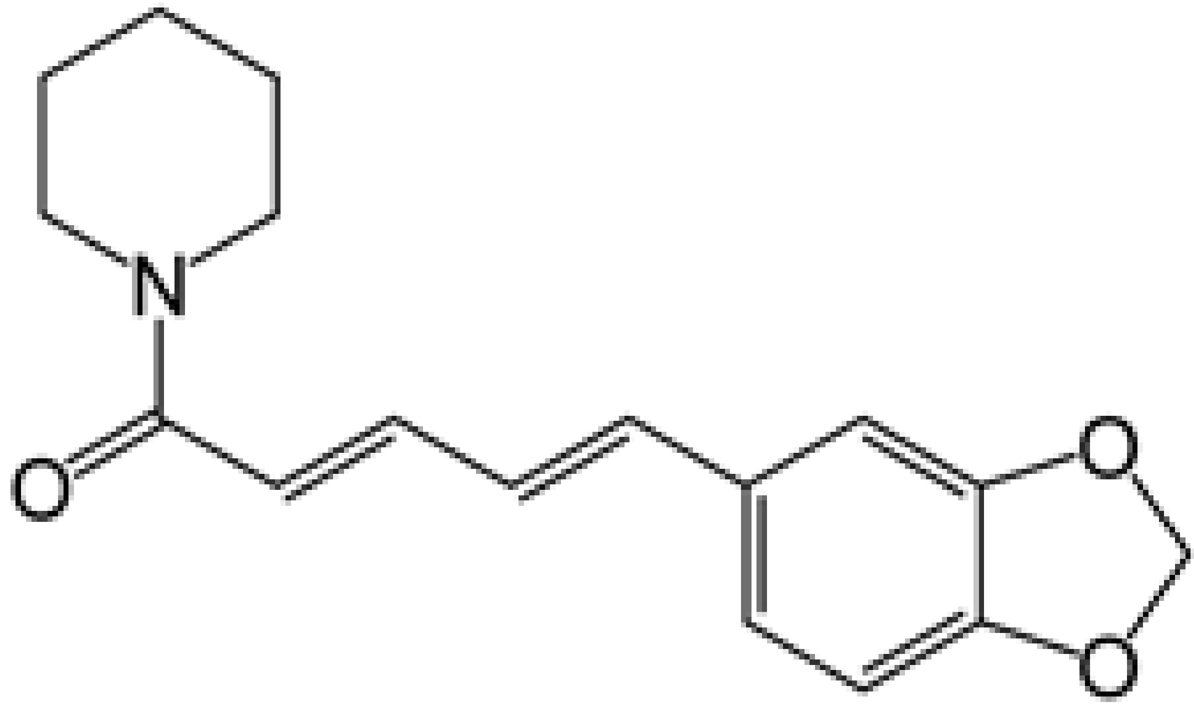
- Japanese perennial from same family
- Extremely strong flavor due to multiple isothiocyanates

Iwasaki (1828) paint of wasabi

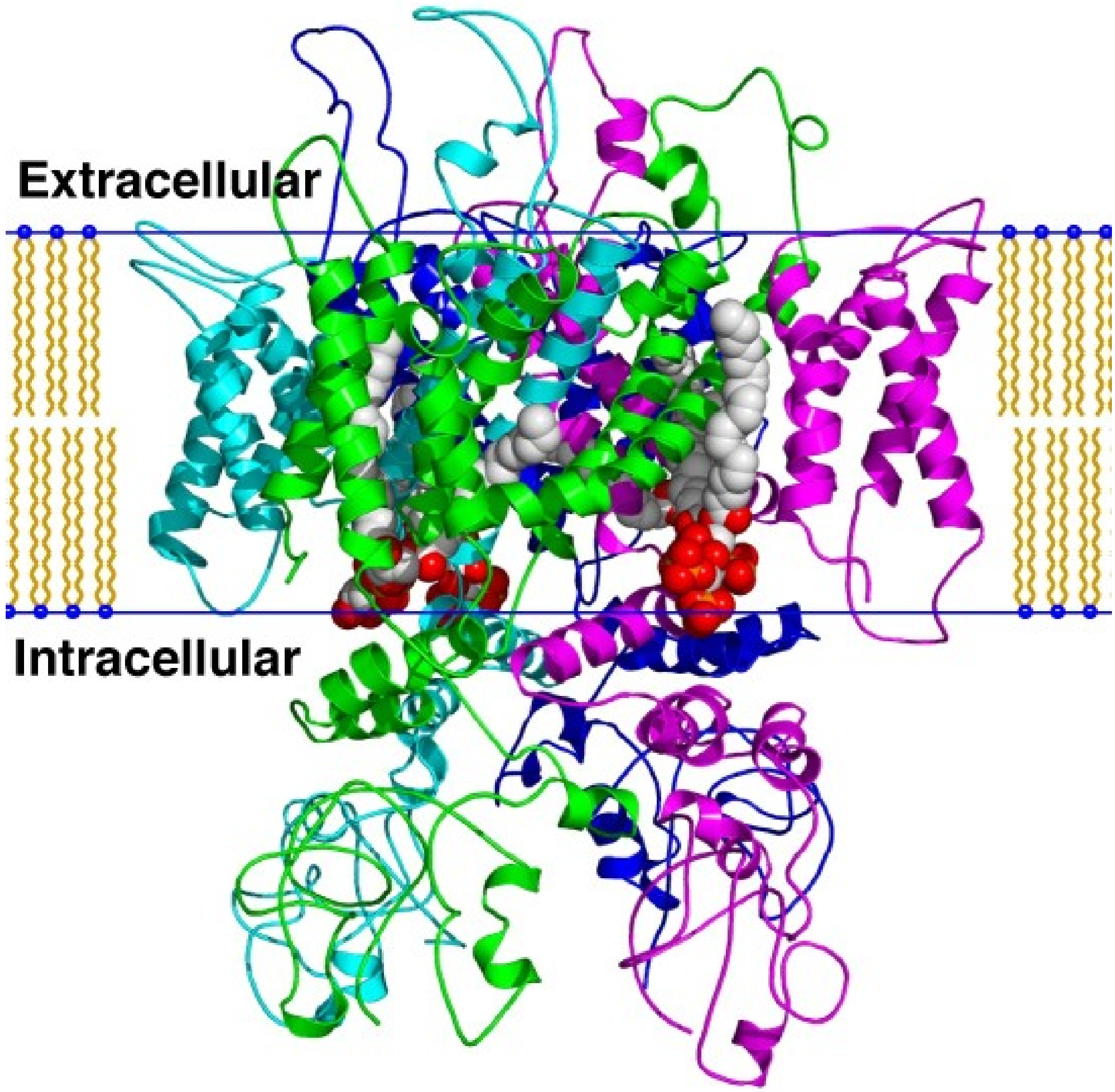
Piperine

- Alkaloid
- Activates TRPV channels in nociceptors

Piperine



TRPV channel



Black pepper, *Piper nigrum*

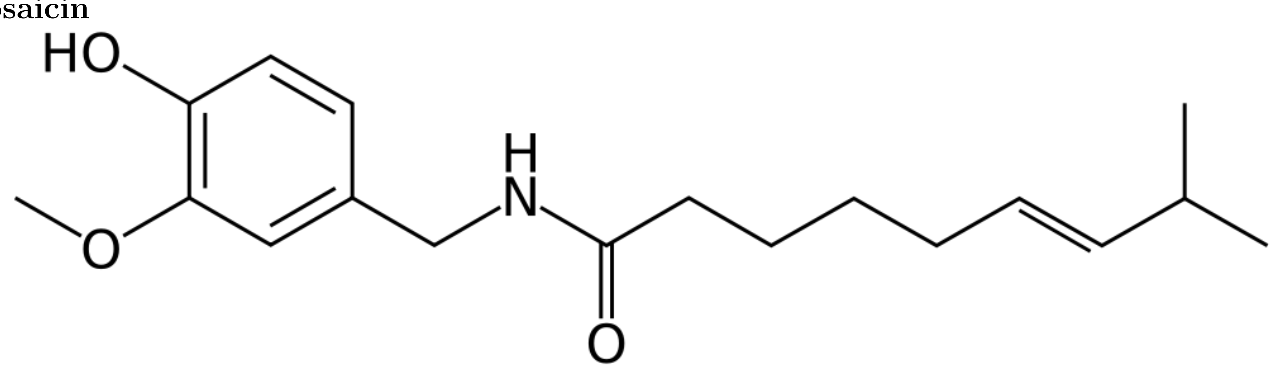
- Perennial vine from pepper family, Piperaceae
- Has the long and rich history: was one of primary causes of Exploration Age

Piper nigrum

Capsaicin

- Amine, irritant for all mammals
- Binds to TRPV and provide sensation similar to burning of call damage

Capsaicin



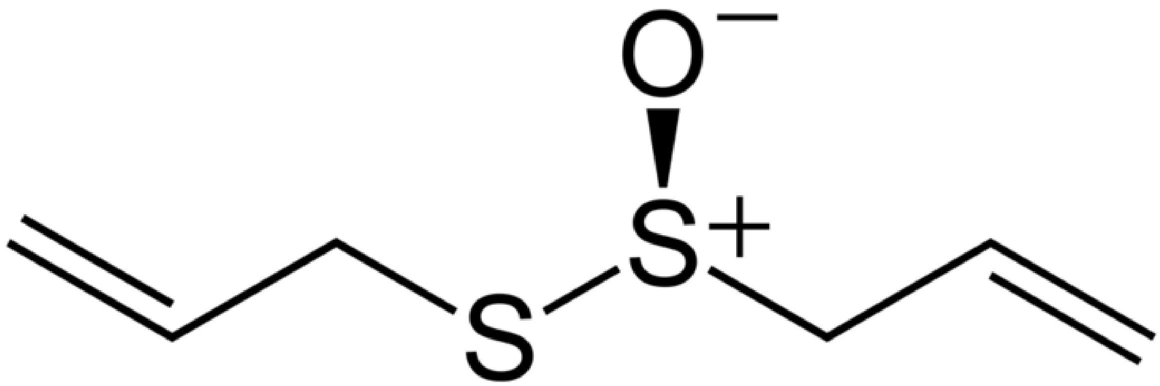
Chili peppers, *Capsicum annuum* and other species

- Multiple species of *Capsicum*, genus of Solanaceae herbs or vines from Central America
- Important component of several tropical cousins

Allicin

- Organo-sulfur compound with anti-bacterial and anti-fungal effects
- Has multiple positive health effects

Allicin



Garlic, *Allium sativum*

- Cultivated species from amaryllis family, Amaryllidaceae
- Probably originated in West Asia from wild *Allium longicuspis*

Essential oil plants from umbel family, Umbelliferae

- Coriander, *Coriandrum sativum* from West Asia, know from pre-historic times
- Dill, *Anethum graveolens* from Europe
- Cumin, *Cuminum cyminum* from Mediteranean
- Caraway (*Carum carvi*), asafoetida (*Ferula asafoetida*), anise (*Pimpinella anisum*), fennel (*Foeniculum vulgare*), sea parsley (*Ligusticum scoticum*), parsley (*Petroselinum crispum*), and many others

Cumin

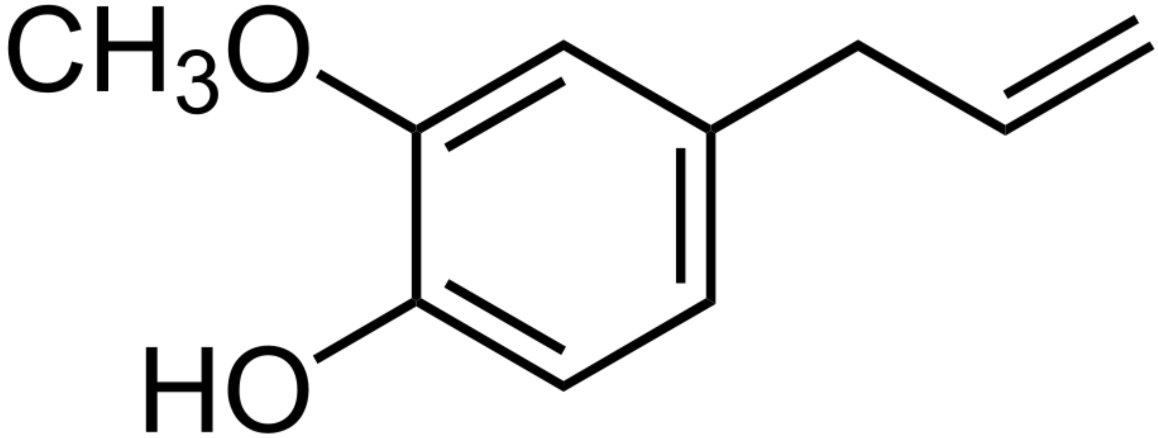
Essential oil plants from mint family, Labiatae

- Peppermint, *Mentha piperita* from Europe
- Basil, *Ocimum basilicum* with wide Eurasian distribution
- Wild bergamot (*Monarda fistulosa*), mint (*Mentha* spp.), majoram (*Origanum majorano*), oregano (*Origanum vulgare*), thyme (*Thymus* spp.), sage (*Salvia officinalis*), and many others

Eugenol and similar compounds

- Essential oils with phenol component
- Often provide a burning sensation similar to other spices

Eugenol



Plants with eugenol-like compounds

- Allspice, *Pimenta dioica* from Myrtaceae family, Caribbean origin
- Bay leaf, *Laurus nobilis* from Lauraceae, Mediterranean origin
- Nutmeg, *Myristica fragrans* from Myristicaceae, Indonesian origin
- Cinnamon, *Cinnamomum verum* from Lauraceae, Southwest Asian origin
- Ginger, *Zingiber officinale* from Zingiberaceae, South Asia
- Turmeric, *Curcuma longa* from Zingiberaceae, South Asia
- Vanilla orchid, *Vanilla planifolia*, Central America
- Sage, *Artemisia spp.* from Compositae, cosmopolitan

Bark of cinnamon

Nutmeg

Vanilla plantation

Summary

- Most of spicy plants produce chemicals with nociceptive (pain) effect

For Further Reading

References

[1] A. Shipunov. *Ethnobotany* [Electronic resource]. 2011—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_310`

[2] P. M. Zhukovskij. *Cultivated plants and their wild relatives* [Electronic resource]. Commonwealth Agricultural Bureaux, 1962. Abridged translation from Russian. Mode of access: `http://ashipunov.info/shipunov/school/biol_310/zhukovskij1962_cultivated_plants.pdf`.

Outline

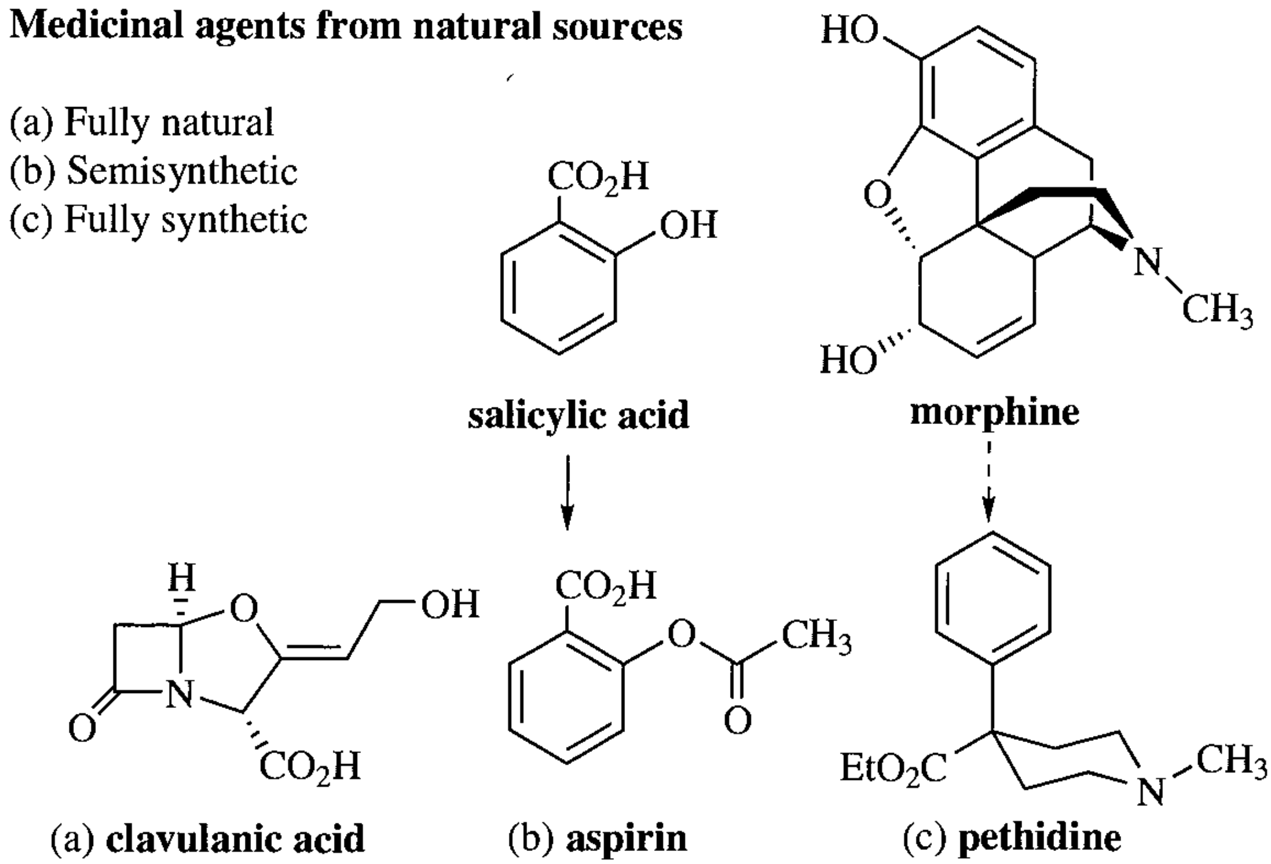
27 Natural product chemistry

27.1 Introduction

Types of drugs

- Fully natural
- Semisynthetic
- Fully synthetic

Types of medicinal agents



Drug discovery

We need new drugs, and plant secondary compounds of plants could accidentally have medicinal value.

- Sampling: soil, markets, natural habitats
- Extraction
- Bioassay screening
- Structure elucidation

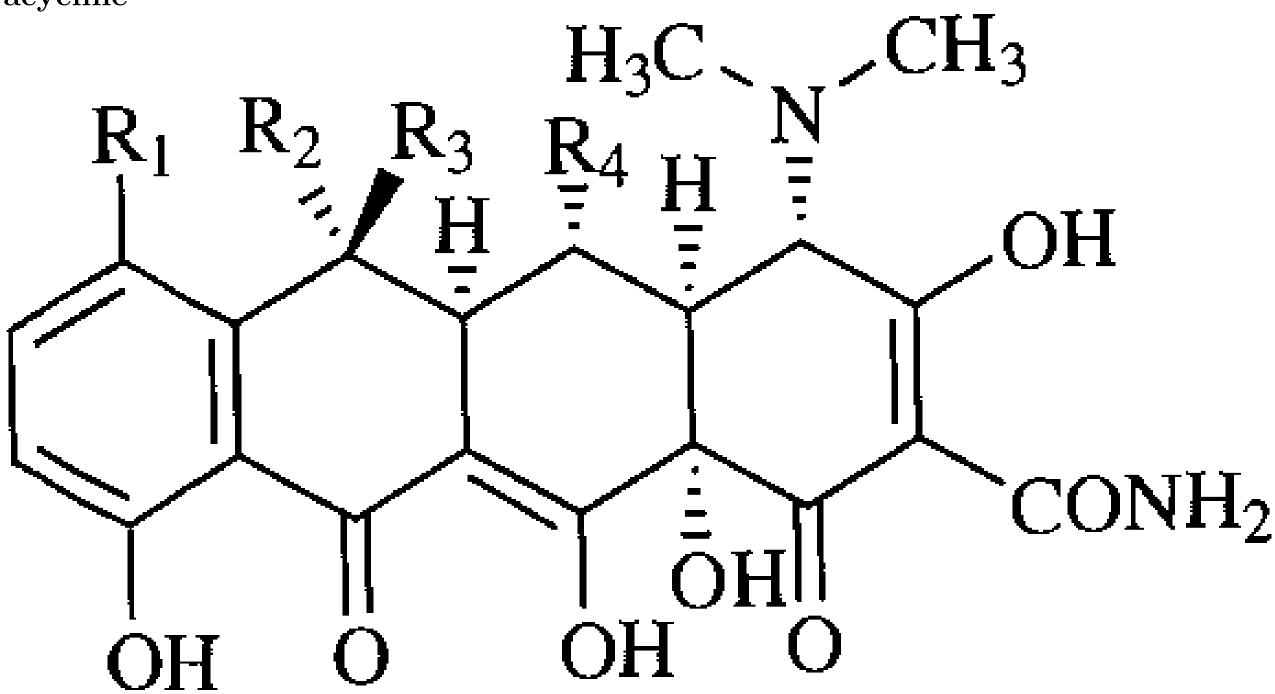
- Chemical modification
- Clinical trials
- Drug

27.2 Polyketides and other small molecules

Polyketides and derived products

- Short molecules with interleaving ketogroups
- Many antibiotics (e.g., tetracycline, erythromycin)

Tetracycline



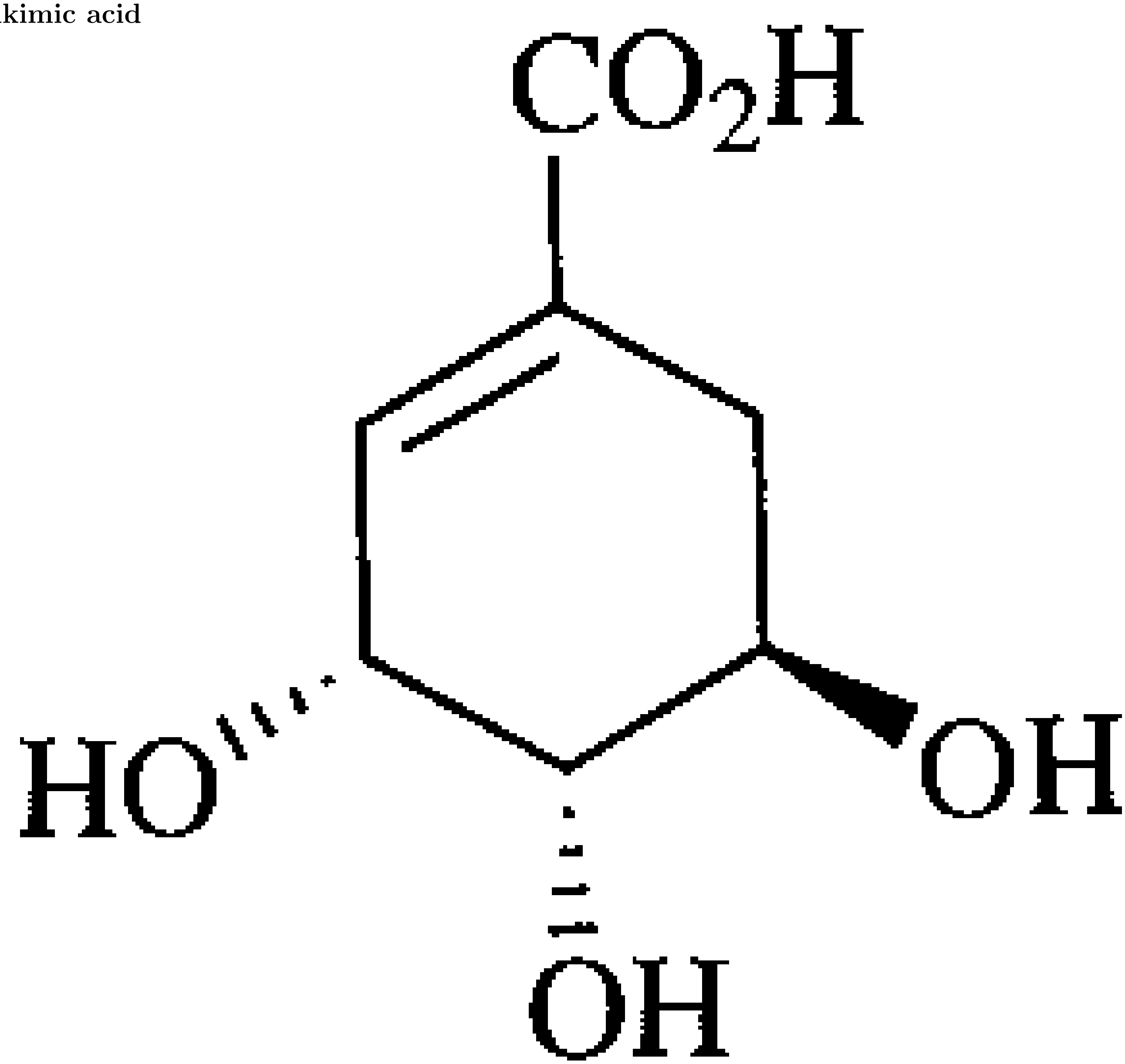
Glycerides

- Saturated fats
- Unsaturated fats, especially omega-n-unsaturated

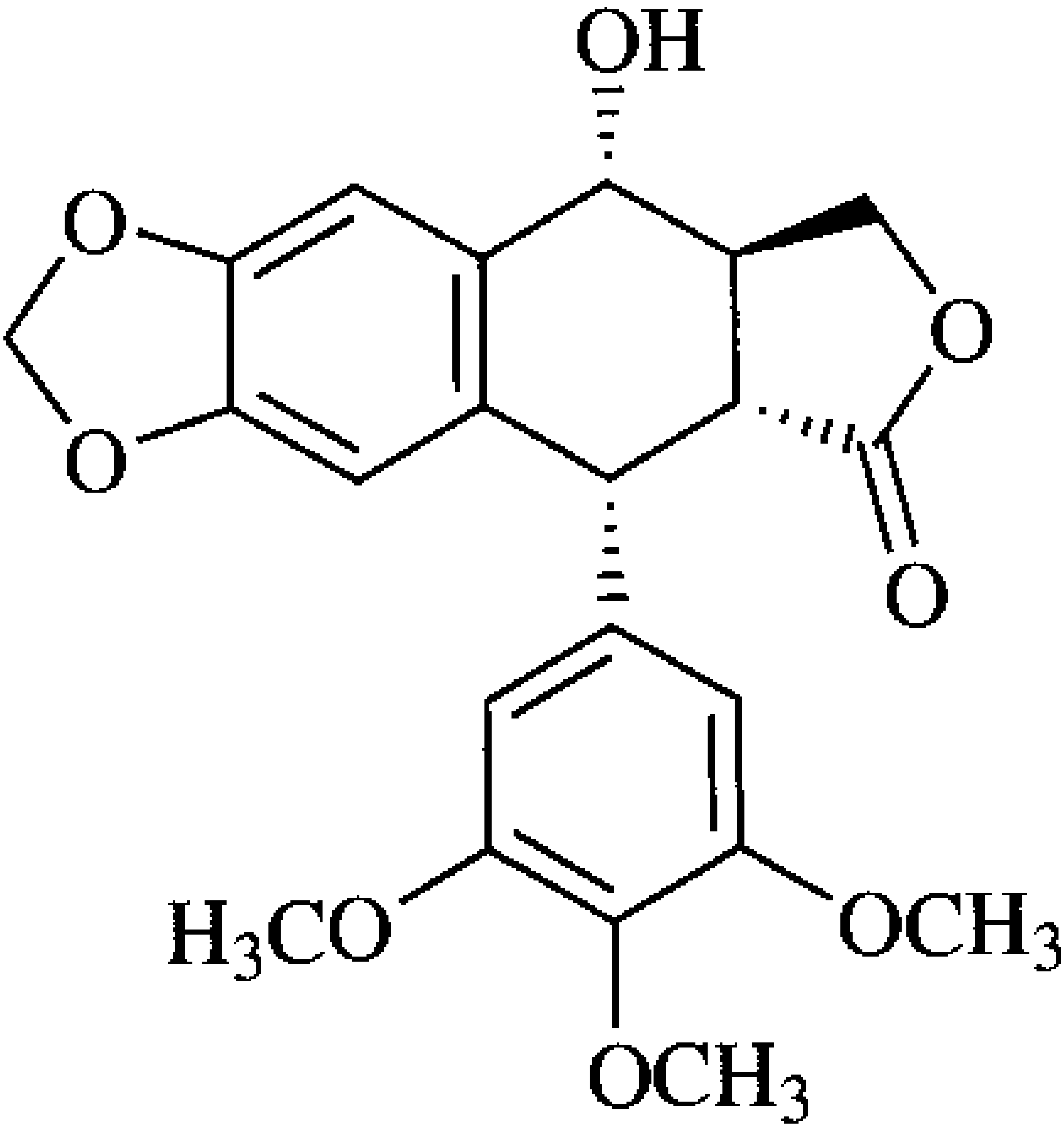
Shikimic acid and derived products

- Phenylpropenes, like eugenol
- Lignans like podophyllotoxin

Shikimic acid



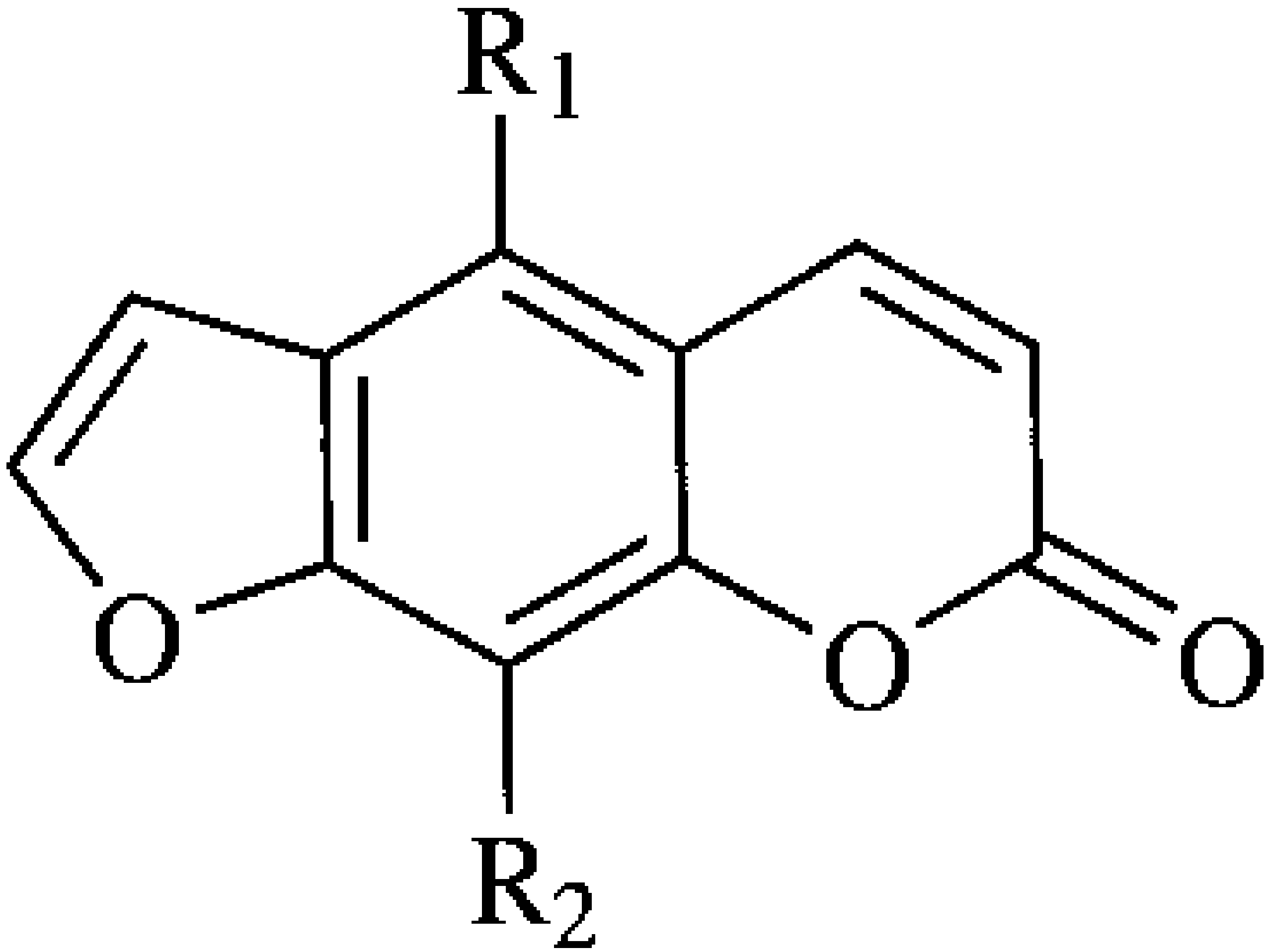
Podophyllotoxin



Coumarins

- Phytoalexins with anti-bacterial properties
- Some (psoralens from umbel family plants and bergapten from citrus family) are phototoxic

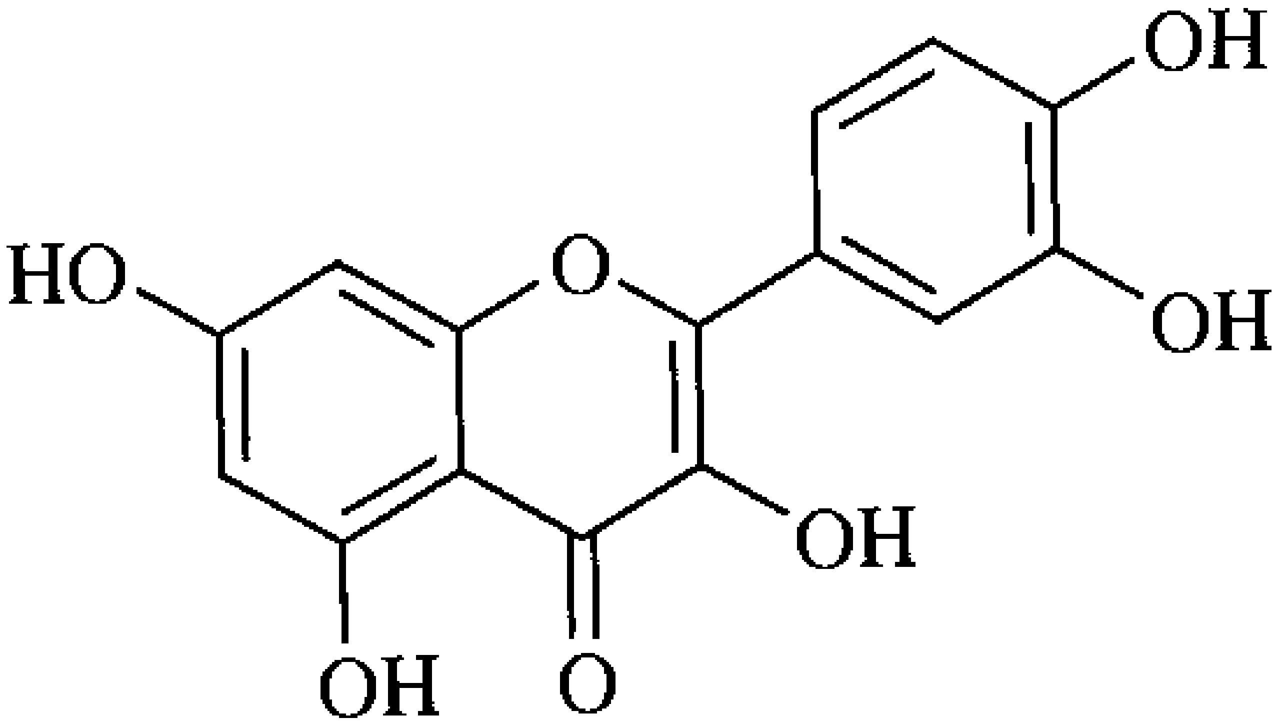
Psoralen



Flavonoids

- Derivatives of phenylpropane (C_6–C_3)
- Strong antioxidants
- Examples: naringin from grapefruit, quercetin from oak and other plants, resveratrol from grapes

Quercetin (flavonoid)



Tannins

- Similar to flavonoids, but much heavier
- Bind to proteins and provide astringent taste

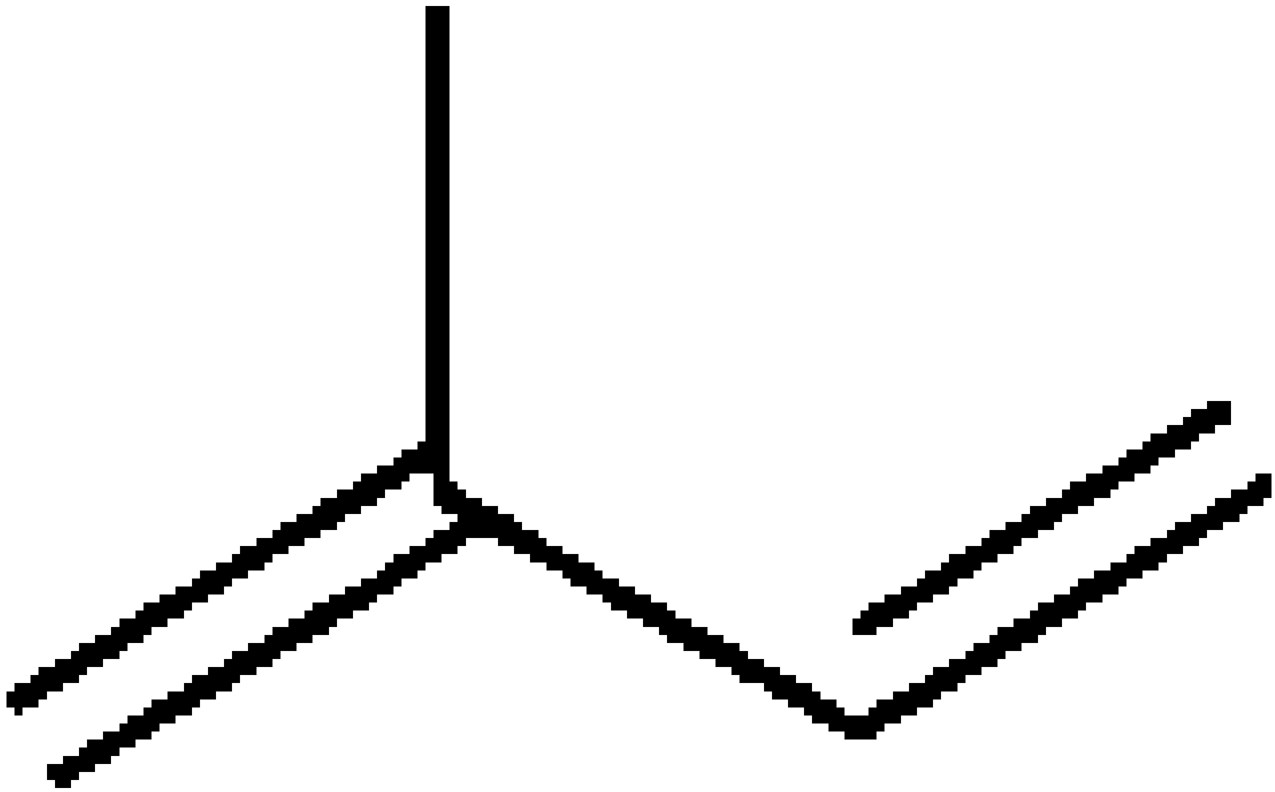
28 Natural product chemistry: what to extract

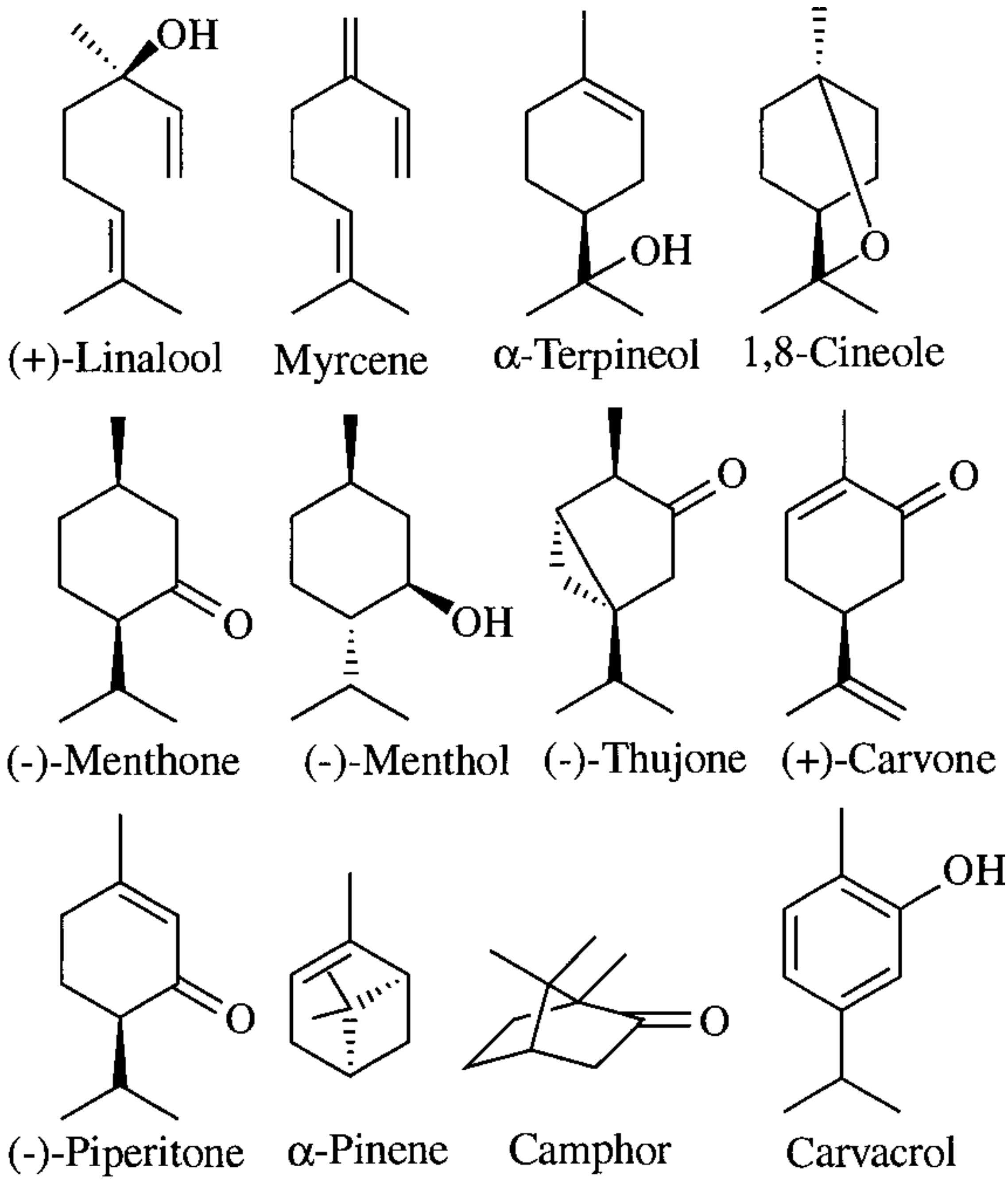
28.1 Terpenes

Terpenes and monoterpenes

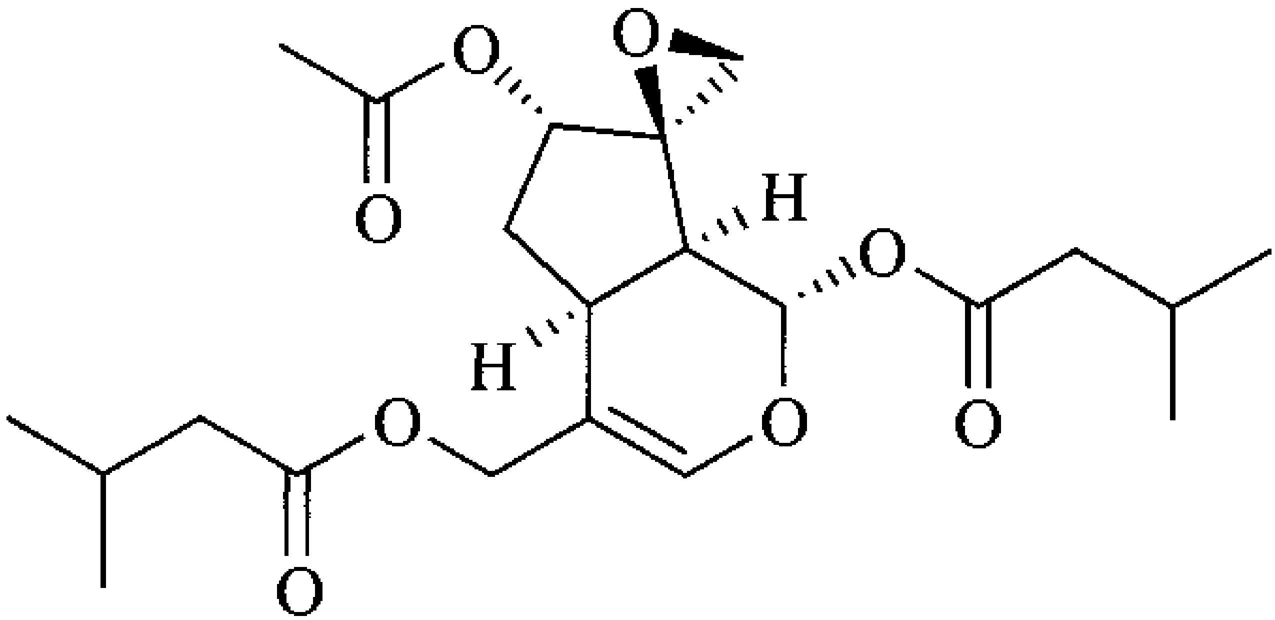
- Terpenes = isoprenoids, derivatives of isoprene (C_5 unit)
- Monoterpenes are simplest, they are constituents of volatile (essential) oils
- Examples: menthol from mint, myrcene from *Eucalyptus*, camphor, iridoids like valepotriates from valerian

Isoprene and mototerpenes





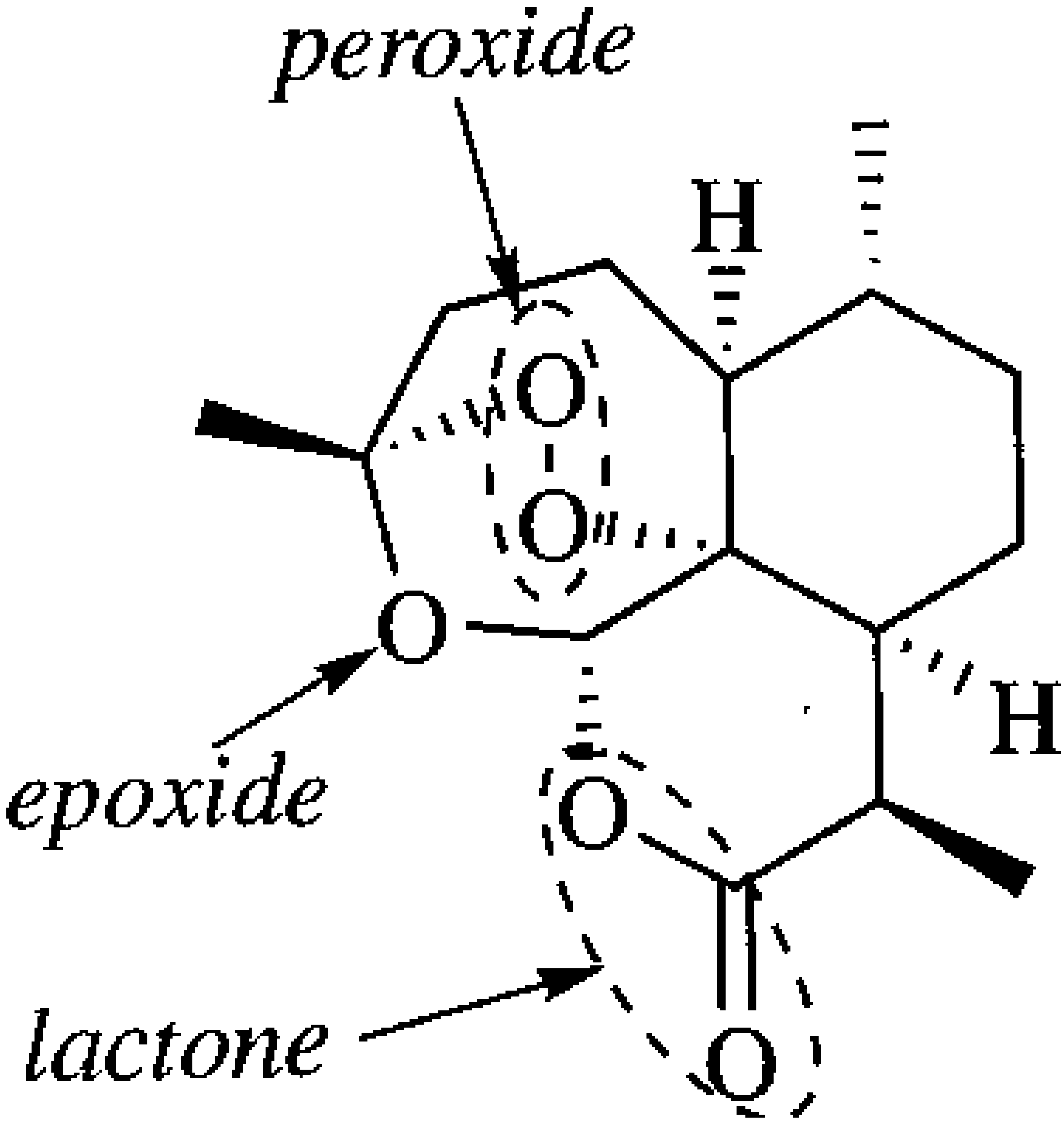
Didrovaltrate (iridoid)



Sesquiterpenes

- Have C_{15} skeleton
- Example: artemisinin from sage

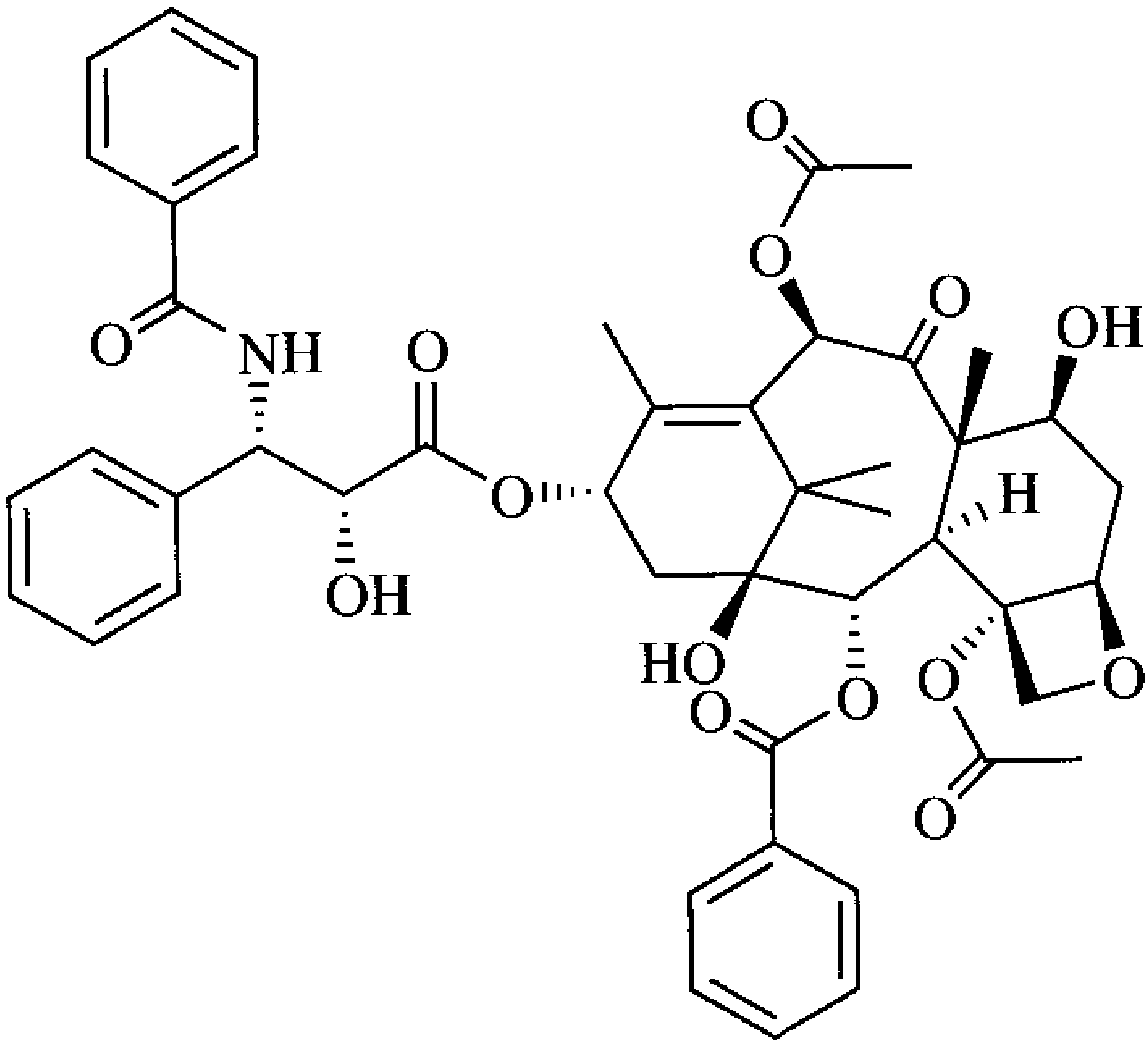
Artemisinin (sesquiterpene)



Diterpenes

- Have C_{20} skeleton
- Example: taxol from yew tree (actually, mostly from its endophyte *Taxomyces*)

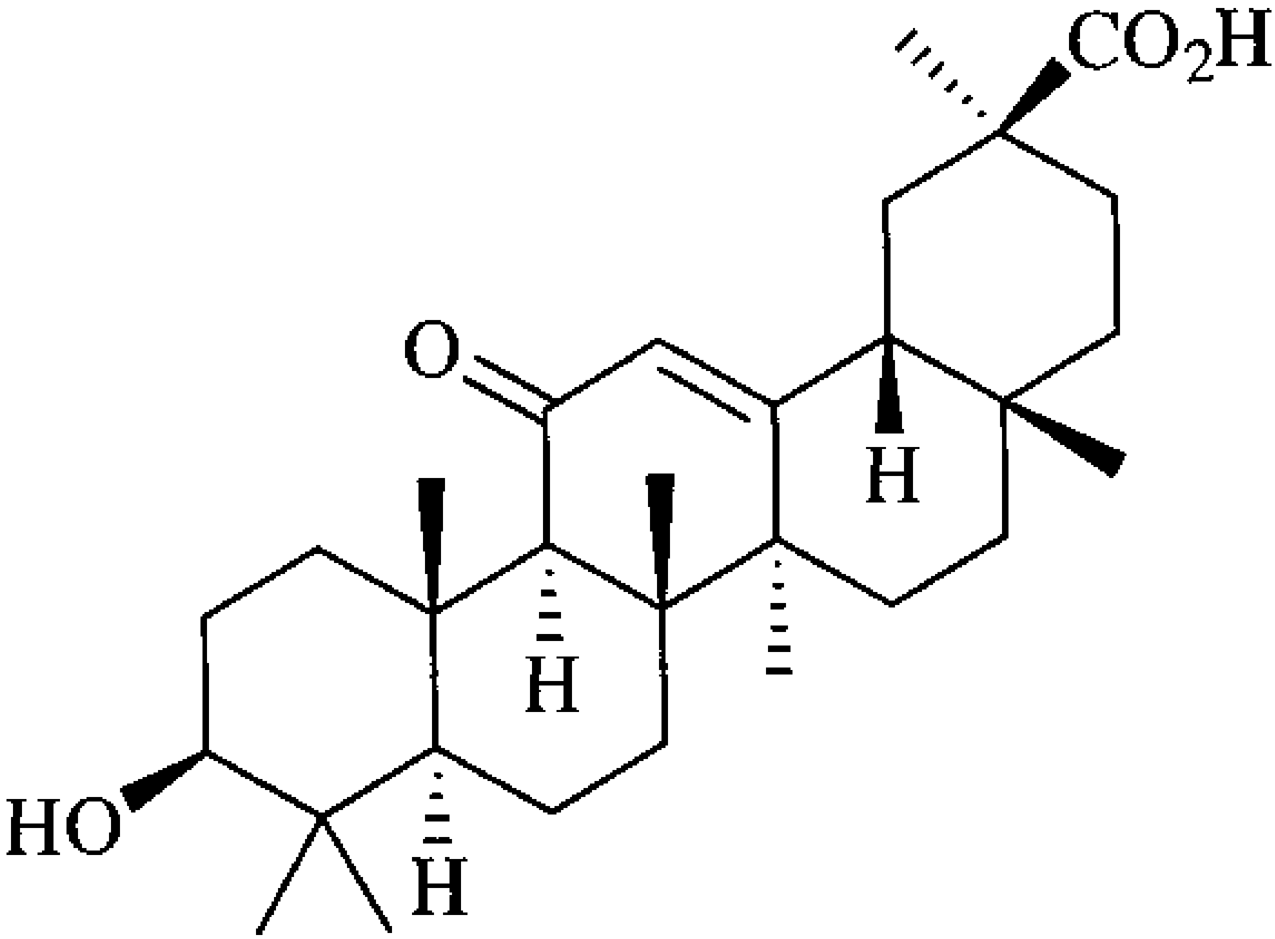
Taxol (diterpene)



Triterpenes

- Have C_{30} skeleton and (often) four condensed rings
- Examples: steroids, glycyrrhetic acid from liquorice and resins

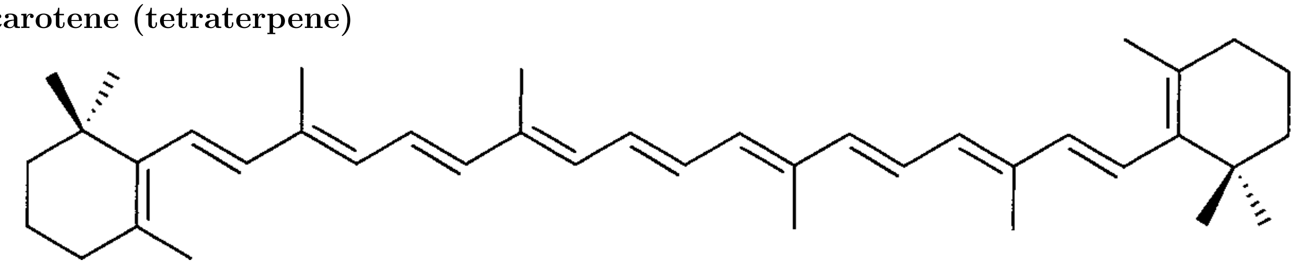
Glycyrrhetic acid (triterpene)



Tetraterpenes

- Have C_{40} skeleton and four condensed rings
- Carotenes, like β-carotene from carrot and lycopene from tomato

β-carotene (tetraterpene)



Summary

- Polyketides are source chemicals to many antibiotics
- Derivatives of shikimic acid are phenylpropenes, lignans, coumarins, flavonoids and tannins
- All terpenes (including carotenes, steroids and resins) are derivatives of isoprene

For Further Reading

References

[1] A. Shipunov. *Ethnobotany* [Electronic resource]. 2011—onwards. Mode of access: http://ashipunov.info/shipunov/school/biol_310

[2] Heinrich et al. 2012 (or 2004). *Fundamentals of Pharmacognosy and Phytotherapy.* Churchill Livingstone, Edinburgh. Mode of access: http://ashipunov.info/shipunov/school/biol_310/heinrich2004_fund_pharm_part.pdf

Outline

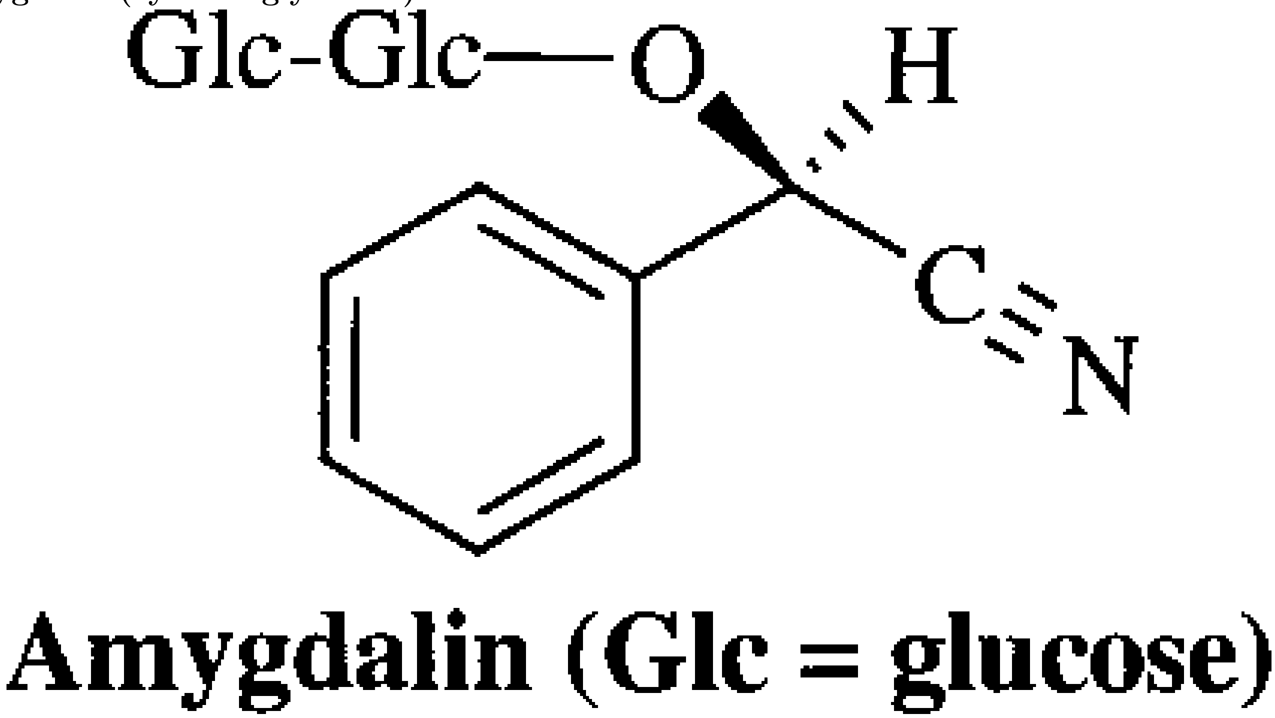
29 Natural product chemistry

29.1 Glycosides

Glycosides I

- Glycosides are any radicals binded to monosaccharides
- Cyanide glycosides have HCN (cyanide group)
- Example: amygdalin from almond
- Glucosinolates contain allyl isothiocyanate group
- Example: mustard oils of cabbage family plants

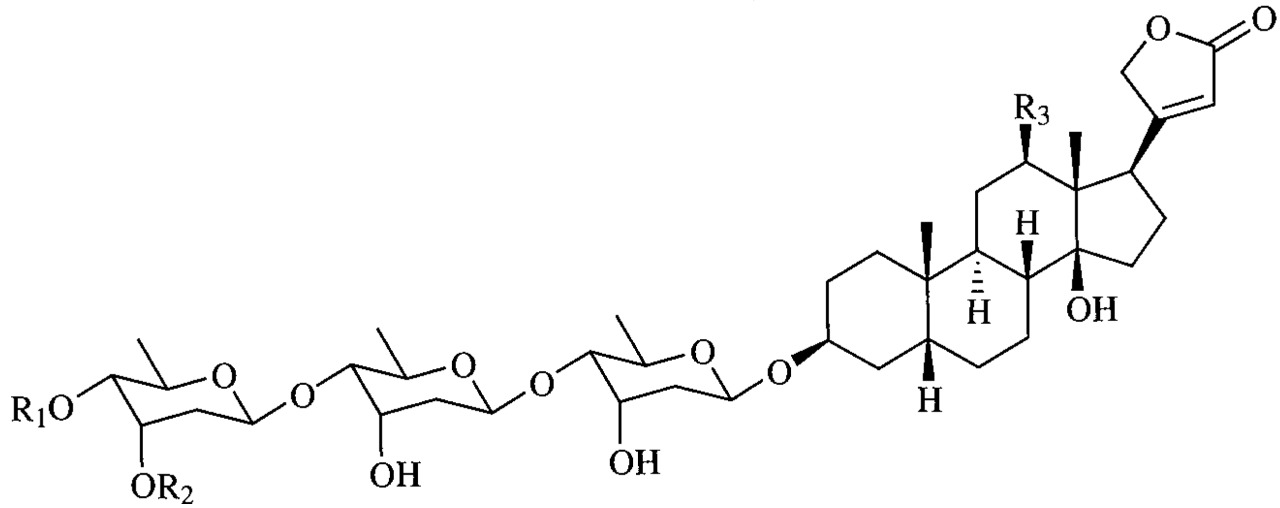
Amygdalin (cyanide glycoside)



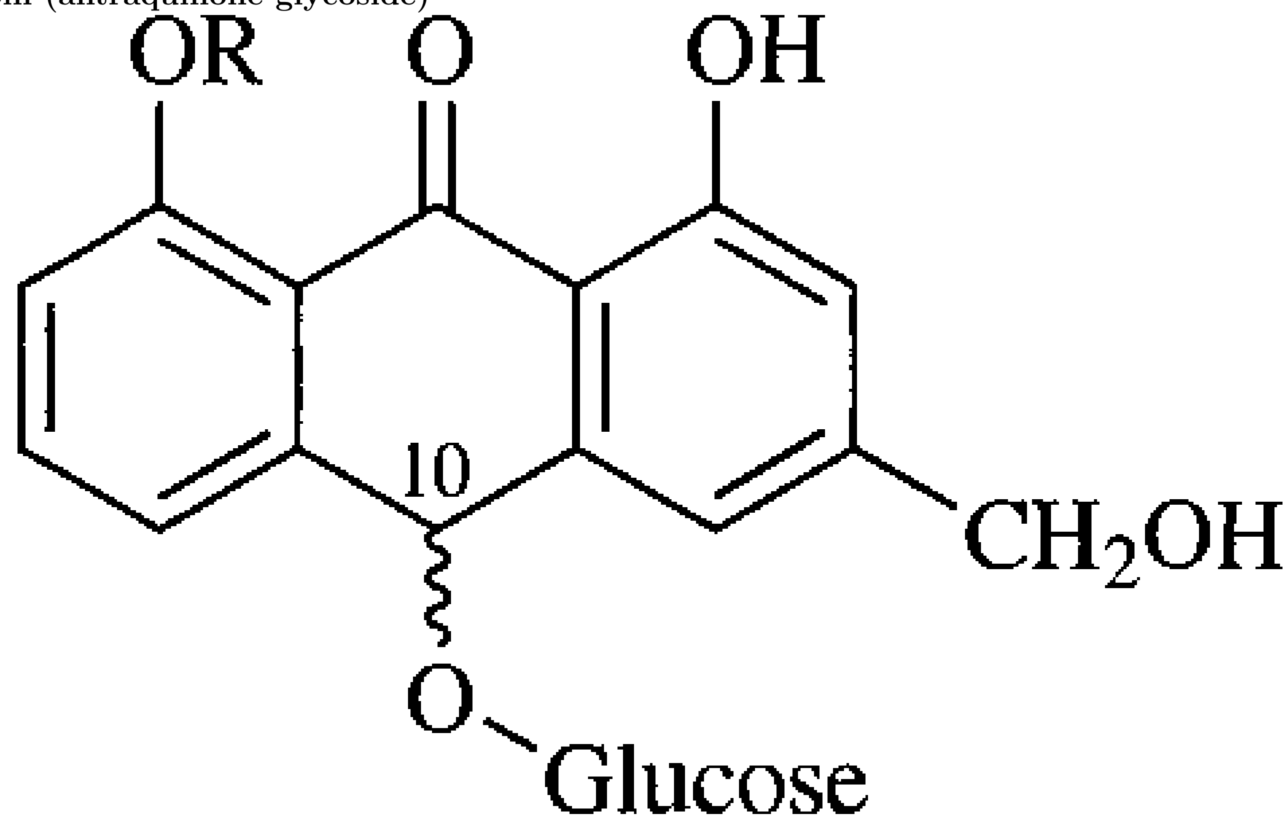
Glycosides II

- Cardiac glycosides are "steroid-like"
- Example: digotoxin from foxglove (*Digitalis*)
- Anthraquinone glycosides contain anthraquinone nucleus (3-ring system)
- Examples: aloin from *Aloë*, cascaroside from cascara (*Rhamnus purchiana*); often laxative

Digitoxin (cardiac glycoside)



Aloin (antraquinone glycoside)

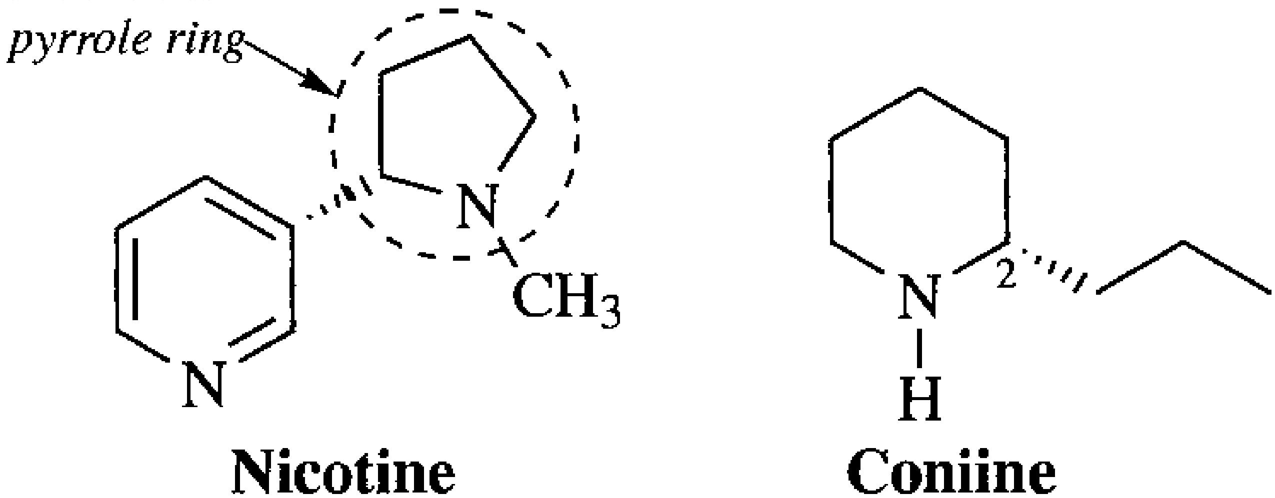


29.2 Alkaloids

Alkaloids I

- Alkaloids are most important pharmaceutical components from plants
- They are based on heterocyclic rings and related to nucleic bases
- Pyridine-like alkaloids are based on pyridine ring
- Examples: nicotine, coniin from hemlock

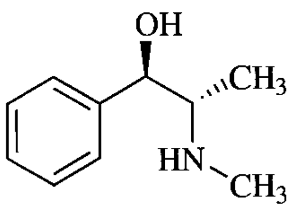
Pyridine alkaloids



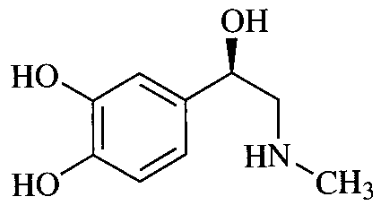
Alkaloids II

- Phenylalkamine alkaloids are amines, not heterocycles
- Ephedrine which is similar to adrenaline; hallucinogenic mescaline from peyote cactus (*Lophophora williamsii*); dangerous colchicine from autumn crocus (Colchicum)
- Quinoline and isoquinoline alkaloids contain more than two rings
- Famous group: quinine from *Cinchona* tree; morphines from opium poppy; tubocurarine, main component of curare poison from *Chondrodendron*; emetine from ipecac (*Caephaelis*)

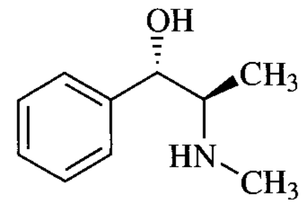
Phenylalkamine alkaloids



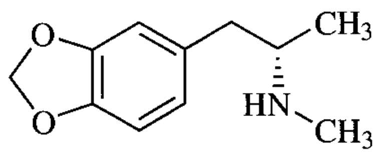
(-)-Ephedrine



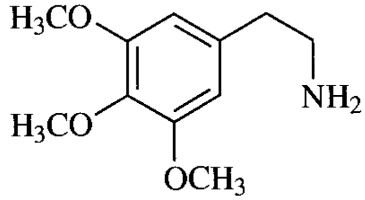
Adrenaline



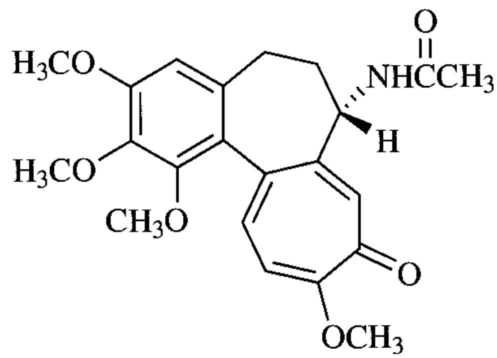
(+)-Pseudoephedrine



MDMA (ecstasy)

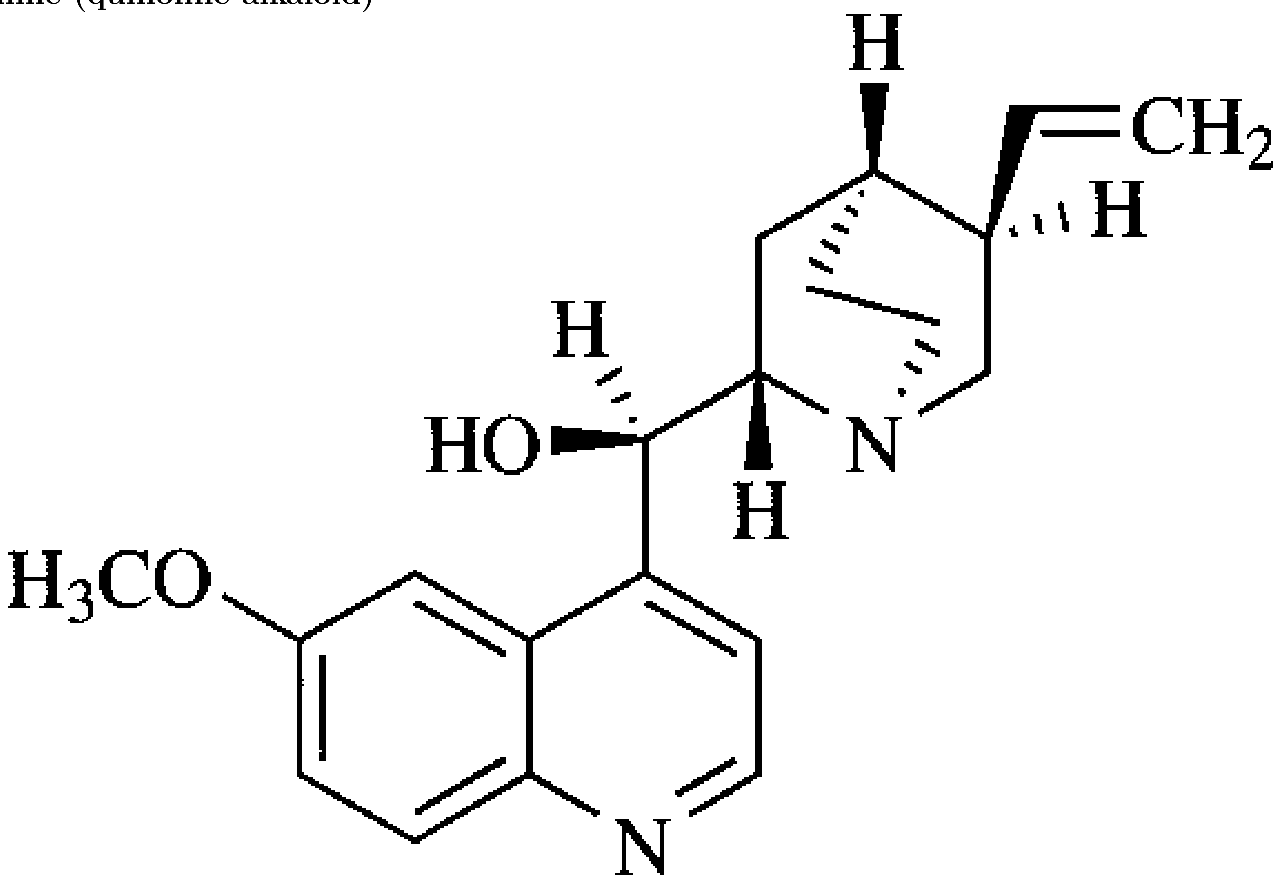


Mescaline

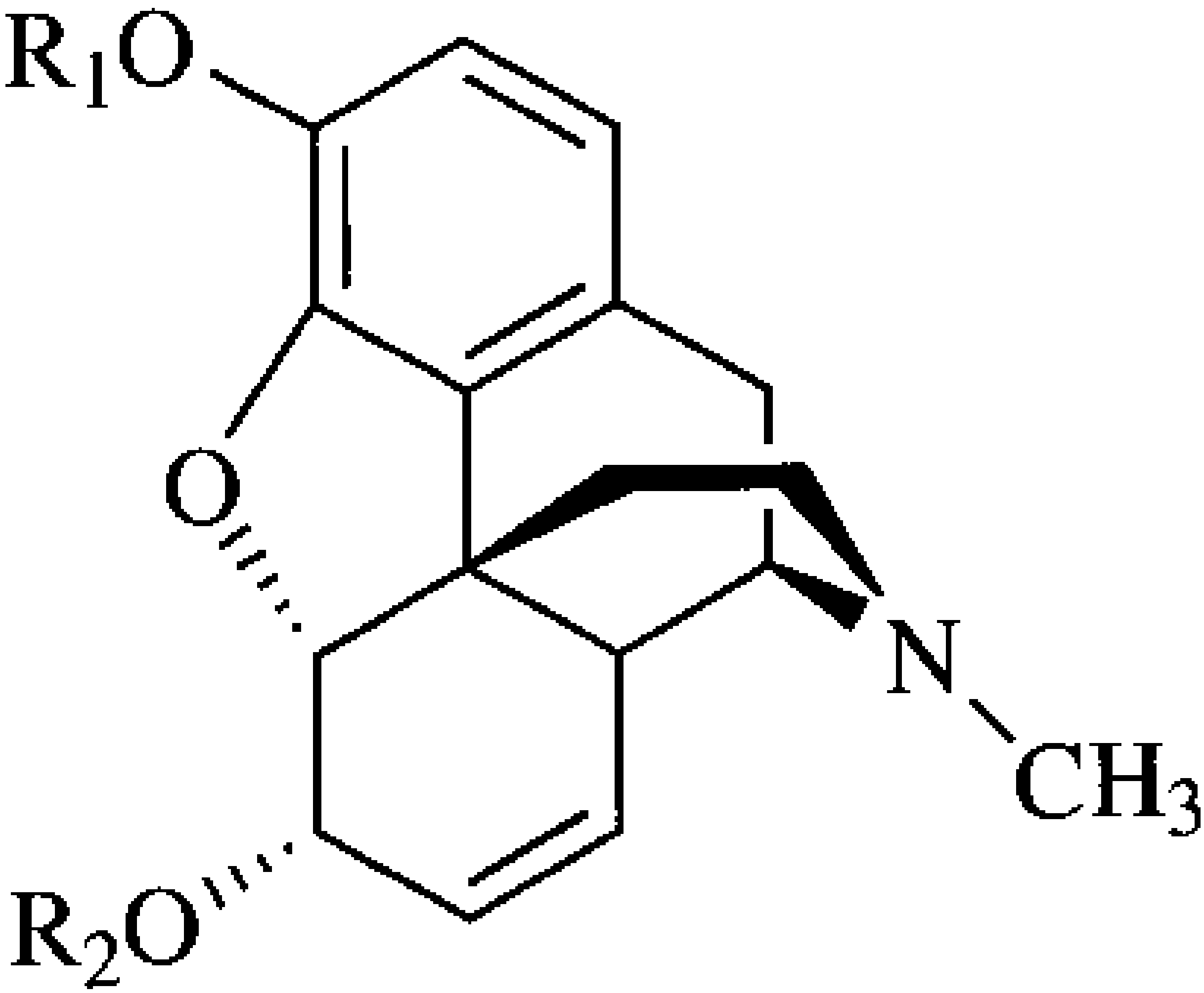


Colchicine

Quinine (quinoline alkaloid)



Morphine (isoquinoline alkaloid)



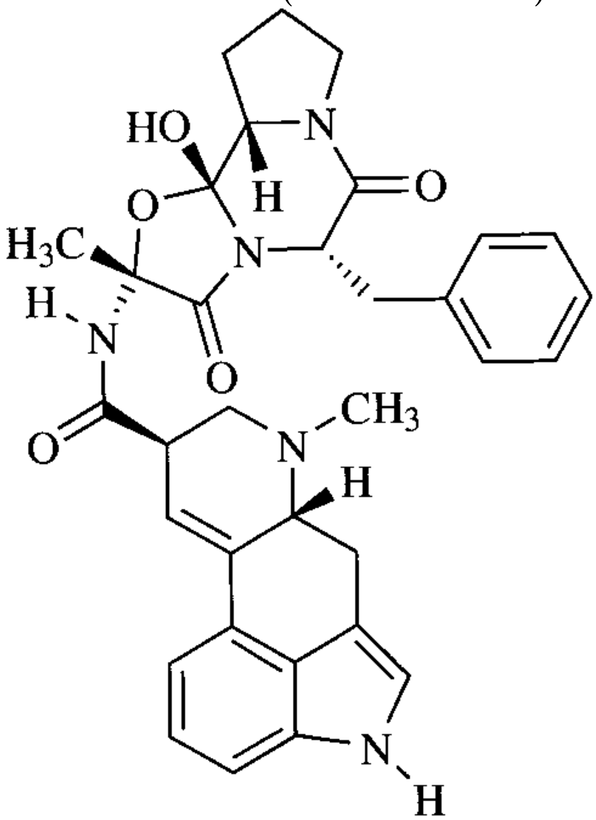
Morphine, $R_1 = R_2 = H$

Heroin, $R_1 = R_2 =$ acetyl

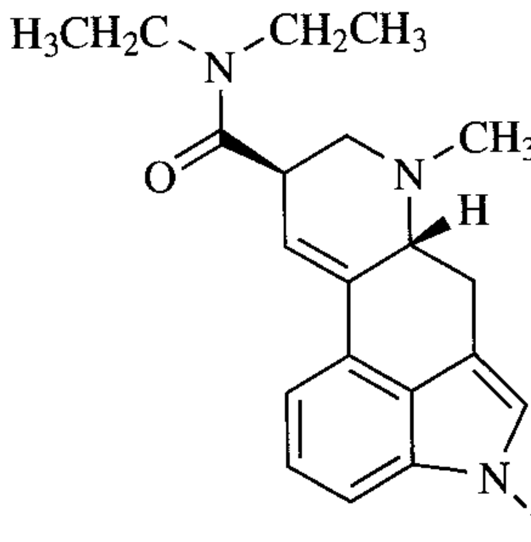
Alkaloids III

- Indole alkaloids contain connecting nitrogen atom
- Examples: reserpine from snake root (*Rauvolfia*), LSD which is a chemical analog of ergotamine from ergot fungus which is a rye parasite; brucine which is a powerful poison from nux-vomica (*Strychnos*).
- Tropane alkaloids contain tropane “chair”
- Examples: hyosciamine from deadly nightshade (*Atropa*) and cocaine from *Erythroxylon*
- Xanthine alkaloids are derivatives of xanthine (with two ketone groups)
- Examples: caffeine, theophylline, theobromine from coffee, tea and cocoa, respectively

Ergotamine and LSD (indole alkaloids)

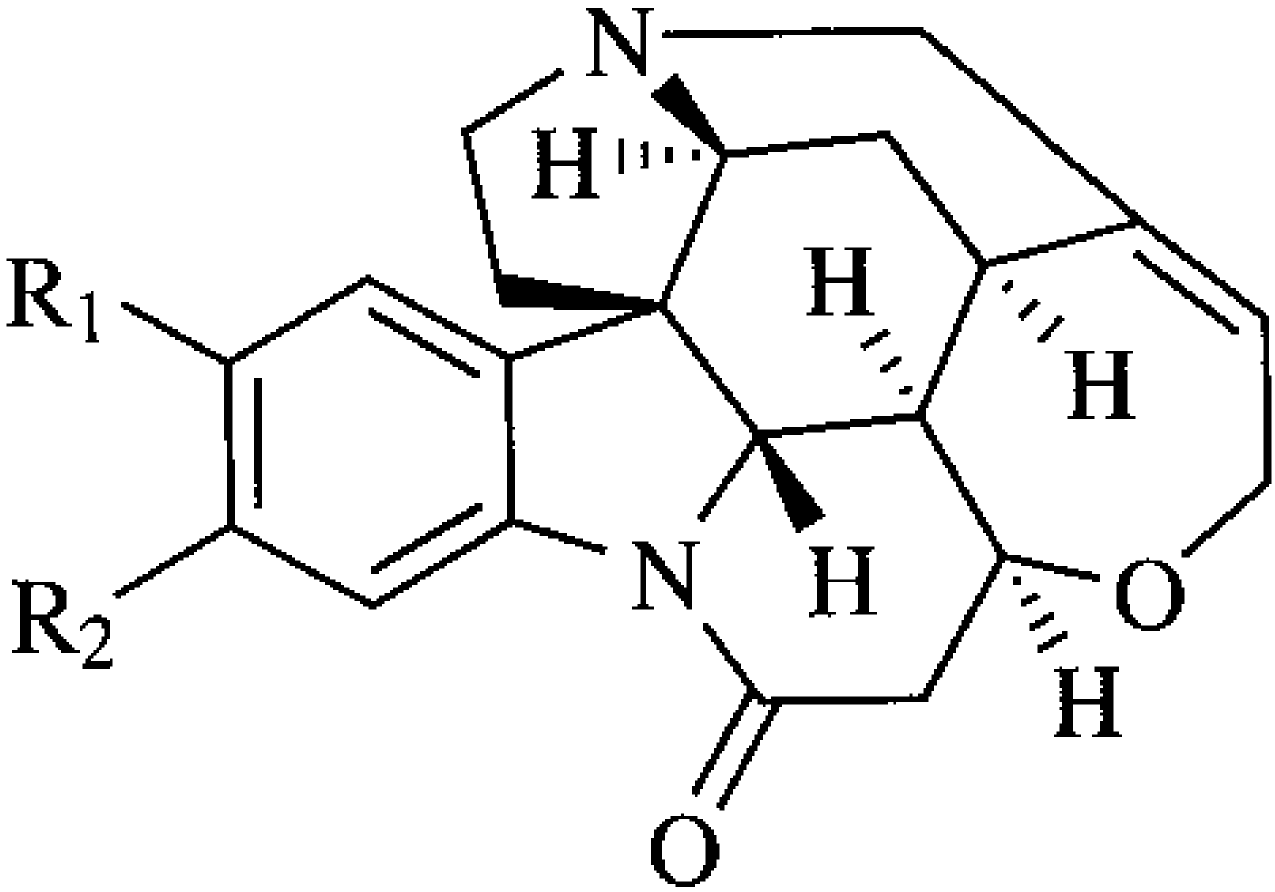


Ergotamine



LSD (Lysergic acid diethylamide)

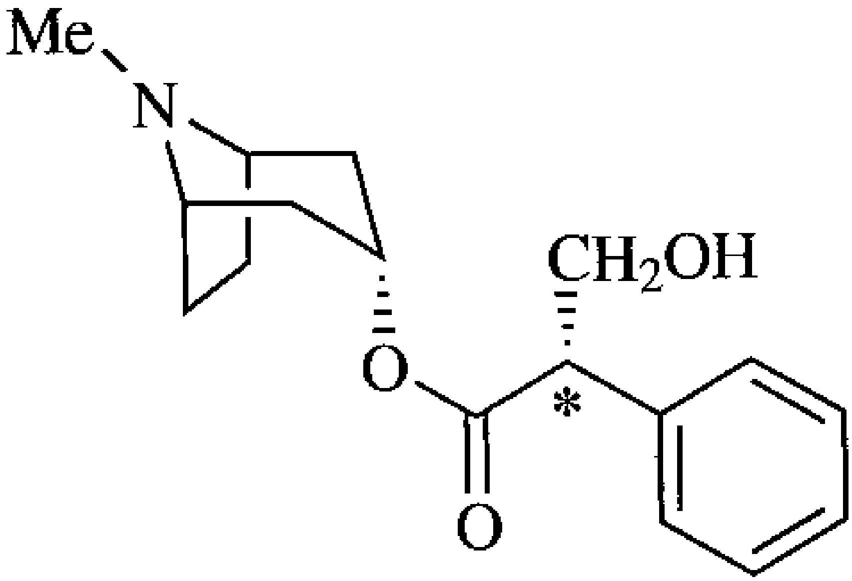
Brucine (indole alkaloid)



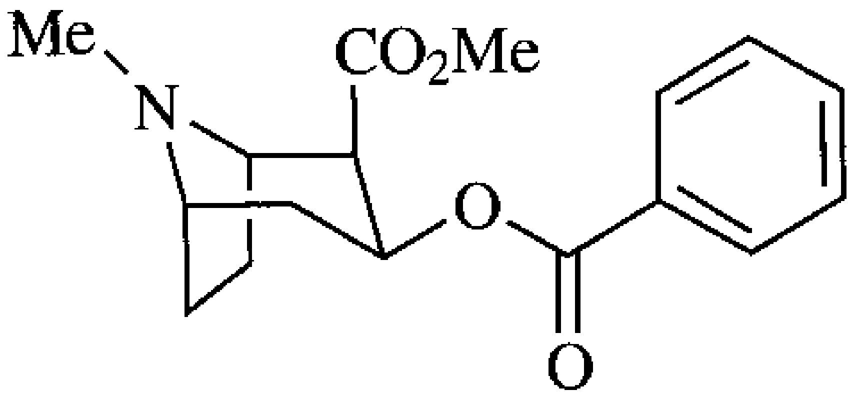
Strychnine, $R_1 = R_2 = H$

Brucine, $R_1 = R_2 = CH_3O$

Tropane alkaloids

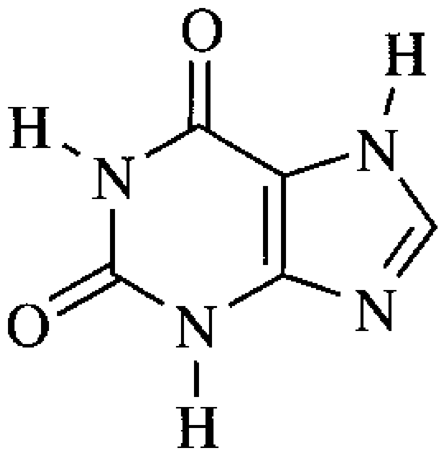


(-)-Hyoscyamine

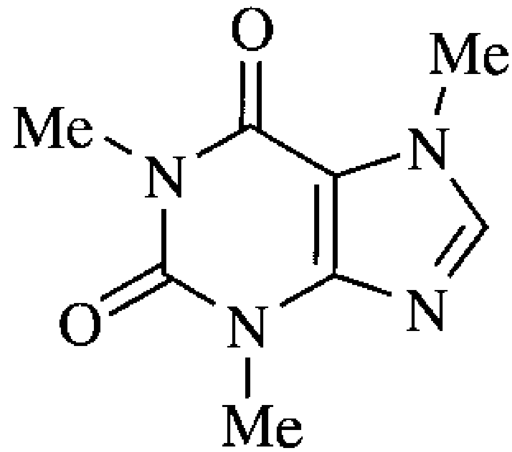


Cocaine

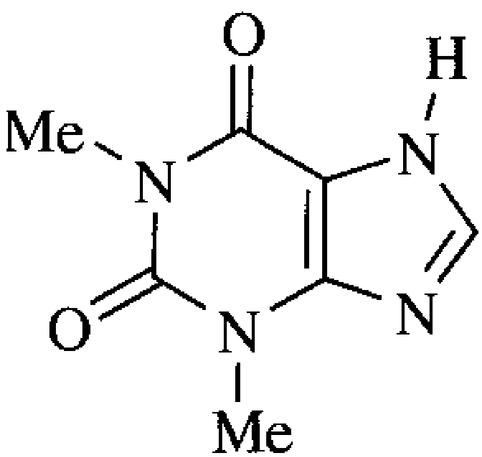
Xanthine alkaloids



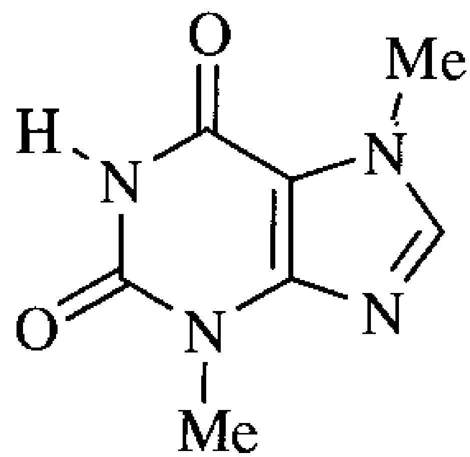
Xanthine



Caffeine



Theophylline



Theobromine

30 Traditional systems of herbal medicine

30.1 Basic aspects

Western medicine

- Developed with the evolution of Western science, based on strict and positive scientific evidence, experiments and statistical analysis
- For the long time, Western science ignored other branches of human medicine

Main non-western medicines

- Traditional Chinese medicine (TCM)
- Ayurveda
- Traditional African medicine
- Traditional American medicinal practices

Some general aspects

- Healing in traditional systems is mostly applicable to minor disorders
- Chronic and serious disorders often considered to be a “super-natural”
- Dose is not calculated
- Too powerful chemicals are not usually used
- There is a strong, but not absolute correlation between traditional and Western systems

30.2 Traditional Chinese medicine (TCM)

Traditional Chinese medicine (TCM)

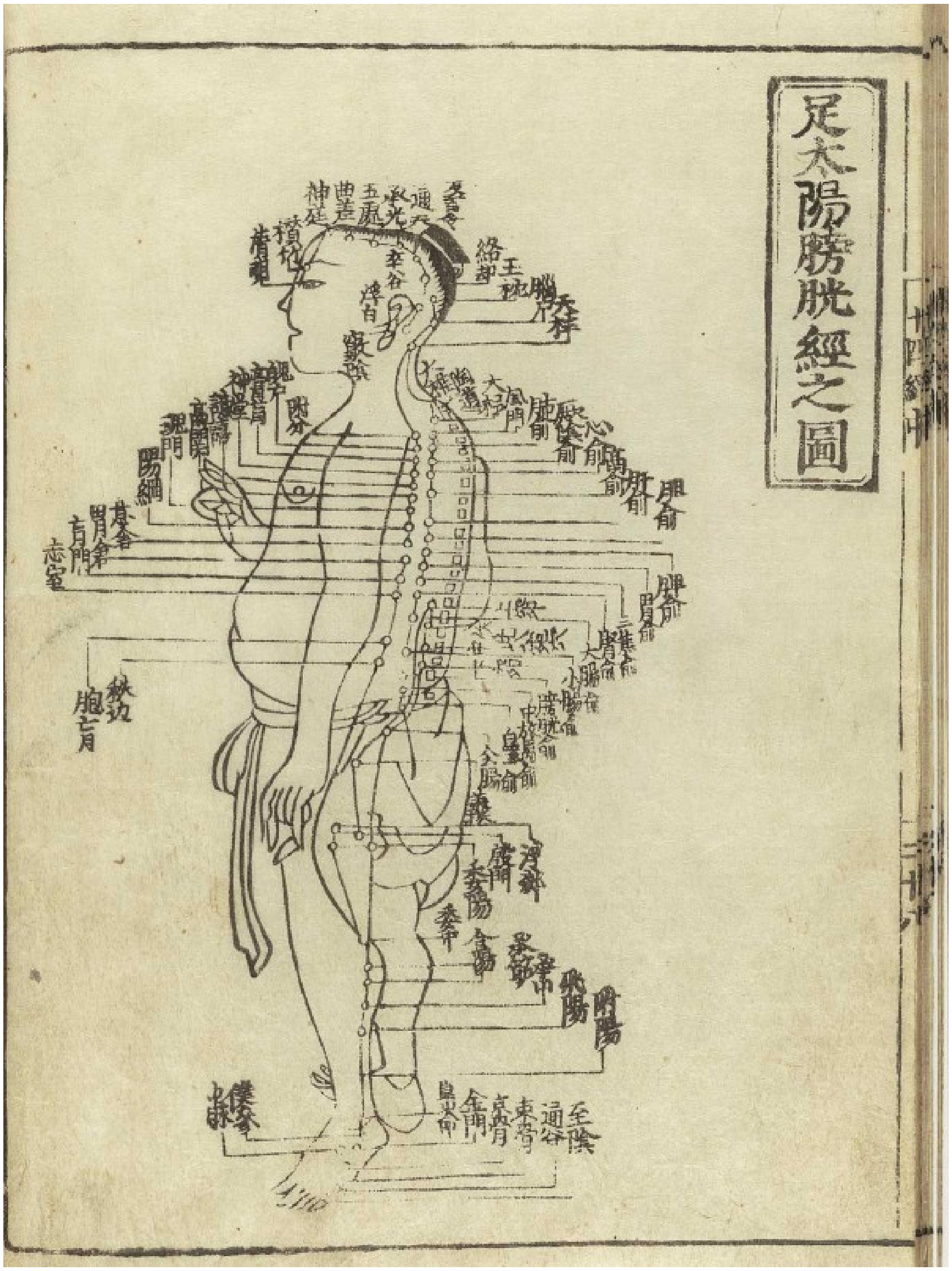
- Started more than 3,000 BC
- Based on specific philosophy
- Uses a large variety of plants, mushrooms, animals (!) and other biological compounds

TCM history

- Started to develop in relation with Taoism and based on philosophical principle of yin and yang
- Knowledge transfered from religion (shamans) to philosophers
- In Han times (200 BC – 200 AD) Zhang Zhogjing invented acupuncture
- In Min dynasty times (≈1550) Li Shizhen pruduced the herbal encyclopedia Ben Cao Gang Mu (52 volumes)

Zhang Zhongjing (150–219)

Acupuncture map



Li Shizhen, 1518–1593

Ben Cao Gan Mu volumes

TCM concepts

- Qi (or chi) is a source of life energy (ynan qi)
- Yin and yang iteractions and five elements (heart/fire, liver/wood, spleen/earth, lungs/metal and kidneys/water)
- Six excesses: wind, cold, summer heat, dampness, dryness and fire
- Seven emotions (internal causes of diseases): joy, anger, anxiety, concentration, grief, fear, fright

Diagnosis in TCM

- Based on observation of **external** characters and interview
- Normally, tongue and pulse are observed, then massage and palpation help to obtain an information

Treatment

- Purpose is to rectify harmony
- For every cause, "antidote" with alternative features should be used
- E.g., for cold TCM uses "warm" herbs as ginger

Qingping market, Guangzhou: plants

Qingping market, Guangzhou: gin seng

Qingping market, Guangzhou: animals

Kampo

- Japanese variant of TCM, started in ≈600 AD
- Based on acupuncture and herbs
- Pharmacopoeia contains ≈170 herbs and mushrooms

30.3 Traditional Indian medicine

Ayurveda

- System of sacred Hindu medicine
- Started 3,000 BC

Ayurveda principles

- Every patient is an individual
- Greatly values subjectivity
- Similarly to TCM, consider human as microcosm which should be rectified and balanced

Ayurveda basics

- Five elements (similar to TCM)
- Three humors of life: vata (air/movement), pitta (fire and water/heat energy), kapha (water and earth/structure)
- Agni (digestive fire) is essential pitta

Ayurveda diagnosis and treatment

- Malas (waste products) are important for the diagnosis
- Diagnosis also involves astrology and karma analysis
- Treatment is based on the idea of cleaning
- Among herbal remedies, rasayana plants (among them, there are amla *Emblica officinalis* and ashwagandha *Withania somnifera*) are most useful

Durga bears remedies

Amla, *Phyllanthus officinalis* (Euphorbiaceae)

Unani

- Close to Ayurveda
- Urdu (Pakistan and India), Arab and Persian traditional medicine
- Avicenna (Ibn Sina from contemporary Uzbekistan) established its main principles which went farther to Europe after translation of Arab books

Avicenna (Ibn Sina, 980–1037)

Summary

- Glycosides is an artificial group
- Alkaloids are relavives of nucleic bases; they are most important plant chemicals
- Traditional Chinese medicine and other non-Western system are holistic (wholesome) approaches
- The goal of traditional healing is to restore a harmony
- These medicines are based on a extensive using of herbs

For Further Reading

References

[1] A. Shipunov. *Ethnobotany* [Electronic resource]. 2011—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_310`

[2] Heinrich et al. 2012 (or 2004). *Fundamentals of Pharmacognosy and Phytotherapy*. Churchill Livingstone, Edinburgh. Mode of access: `http://ashipunov.info/shipunov/school/biol_310/heinrich2004_fund_pharm_part.pdf`

Outline

31 Traditional systems of herbal medicine

31.1 Traditional African systems

Traditional African systems (TAMS)

- Multiple systems, often independent and unrelated
- Zulu (South Africa) and Yoruba (Nigeria) traditions are best known

TAMS concepts

- Every living thing, gods and ancestral spirits are connected
- Disharmony in these connections will cause a disease
- Invisible insects and worms may start to inhabit human body and also cause disease

TAMS diagnosis and treatment

- Diagnosis involve religious practices
- Plant remedies are often not taken, but used as amulet or even without contact with patient

Sangoma healers, South Africa

31.2 Traditional American systems

Traditional American medical systems

- Multiple, often unrelated and non-standardized practices
- Have a big ceremonial component related with shamanism
- Tribal women are most important carriers of medicine information

Eskimo medicine man

Shaman dance

32 Complementary and alternative medicine (CAM)

32.1 Introduction

CAMs

- Whole medical systems such as homeopathy, naturopathy, TCM, and Ayurveda
- Mind-body medicine such as meditation, prayer, mental healing, art therapy, music therapy, and dance therapy
- Biologically based practices such as dietary supplements, herbal supplements, and other scientifically unproven therapies such as shark cartilage
- Manipulative and Body-Based Practices such as spinal manipulation (both chiropractic and osteopathic) and massage
- Energy therapies such as qi gong, reiki, therapeutic touch, and electromagnetic therapy

Alternative approaches used plants

- Medical herbalism

- Homeopathy
- Antroposophical medicine
- Aromatherapy
- Flower remedy therapy
- Naturopathy
- Orhtomolecular medicine

32.2 Herbalism

Medical herbalism

- Based on pre-scientific traditions of European cultures
- Holistic approach, similar to Eastern practices

Conditions treated

- Normally, chronic conditions which are not treated well in common medicine
- Eczema, arthritis, depression, migraine, PMS and others

Differences from rational phytotherapy

- Typically, combination of 4–6 herbs (assumes synergy)
- Most of remedies are taken as tinctures
- There is a flow of information between phytotherapy and herbalism

32.3 Homeopathy

Homeopathy

- Samuel Hahnemann (Germany, 1755–1843) founded homeopathy
- "Likes cures like"
- Always minimal dose and extremely high dilutions!
- One remedy at a time

Samuel Hahnemann (1755–1843)

Modern homeopathy

- They believe in stimulating of body's own "vital force"
- "Vital force" is strongly individual

Remedies

- Highly diluted (and poisonous when undiluted)
- 65% originates from plants

Evidence

- Despite of hundreds of trial, results are still controversial
- Some experiments on "water memory" provided the support for dilution theory, but scientific value of these experiments is also dubious

"Nature" publication of Benveniste group (1988)

32.4 Anthroposophy

Anthroposophical medicine

- Rudolf Steiner (Germany, 1861–1925) founded anthroposophy and related medicine approach
- Three functional systems: sense-nervous, reproductive-metabolic and rhythmic
- Popular in Germany, Austria and other continental Western European countries

Rudolf Steiner (1861–1925)

Conditions treated

- The approach is therapeutic, but sometimes used for supportive treatments of serious diseases like cancers
- Several German hospitals practice anthroposophical medicine

Antroposophic medicines

- Normally are combinations of plant components (often diluted) and minerals
- Mistletoe from different trees is a source of common drug "Iscador"
- Plants should be specifically grown in accordance to anthroposophic "biodynamic farming"

Mistletoe, *Viscum album*, Santalaceae

32.5 Aromatherapy

Aromatherapy

- Rene-Maurice Gattefosse (French perfumer, 1881–1950) is a founder of aromatherapy
- Main idea is that essential oils could be used to provide general well-being
- Aromas are prescribed holistically, in terms of "energy" etc.

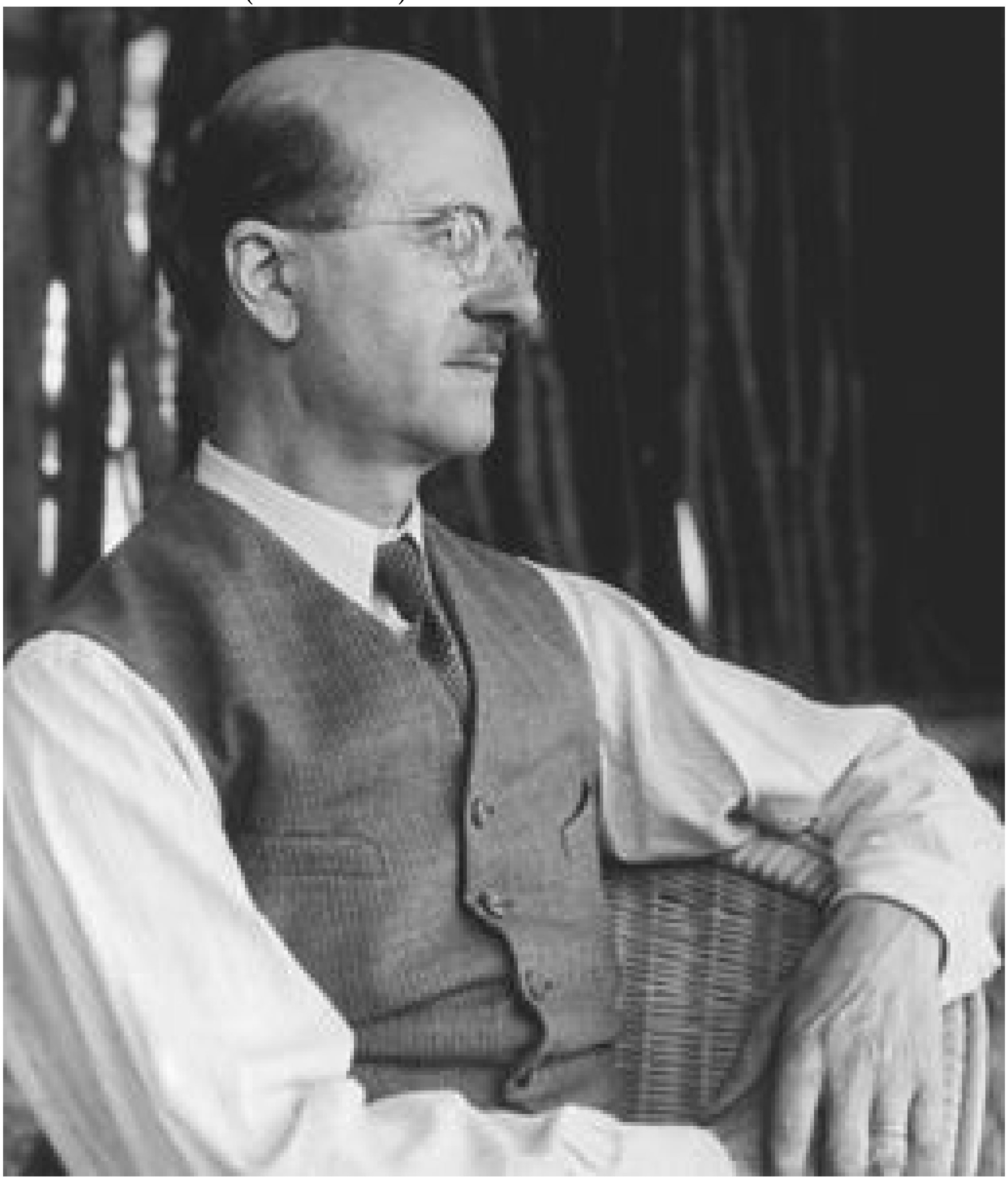
Conditions treated

- All conditions which require relaxation
- Skin diseases, different chronic disorders etc.

Aromatherapy medicines: essential oils

- Used in combinations
- Mostly by massage, but also by baths, inhalations, compresses and other external ways

Rene-Maurice Gattefosse (1881–1950)



Efficacy

- Sometimes work in relation with conventional phytotherapy
- However, most of uses were not proved scientifically

32.6 Other CAMs

Flower remedy therapy

- Edward Bach (UK, 1886–1936) invented the idea of flower remedies
- Every remedy is a flower extract which is supposed to heal specific condition

Edward Bach (1886–1936)

Remedies

- Whole flowers which are dried and/or boiled to prepare tincture or water essence
- Single species are used in majority of cases

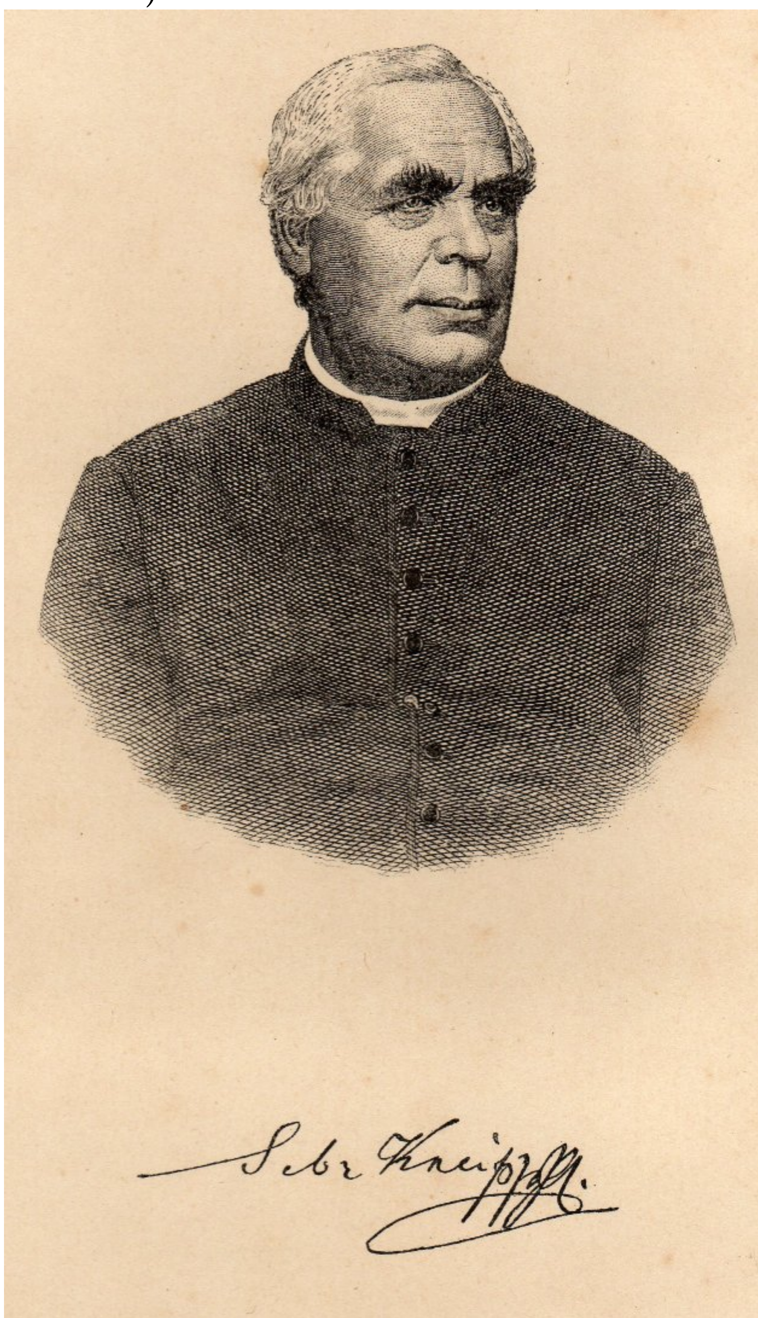
Efficacy

- Nothing has been proved scientifically
- Requires future research

Naturopathy

- Founded by Sebastian Kneipp in 1850s
- Combination of "natural", "organic" methods of medicine including herbalism
- Similarly to other practices, individualistic and holistic
- Includes, for example, hydrotherapy (Vincenz Priessnitz, ca. 1820) and cryotherapy

Sebastian Kneipp (1821–1897)



Orhtomolecular medicine

- Founded by Linus Pauling in 1960s
- In particular, it is a belief that over-large doses of some supplements (like vitamin C) may treat diseases

CAM in USA

- There are multiple accredited schools of CAM
- National Center for Complementary and Alternative Medicine focuses on research and integration of CAM techniques and practices

Summary

- The goal of traditional healing is "to restore a harmony"; these medicines are based on a extensive using of herbs
- Alternative medicine approaches are also widely using different herbal remedies; however, efficiency for most of these methods has not been scientifically proved

For Further Reading

References

[1] A. Shipunov. *Ethnobotany* [Electronic resource]. 2011—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_310`

[2] Heinrich et al. 2012 (or 2004). *Fundamentals of Pharmacognosy and Phytotherapy*. Churchill Livingstone, Edinburgh. Mode of access: `http://ashipunov.info/shipunov/school/biol_310/heinrich2004_fund_pharm_part.pdf`

Outline

33 Pharmacognosy

33.1 Plant remedies for gastrointestinal and biliary systems

Diarrhea

- Very common, especially in children
- Oral rehydration works well in most cases

Plants for rehydration

- Na^+
- Starch from potatoes, corn or rice, or glucose

Constipation and laxatives

- By medical definition, defecation less frequent than once in 2–3 days
- Not a serious problem but increase risks of other diseases

Bulking laxative from plantains, ***Plantago*** spp.

- *Plantaginis ovatae semen*, *Psyllii semen*
- Have high swelling factor (> 40) due to the presence of specific polysaccharides

Isphagula, ***Plantago ovata***

Psyllium, *Plantago sempervirens*

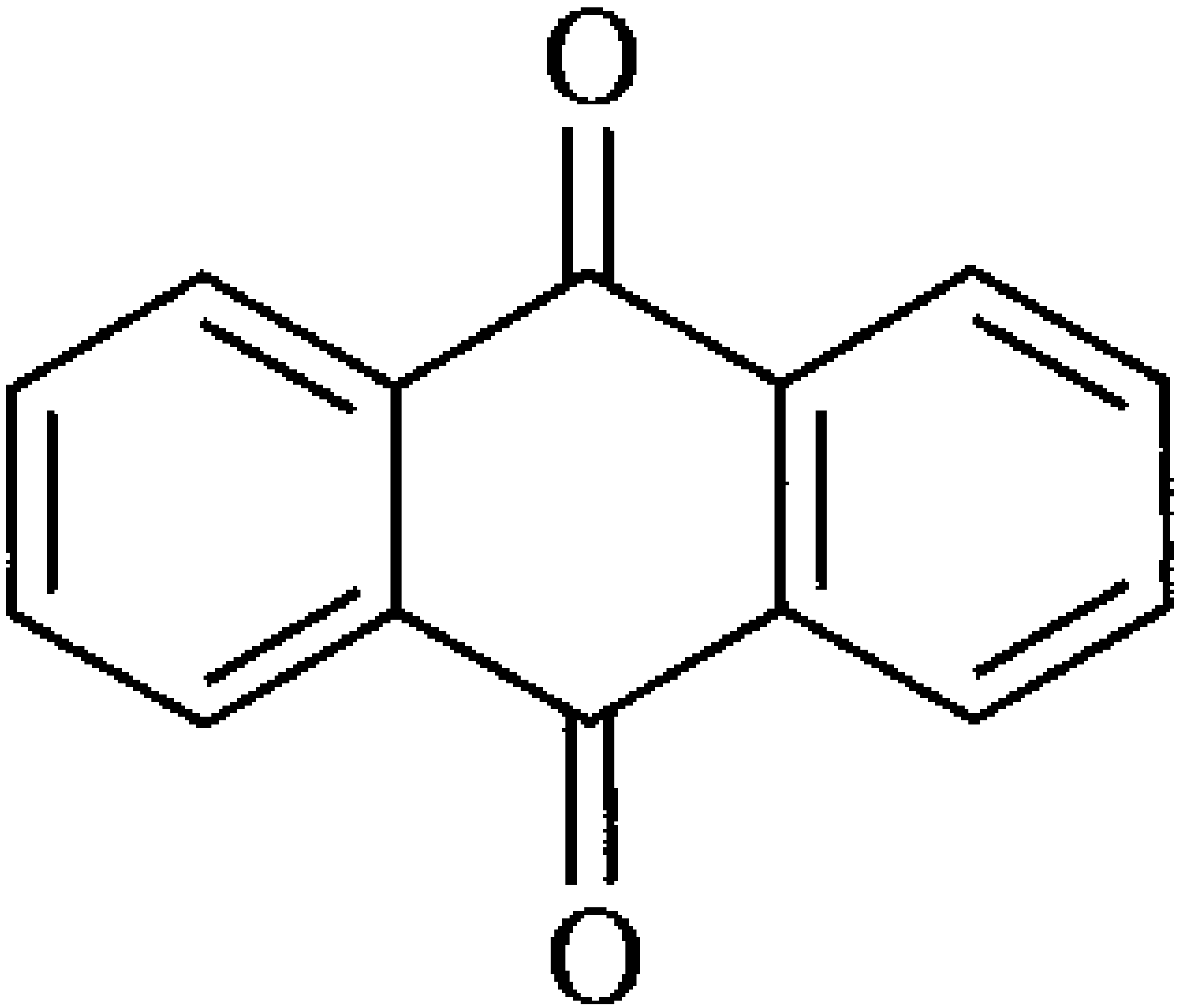
Linseed, *Linum usitatissimum*

- *Lini semen*
- Should be used as whole seed

Stimulant laxatives

- Normally, stimulant laxatives are antraquinones
- Increase a peristaltic activity of a colon

Antraquinone

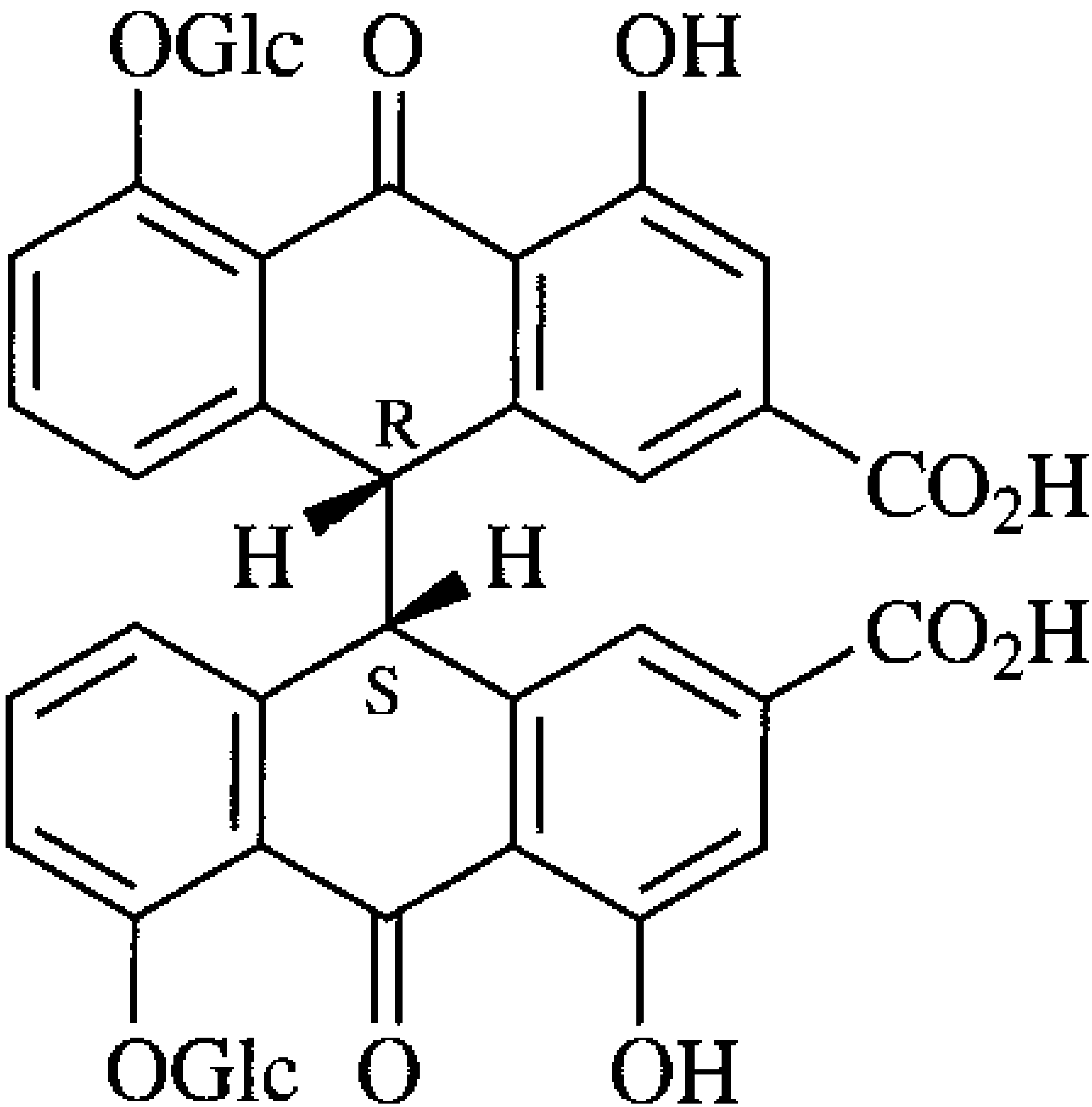


Senna, *Cassia* spp.

- *Sennae fructus/folium*
- Contain sennosides

Senna, *Cassia senna*

Sennoside B

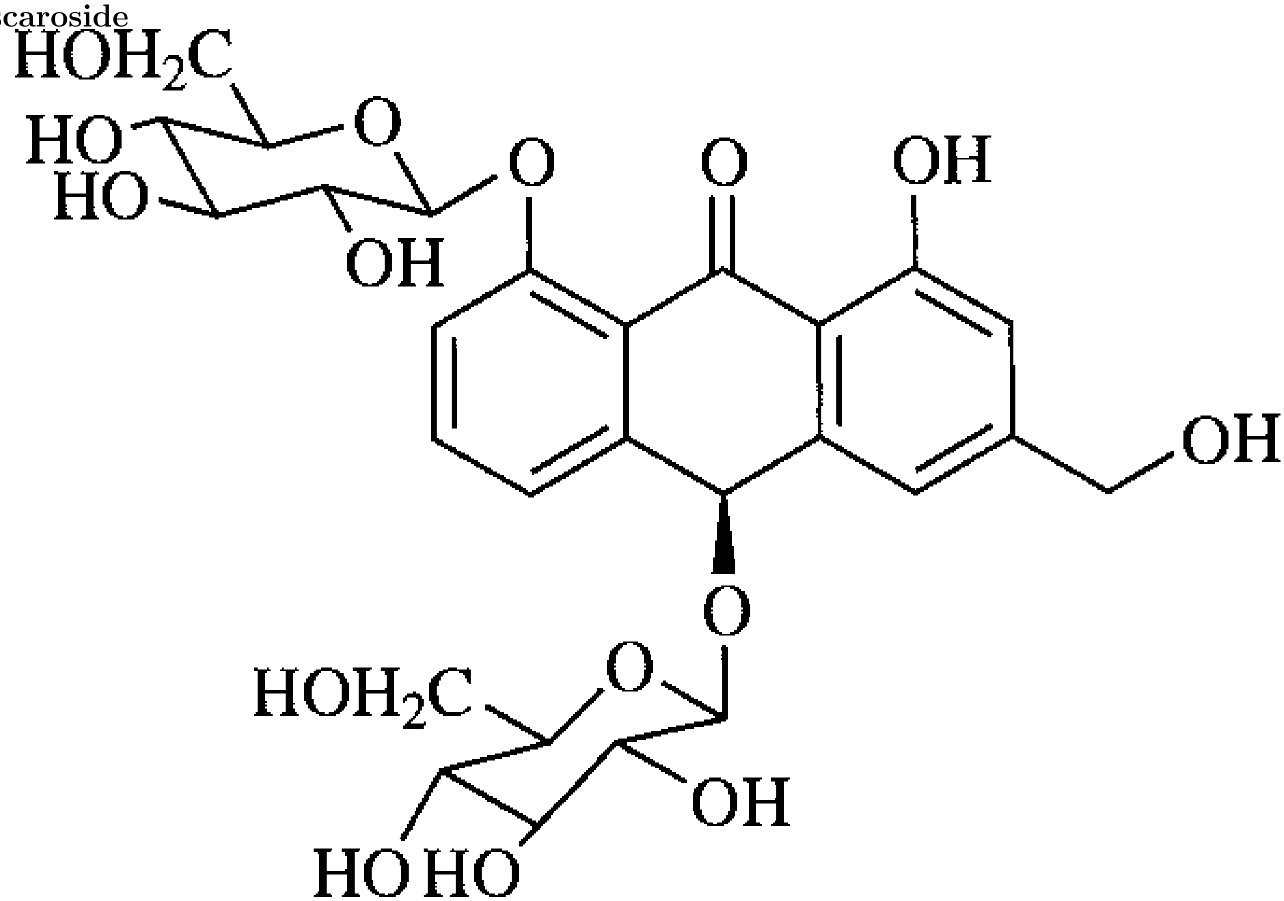


Cascara, *Rhamnus* spp.

- *Rhamni/Frangulae cortex*
- *Rhamnus purshiana* is native to Pacific coast
- Contain emodin, cascarosides and other antraquinone glycosides

Cascara, *Rhamnus purshiana*

Cascaroside



Inflammatory problems

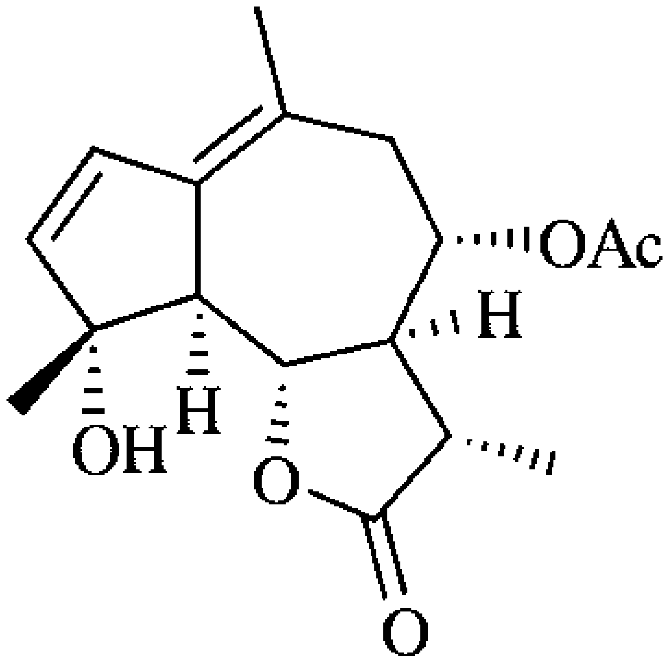
- May be a signal about infectious gastritis
- Mixtures of emollient and antacid are mostly used

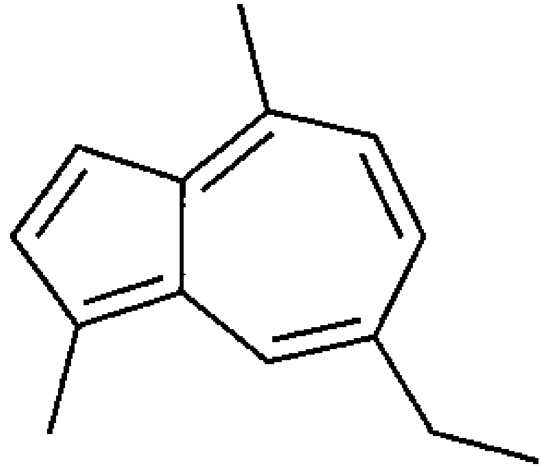
Chamomile, *Matricaria recutita*

- *Matricariae flos*
- European herb ("German chamomile")
- Multiple-effect drug, essential oils and other constituents are anti-inflammatory and anti-bacterial

Chamomile, *Matricaria recutita*

Matricin and chamazulene

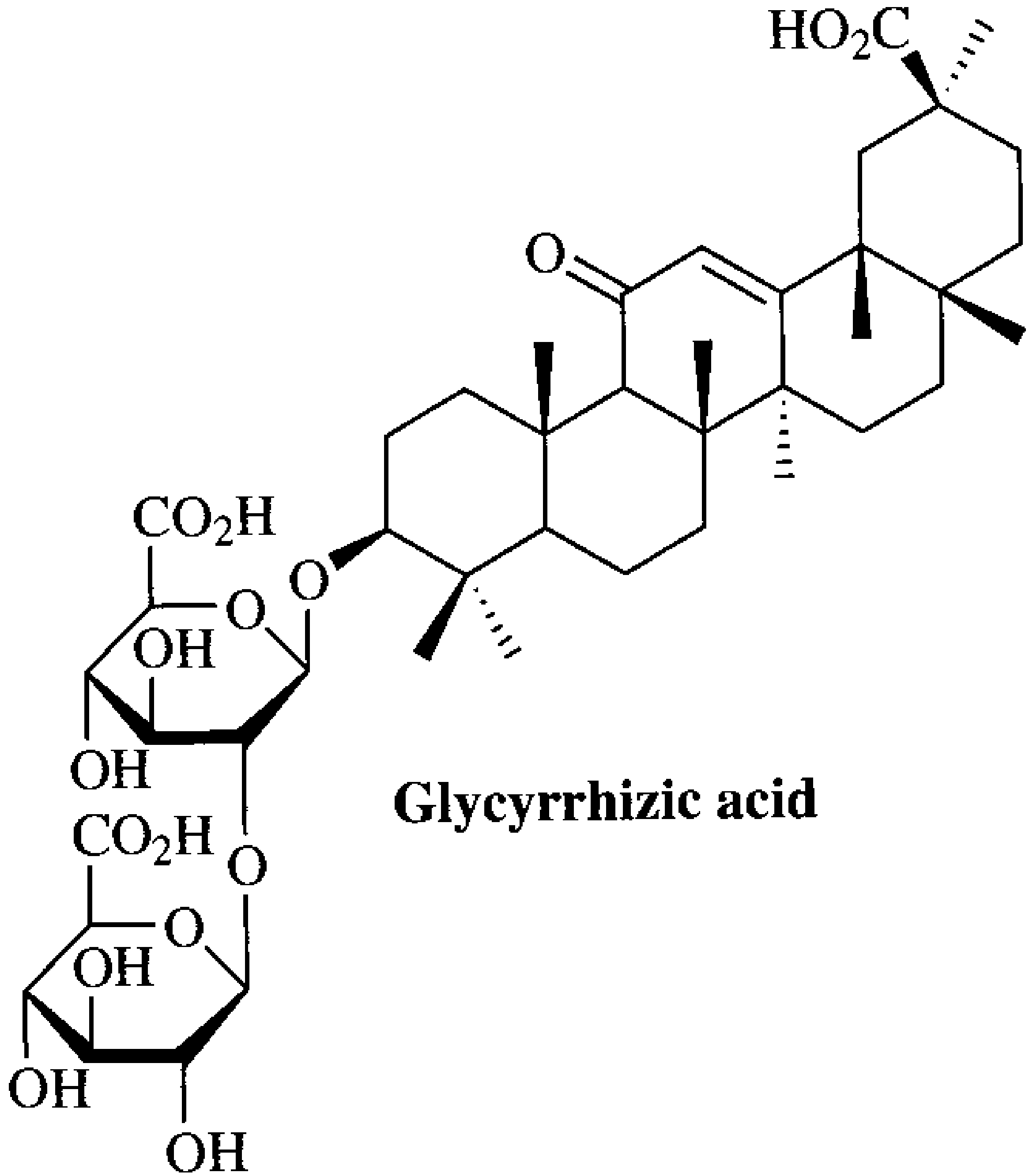




Liquorice, *Glycyrrhiza glabra*

- *Liquiritiae radix*
- Main component is glycyrrhizic acid, traditional but controversial remedy

Glycyrrhizic acid



Glycyrrhizic acid

Dyspepsia and liver disorders

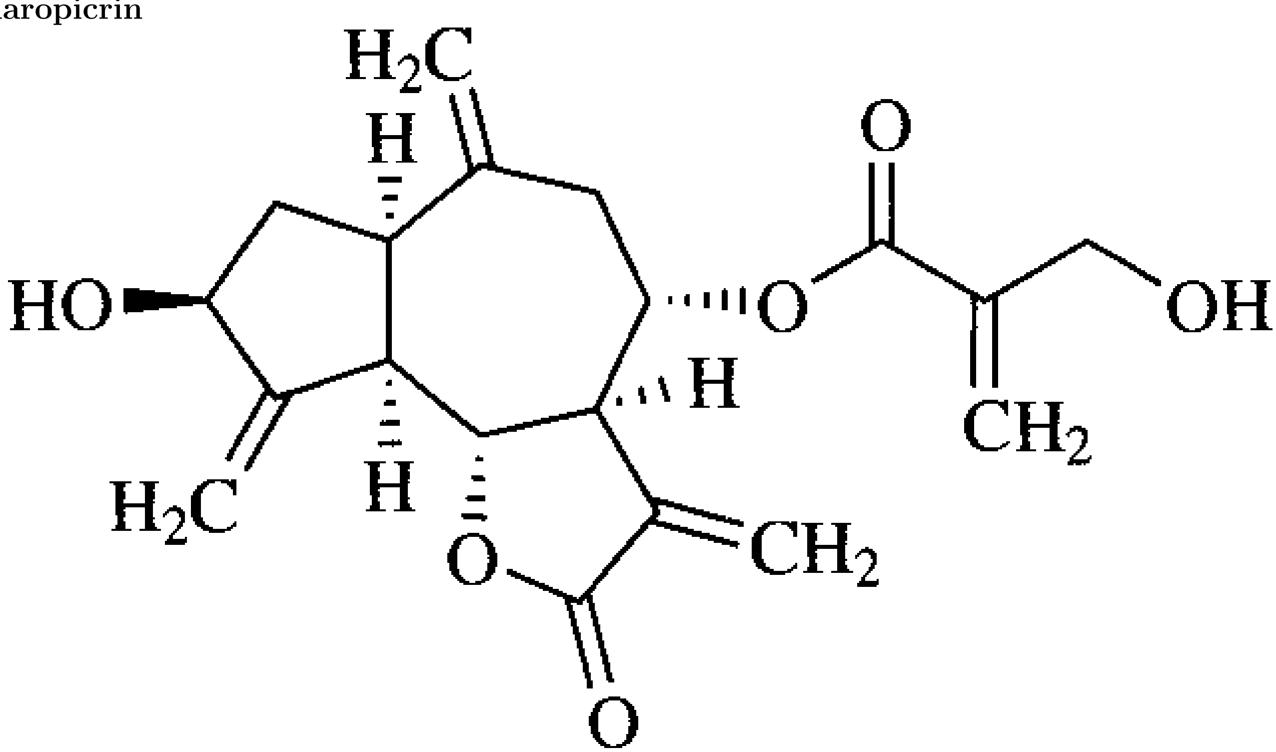
- Often are a sideway symptoms of more serious diseases
- Closely associated with eating habits
- Cholagogues and bitter stimulants are popular remedies

Artichoke, *Cynara scolymus*

- *Cynarae folium*
- Main component is a bitter sesquiterpene cynaropicrin

Artichoke, *Cynara scolymus*

Cynaropicrin



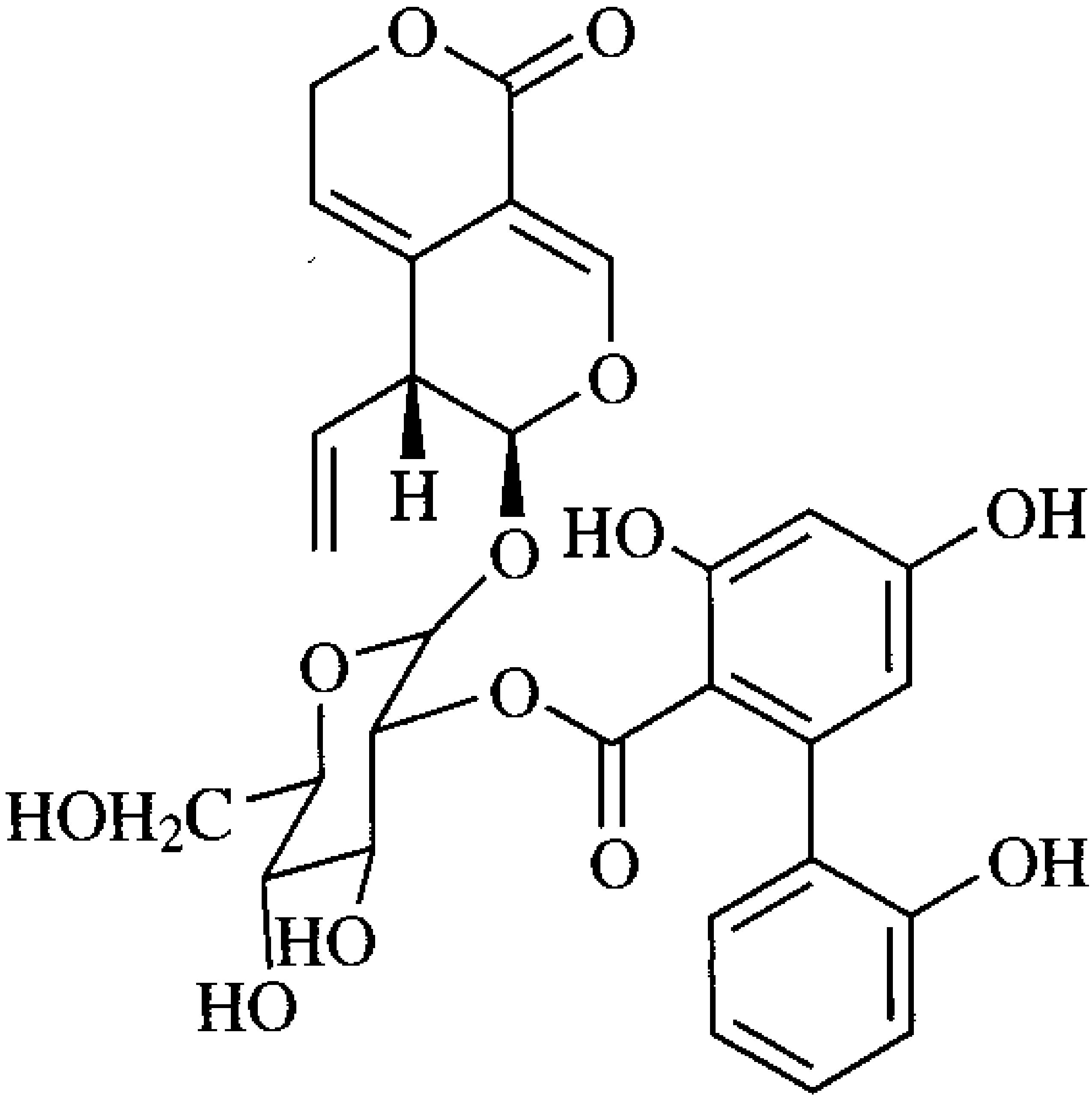
Gentian, *Gentiana lutea*

- *Gentianae radix*

- Gantiopicroside and amarogentin (bitter value of 58,000,000) are iridoids
- Bitters stimulate secretion of gastric juices

Yellow gentian, *Gentiana lutea*

Amarogentin



Wormwood, *Artemisia absinthium*

- *Herba absinthii*
- Traditionally used as liqueur
- Bitter value of sesquiterpene absinthin is ≈15,000

Wormwood, *Artemisia absinthium*

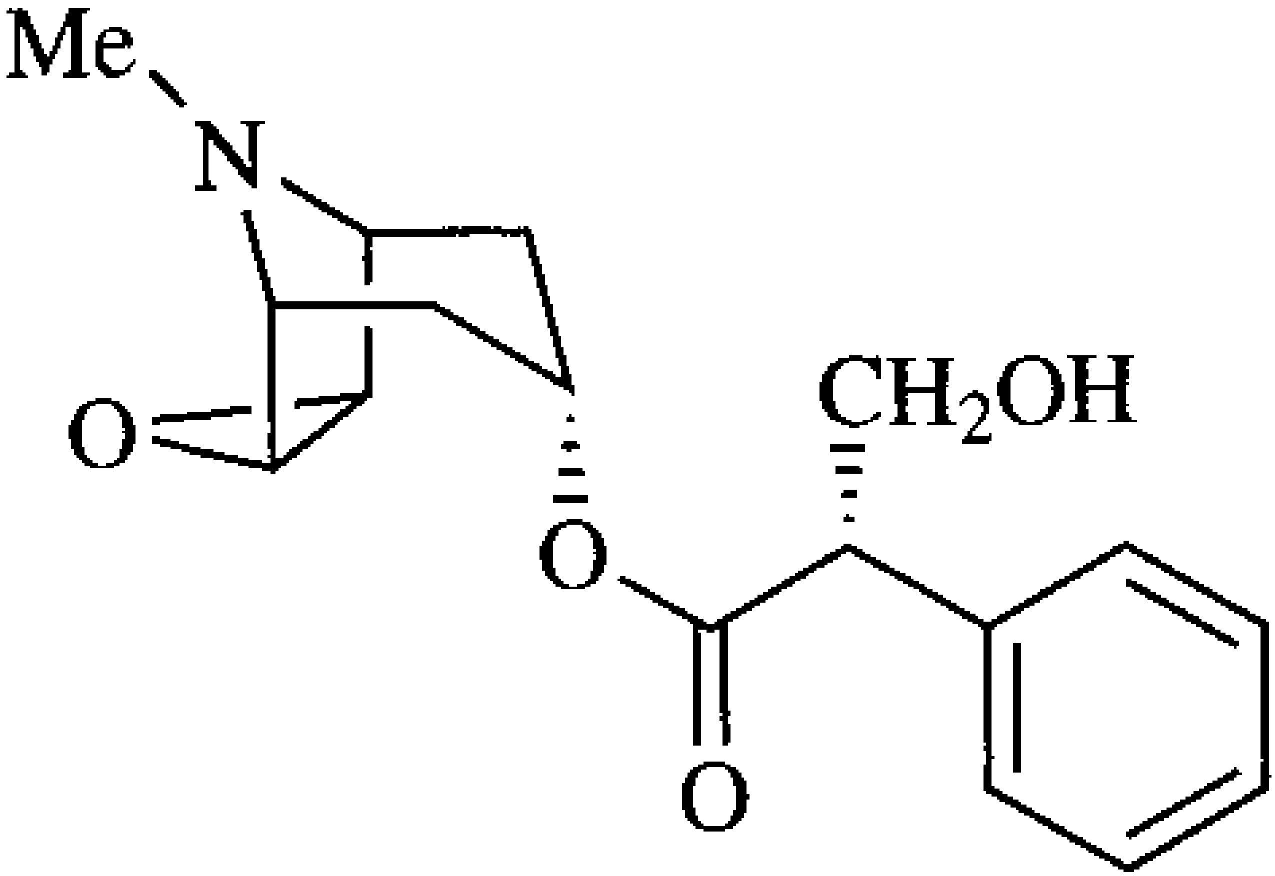
Nausea and vomiting

- Often components of “motion sickness”
- Spasmolytic constituents are often used

Hyoscine from Solanaceae plants

- Occur in *Scopolia*, *Hyoscyamus* and *Datura*
- Tropane alkaloid, poisonous

Hyoscine

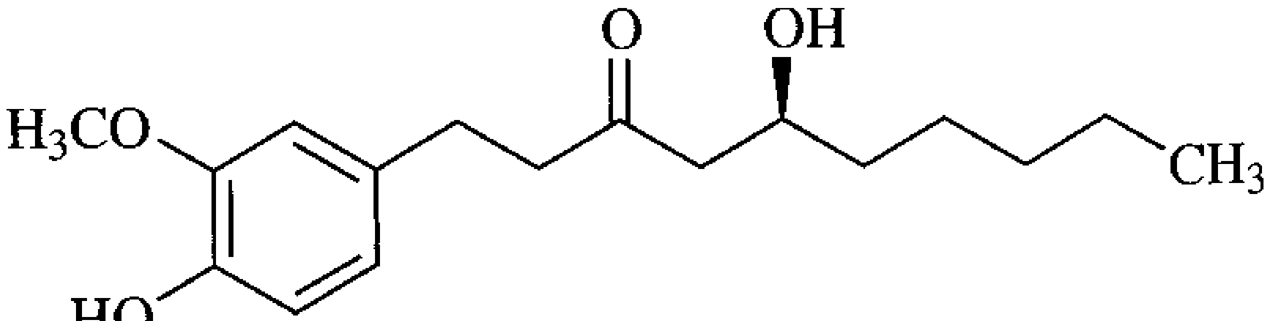


Ginger, *Zingiber officinale*

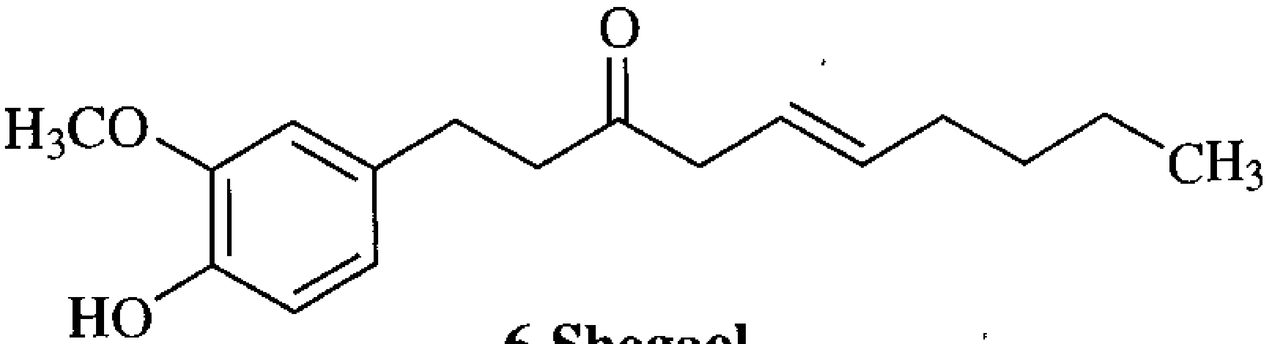
- *Zingiberis rhizoma*
- Multiple effect plant, essential oils gingerol and shogaol are responsible for pain relief, anti-sickness and other activities
- Extremely valuable in Eastern medicines

Ginger, *Zingiber officinale*

Gingerol and shoagol



6-Gingerol



6-Shogaol

Bloating and carminatives

- Bloating may be a result of bacterial activity (especially on arabinose)
- Carminatives provide both pleasant taste and anti-gas effect (precise mechanism is still unclear)

Mints, *Mentha* spp.

- *Menthae folium*
- Essential oil menthol and similar compounds

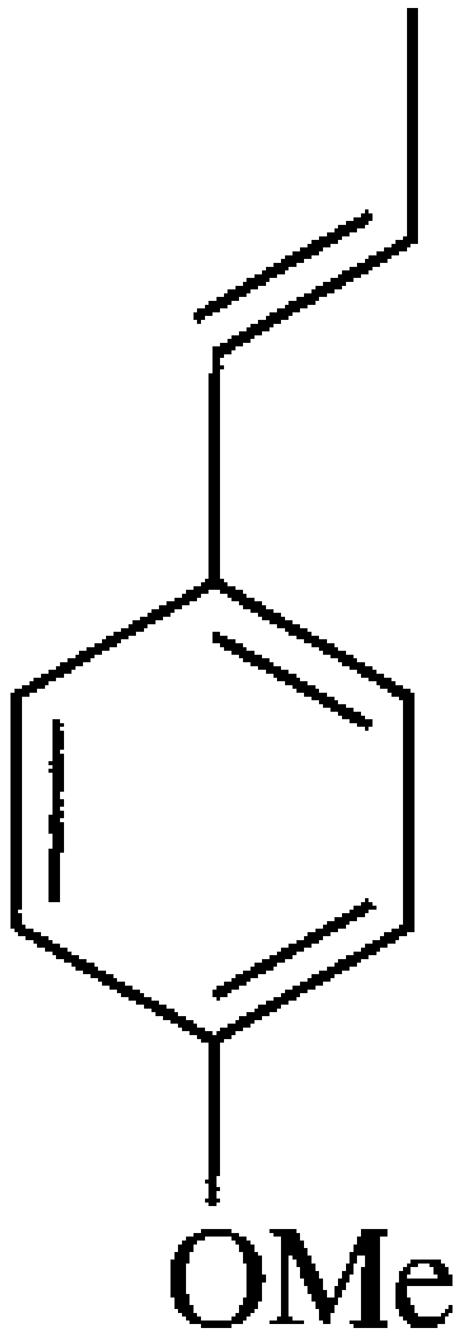
Umbelliferous fruits

- *Carvi fructus* from caraway (*Carum carvi*)
- *Foeniculi fructus* from fennel (*Foeniculum vulgare*)
- Contain essential oils like carvone, anethole and others

Caraway, *Carum carvi*

Section of mericarp

Anethone



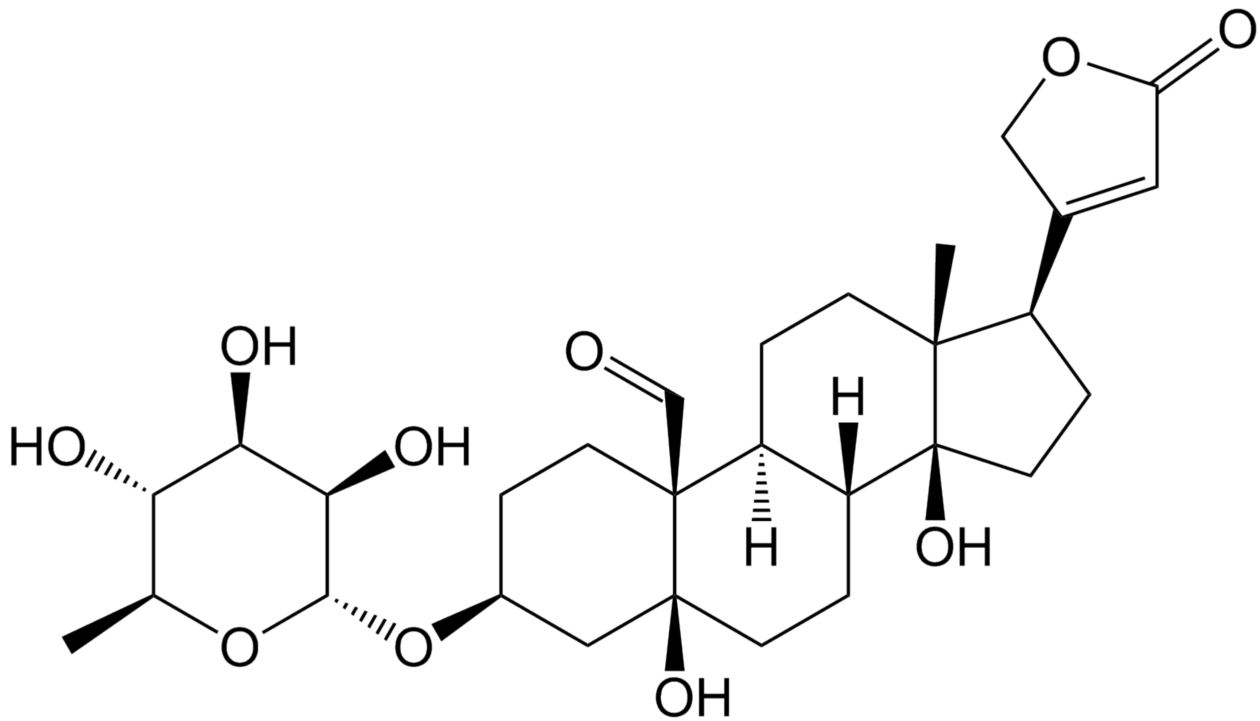
33.2 Plant remedies for cardiovascular system

Heart problems (arrhythmic conditions, failure etc.)

- Plants with cardiac glycosides
- In addition, lily of valley (*Convallaria majalis* with convallatoxin) and motherwort (*Leonurus cardiaca* with specific essential oils)

Lily of valley, *Convallaria majalis*

Convallatoxin



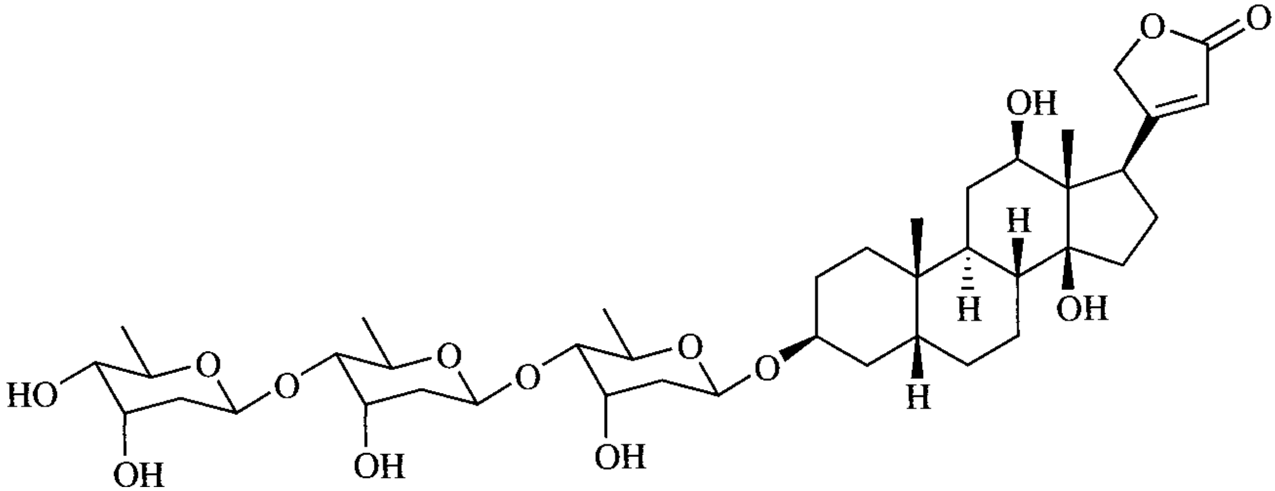
Common motherwort, *Leonurus cardiaca*

Foxglove, *Digitalis purpurea*, Plantaginaceae, Europe

- *Digitalis purpureae folium*
- Contain digoxin and other cardiac glycosides
- Increase the heart muscle contractility and reduces conductivity inside a atrioventricular node

Foxglove

Digoxin



Hawthorn, *Crataegus* spp., Rosaceae, North hemisphere

- *Crataegi folium/flores*
- The mixture of cyanide glycosides and flavonoids
- Blocks repolarizing potassium current in ventricular muscle and prolongs its activity

Venous insufficiency problems

- Hemorrhoids, varicose veins
- Antioxidants are normally used as remedies

Bilberry, *Vaccinium myrtillis*, Ericaceae, Eurasia

- *Myrtilli fructus*
- Anthocyanosides have vascular spasmolytic effects

Bilberry

Butcher's broom, *Ruscus aculeatus*, Asparagaceae, Eurasia

- *Rusci rhizoma*
- Saponin glycosides, inculding ruscine have been shown to produce positive effects to lipid profiles

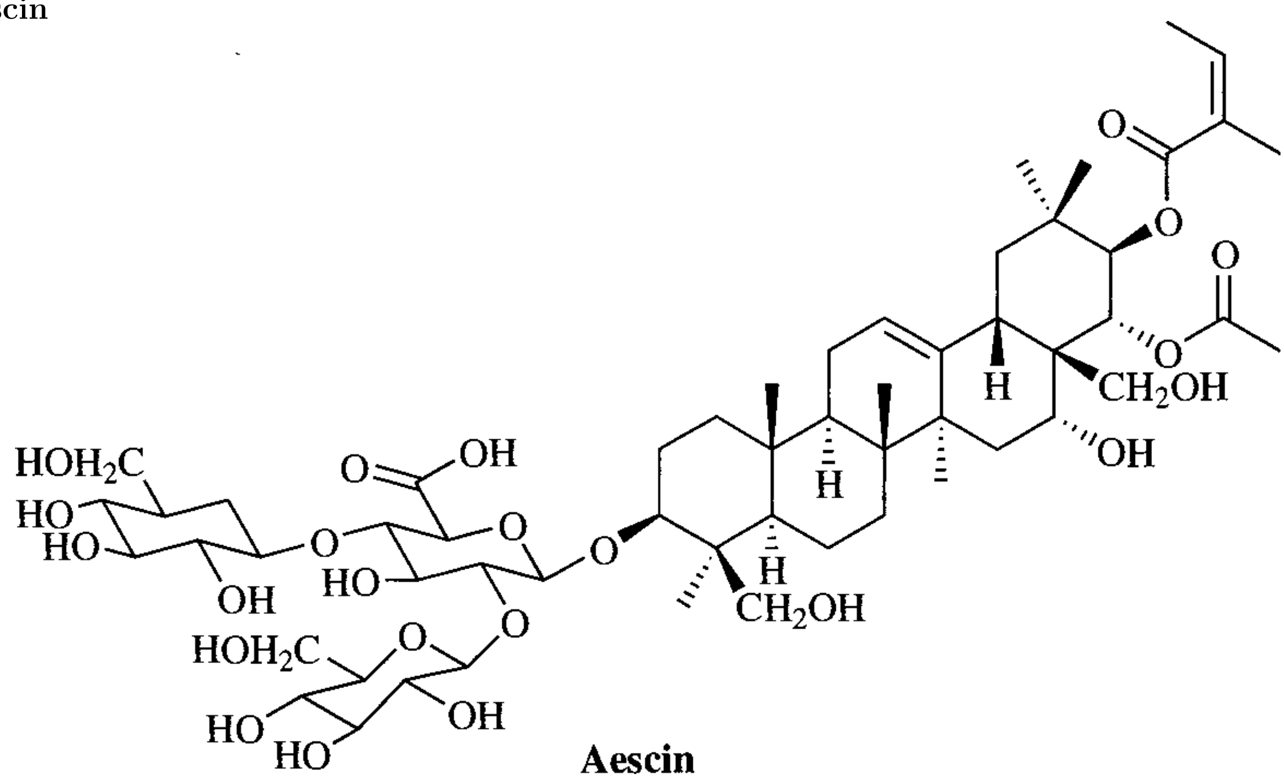
Ruscus

Horse chestnut, *Aesculus* spp., Sapindaceae, North hemisphere

- Seeds contant mixture of saponin flavonoids, e.g., aescin
- Have multiple membrane-related effects: anti-edema, thrombolytic etc.

Horse chestnut

Aescin



Aescin

Atherosclerosis

- Drugs should decrease platelet formation and risks of thrombosis and atherosclerosis

- Aspirin (modified salicilyc acid from willows, *Salix* is the main drug)

Garlic, *Allium sativum*, Alliaceae, Eurasia

- *Allii sativi bulbi*
- Sulphuric compounds like allicin and ajoene inhibit sythesis of LDL (low density lipoprotein)

33.3 Plant remedies for respiratory system

Bronchitis and nasal congestion

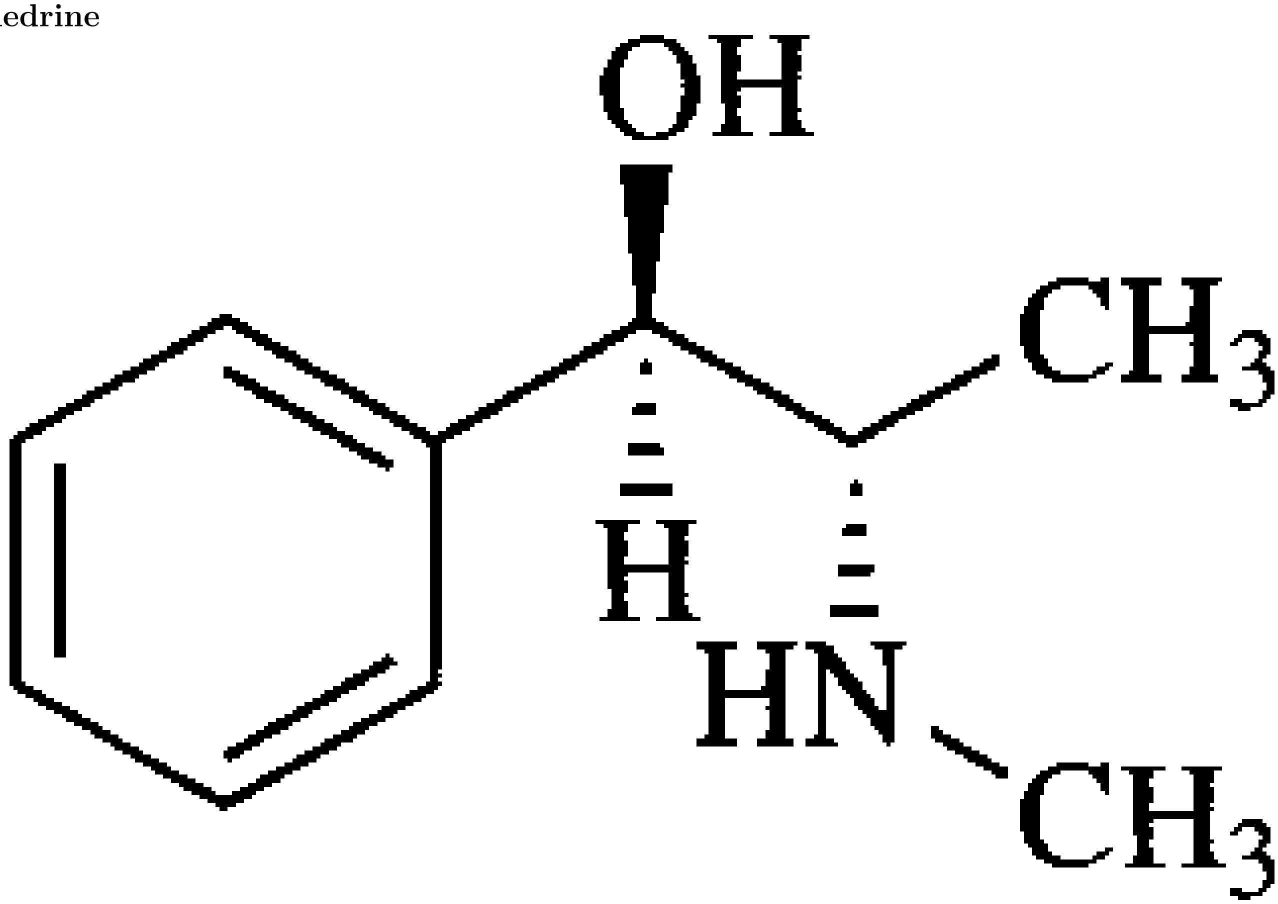
- Overproduction of mucus, the effect similar to edema
- Synthetic analogs of adrenalin (oxymetazolin etc.) are normally used

Ephedra, ma huang, *Ephedra* spp., Ephedraceae, wordwide

- Old component of TCM
- Ephedrine alkaloid has multiple effects (stimulation of CNS, decongestion etc.)
- Theophylline from tea and cocoa may be used for the same purposes

Ephedra

Ephedrine



Asthmatic conditions

- Inhalations have a positive, broncholytic effect
- Essential oils and camphor are common component of inhalations

Eucalyptus, *Eucalyptus* spp., Myrtaceae, Australia

- *Eucalypti aetheroleum*
- 1,8-cineole is a major component
- Has multiple effects like antiseptic and antispasmodic

Eucalyptus

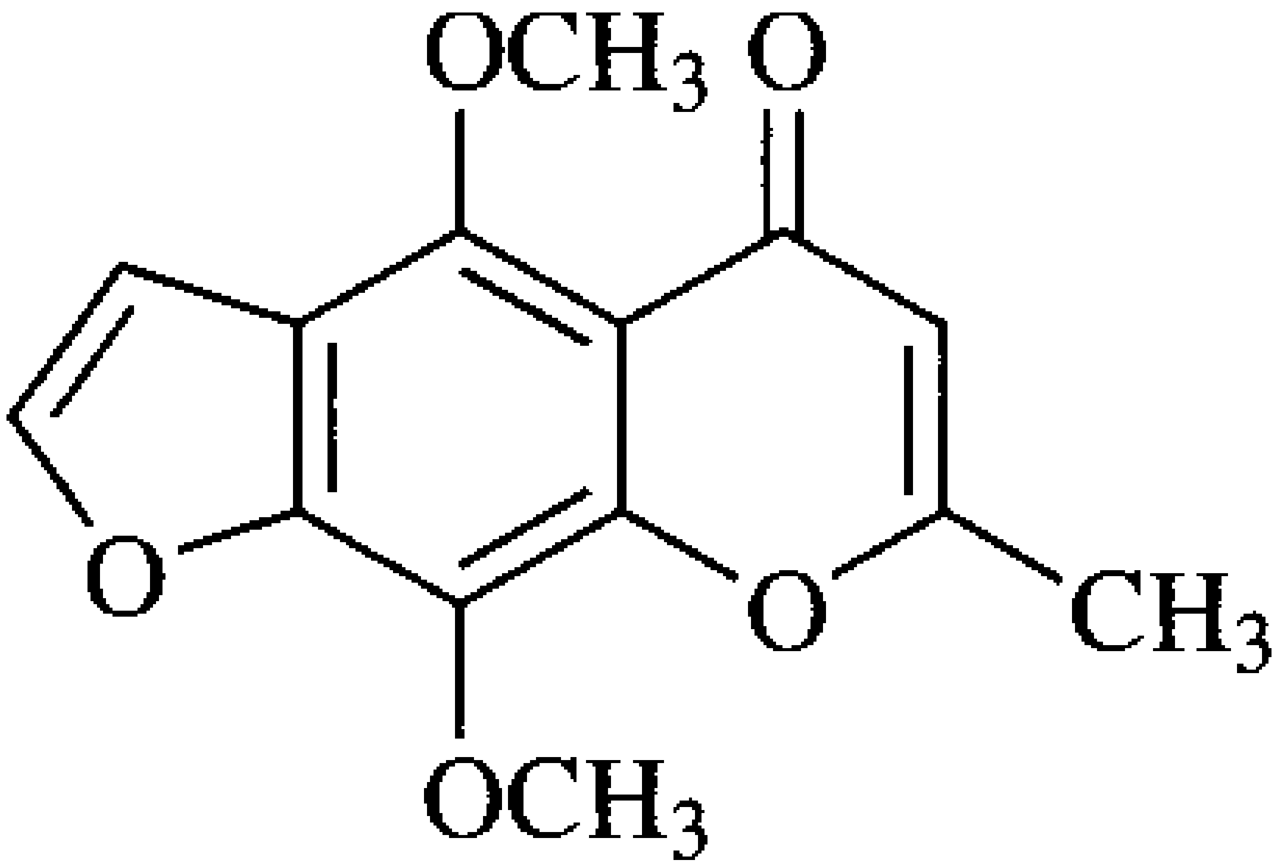
Allergy

- Mostly due to the activation of histamin receptors
- Synthetic drugs (like cetirizine etc.) have multiple side effects

Khella, *Ammi visnaga*, Umbelliferae, Mediterranean

- Active compounds are coumarins like khellin
- Have vasodilating effects, blocks calcium membrane channels

Khella



Khellin

Butterbur, *Petasites hybridus*, Compositae, Eurasia

- Sesquiterpene lactones (eremophinolides like petasin)
- Traditionally used as anti-asthmatic and against migraine, but has strong anti-histamin effect

Butterbur

Mucolytics

- Have a softening effect for cough
- Reduce viscosity of mucus

Sage, *Salvia officinalis*, Labiatae, Eurasia

- *Salviae folium*
- Contains essential oil thujone
- In addition, has a memory-stimulating and antimicrobial effects

Senega, *Polygala senega*, Polygalaceae, North America

- *Polygalae radix*
- Triterpenoid saponins: senegin
- Mucolytic and antiseptic effects

Senega

Summary

- Most of plant remedies for gastrointestinal system are symptomatic
- Most of them are terpenes or glycosides
- Heart and vessel system problems are often threatening with glycosides
- Respiratory system remedies are essential oils and alkaloids

For Further Reading

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[1] A. Shipunov. *Ethnobotany* [Electronic resource]. 2011—onwards. Mode of access: http://ashipunov.info/shipunov/school/biol_310

[2] Heinrich et al. 2012 (or 2004). *Fundamentals of Pharmacognosy and Phytotherapy*. Churchill Livingstone, Edinburgh. Mode of access: http://ashipunov.info/shipunov/school/biol_310/heinrich2004_fund_pharm_part.pdf

Outline

34 Pharmacognosy

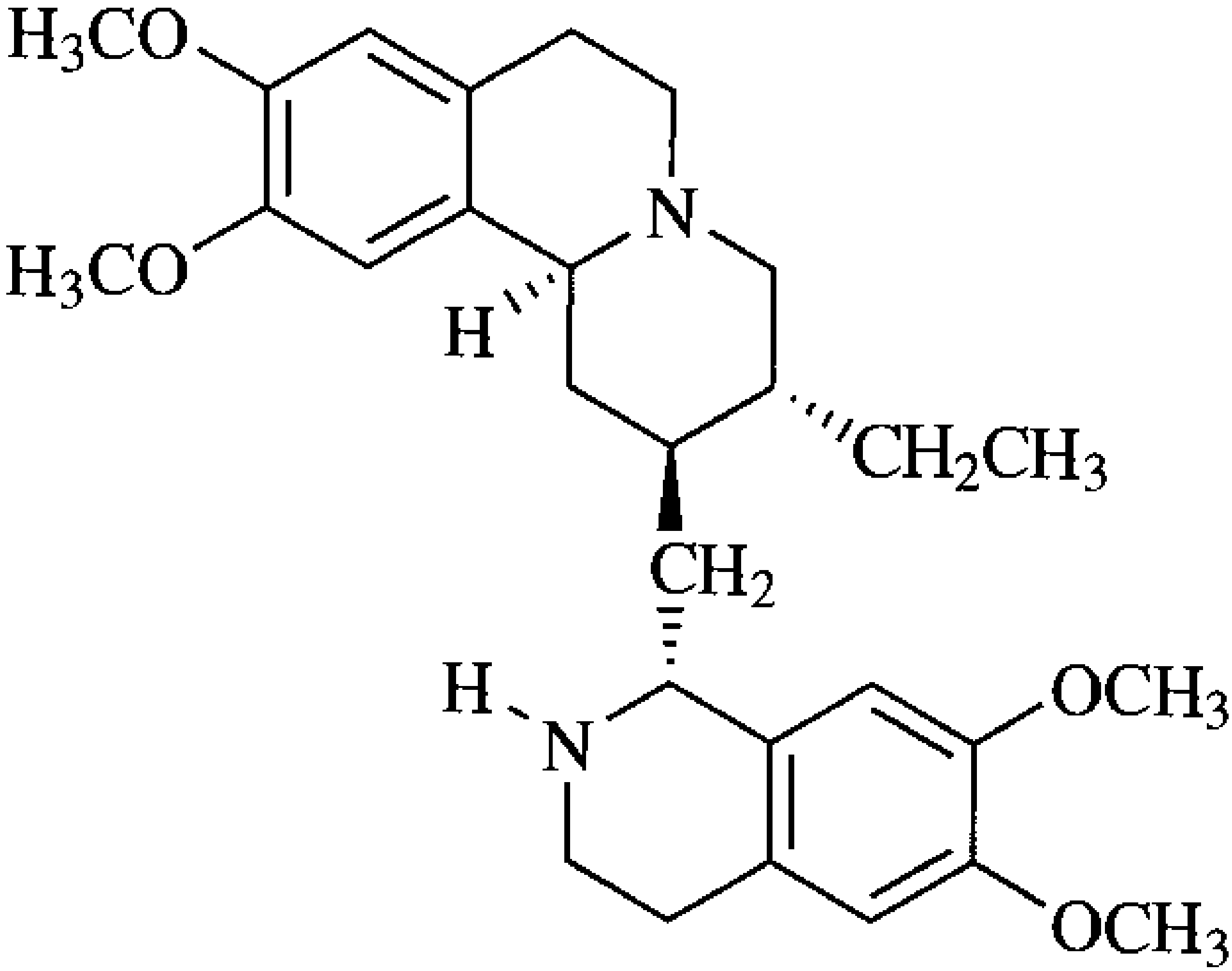
34.1 Plant remedies for respiratory system

Ipecac, *Cephaelis* (Psychotria) spp., Rubiaceae, Central America

- *Ipecacuanhae radix*
- Ioquinoline alkaloids as emetine
- Has both mucolytic and emetic effects (frequently used as anti-toxic)

Ipecac

Emetine



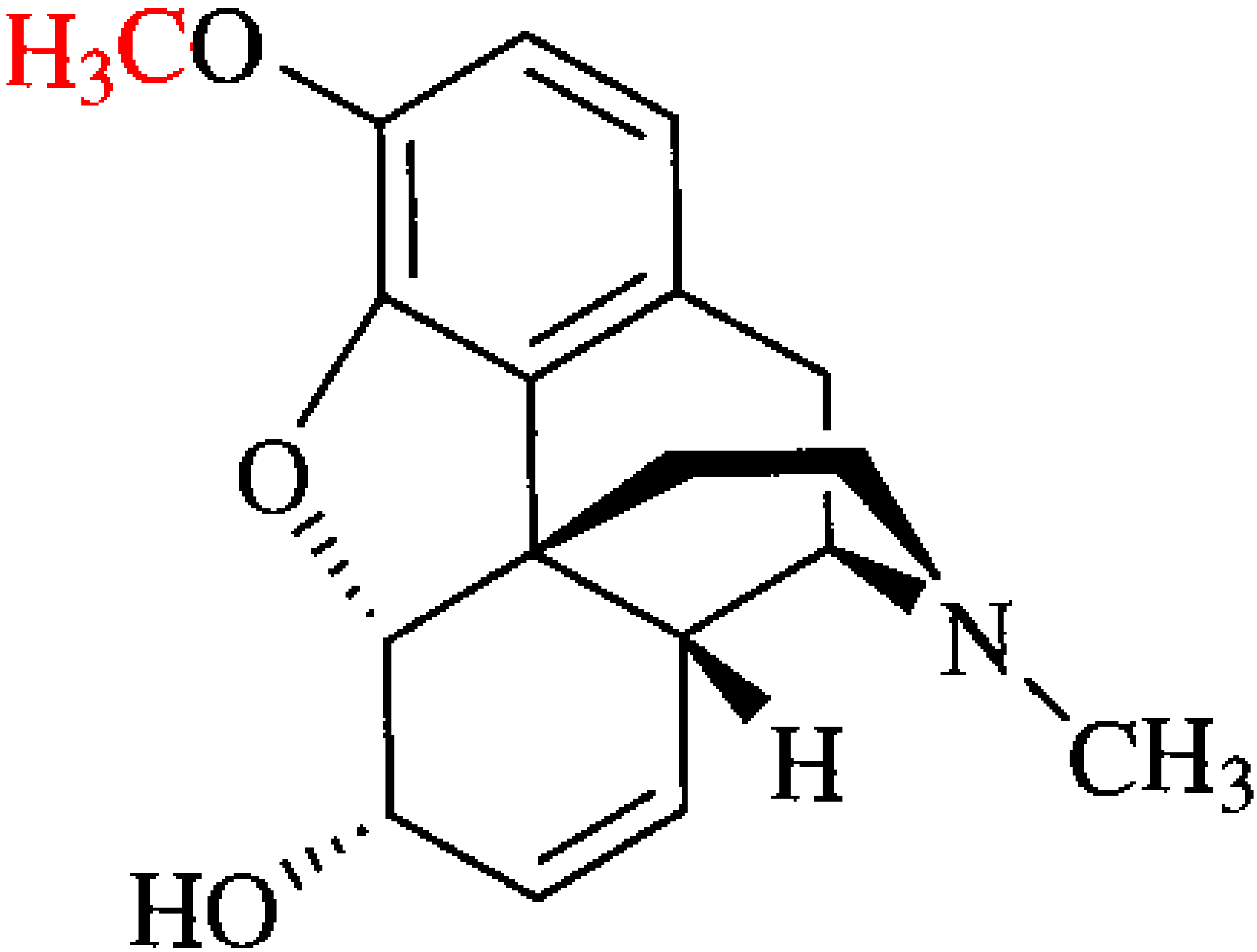
Cough

- Normally a symptom of other diseases
- Suppression of brain nervous centers will reduce the cough

Opium poppy, *Papaver somniferum*, Papaveraceae, Asia

- Contain alkaloids codeine and morphine
- Codeine is toxic in large doses because of respiratory depression effect
- Morphine causes strong addiction and painful withdrawal syndrome
- Opioids mimic endogenous opioids: endorphins, enkephalins, dynorphins neurotransmitters

Codeine and morphine

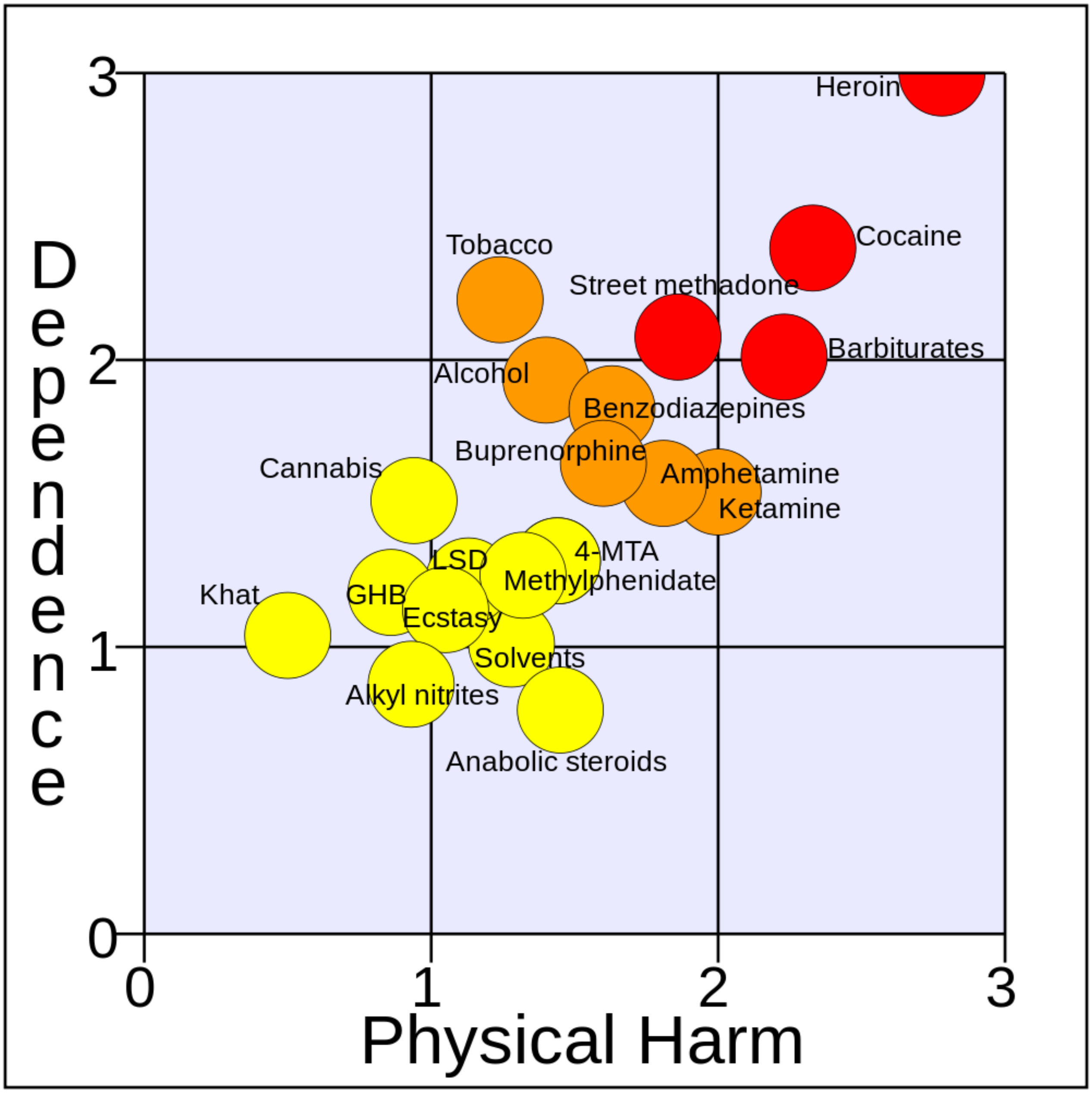


34.2 Plant remedies for nervous system; stimulants

Stimulants and narcotics

- Most of them substitute natural synaptic neurotransmitters
- Withdrawal syndrome is due to flexibility of our biosynthesis

From Nutt et al. (2007) in "Lancet"

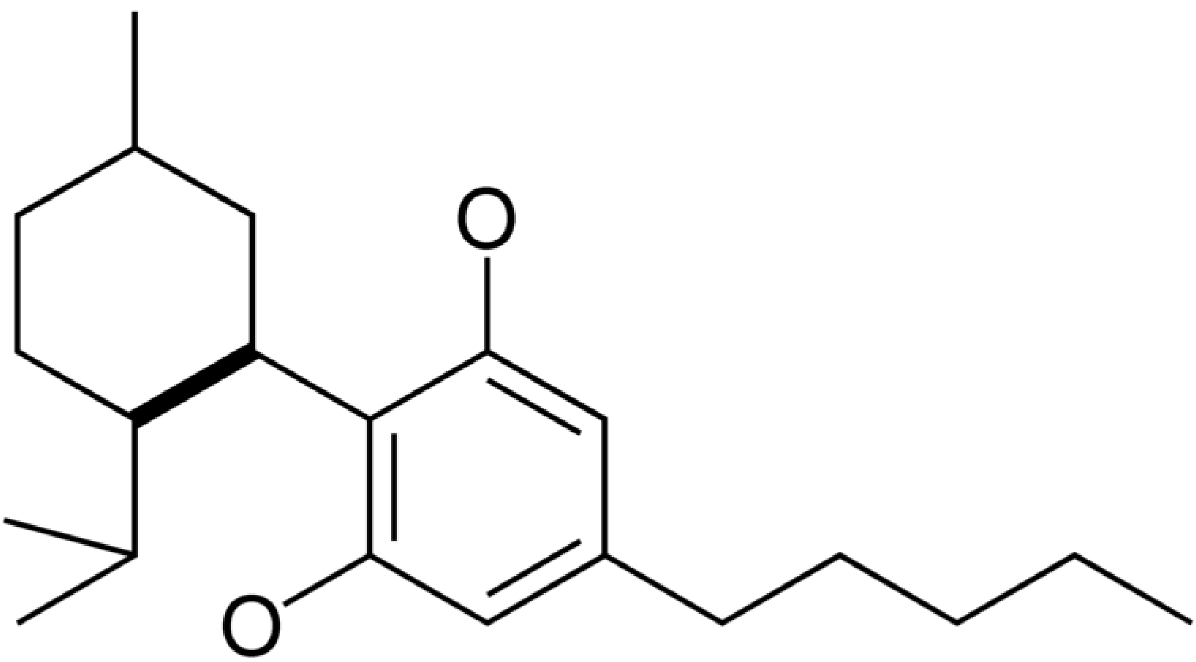


Cannabis, *Cannabis sativa*, Cannabaceae, South Asia

- Annual or perennial herb
- Leaves contain unique family of terpeno-phenolic compounds called cannabinoids (some psychoactive like THC, tetrahydrocannabinol; some are not like CBD, cannabidiols)
- THC is known to activate protein-coupled cannabinoid receptors 1 and 2 (CB_1, CB_2)
- Cannabinoids mimic endocannabinoids which acts as retro-neurotransmitters which go backward in synapse and terminate release of "normal" neurotransmitters

Cannabis

CBD, cannabidiol

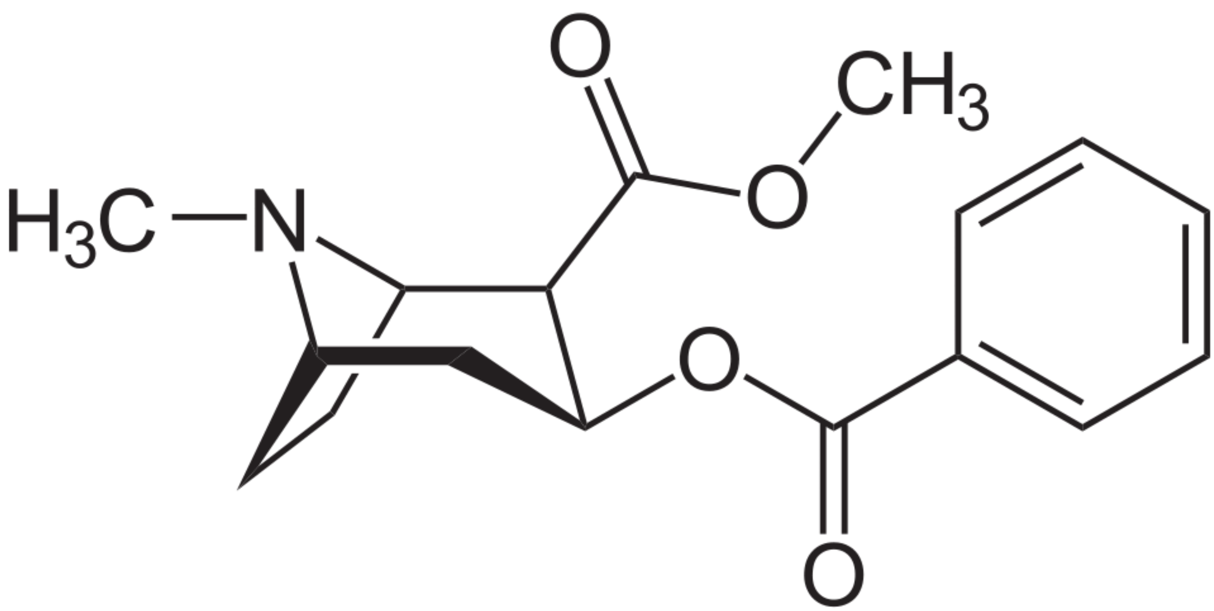


Coca, *Erythroxylon coca*, Erythroxylaceae, South America

- Andean evergreen shrub
- Contains cocaine, anesthetic and strong stimulant narcotic
- Cocaine blocks the dopamine transporter protein

Coca

Cocaine

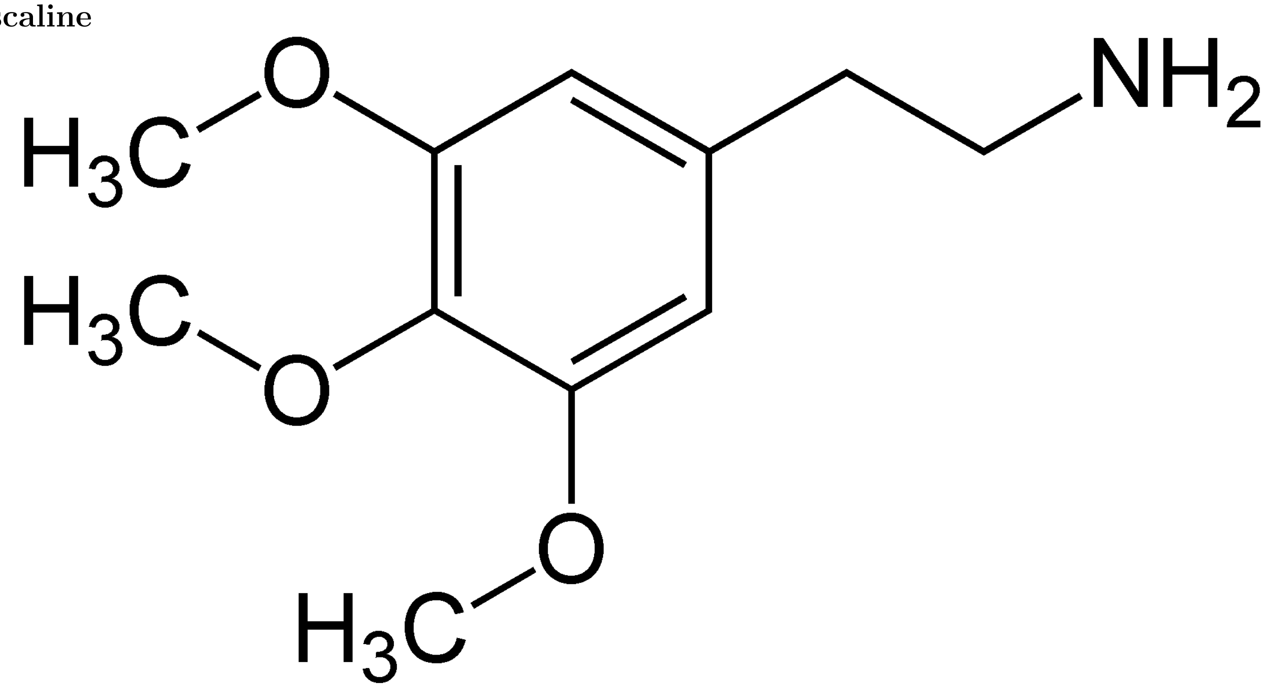


Peyote cactus, *Lophophora williamsii*, Cactaceae, Mexico

- Cactus plant containing mescaline, LSD/psilocybin group hallucinogen narcotic
- Agonist of serotonin 5-HT2A receptor

Lophophora

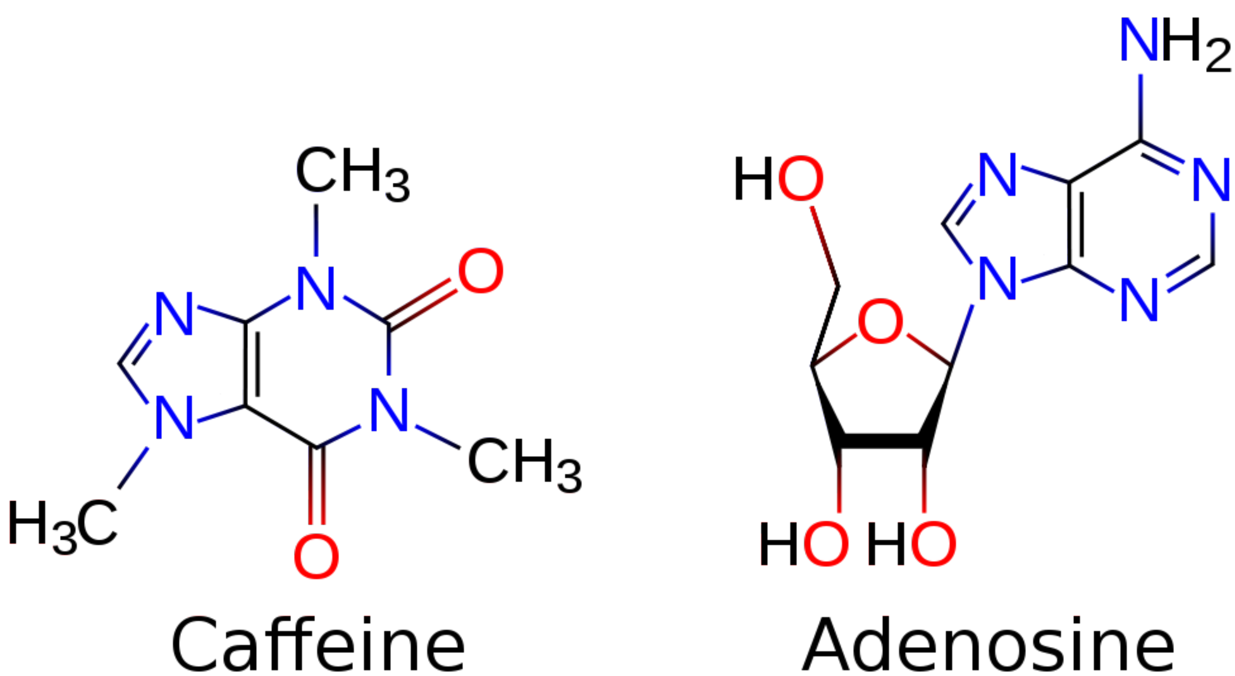
Mescaline



Cola, *Cola acuminata*, Malvaceae, West Africa

- *Colae semen*
- Tropical tree, seeds contain caffeine and kolanins
- Caffeine is antagonist of adenosine inhibitory receptors and natural insecticide

Cola



Caffeinated spiders make wrong webs

Tea, *Camellia sinensis*, Theaceae, East Asia

- Small evergreen shrub
- Native to China, cultivated there from 2500 BC

Tea

Tea facts

- Young leaves and buds are mostly used
- There are fermented (black, pu-ehr, up to 3% of caffeine!) and non-fermented (green) teas
- All contain caffeine and small amounts of theobromine and theophylline

Coffee, *Coffea arabica*, Rubiaceae, East Africa

- Small evergreen tree with regular growth
- Native to Ethiopia, was a local Yemen culture until XVIII century

Coffee

Coffee facts

- Seeds contain up to 2.5% of caffeine
- Most of aromatic compounds (caffeol) are activated when frying

Cocoa, *Theobroma cacao*, Malvaceae, South America

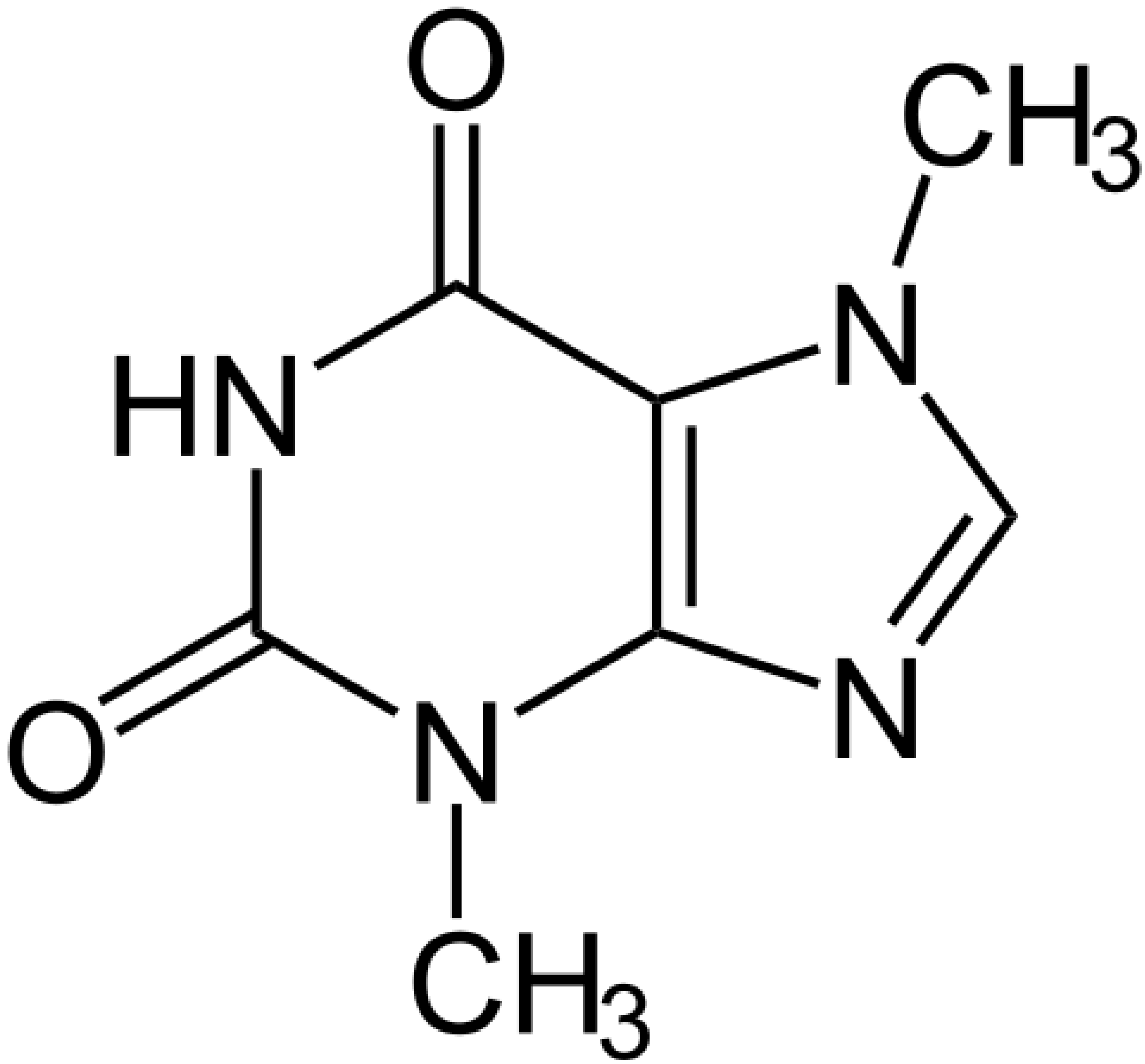
- Evergreen small tree with cauliflory
- Cocoa beans are large fruits which go to cocoa, chocolate and oil production

Cocoa

Cocoa facts

- Fermented and fried seeds contain 2% of theobromine
- Phosphodiesterase inhibitor which raises intracellular cAMP
- 43% of world cocoa come from Côte d'Ivoire

Theobromine



Yerba mate, *Ilex paraguariensis*, Aquifoliaceae, South America

- Evergreen shrub from semi-deserts of South America
- Leaves contain up to 2% of caffeine
- Anti-cancer and cancer effects were both stated

Mate

Yerba mate

Guarana, *Paullinia cupana*, Sapindaceae, South America

- Tropical shrub with pinnate leaves; seed powder is used as a drink
- Extremely high in caffeine (up to 6%), actually caffeine old name was "guaranine"

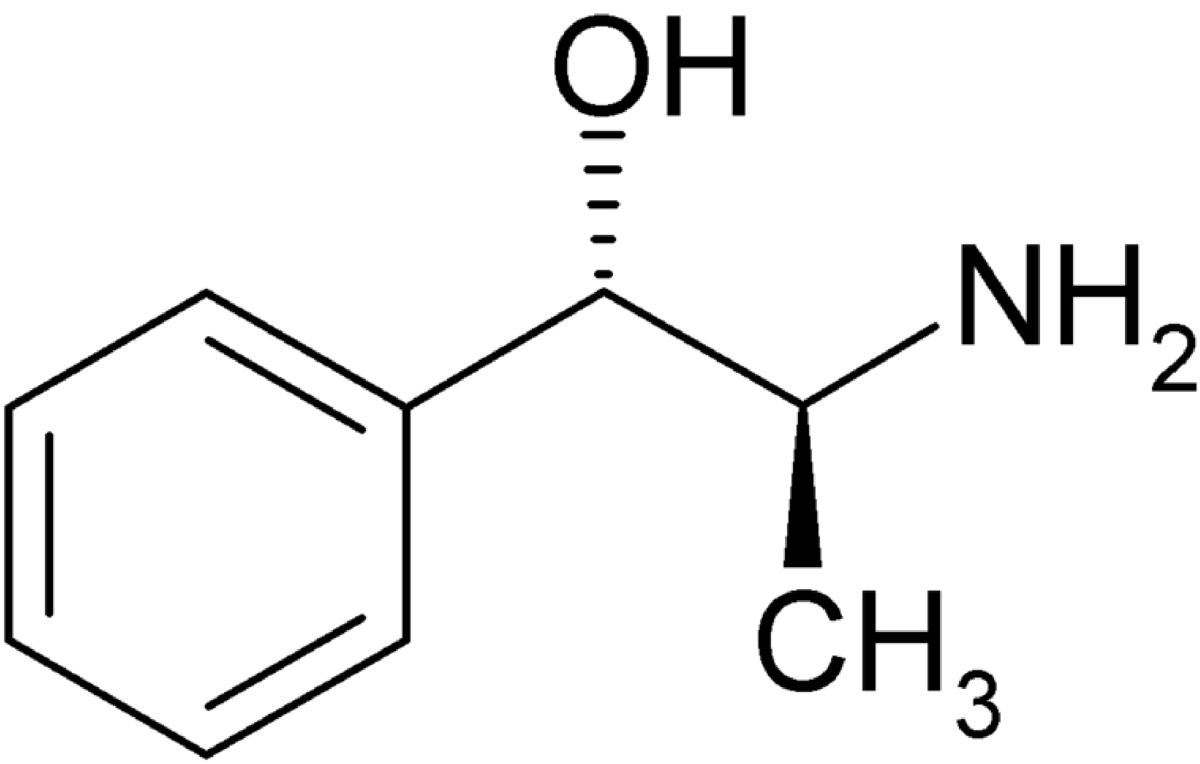
Guarana

Khat, *Catha edulis*, Celastraceae, East Africa

- Evergreen shrub ecologically similar to coffee
- Leaves contain cathine (pseudonorephedrine), agonist of noardrenaline receptors, which mild psychoactive effects

Khat

Cathine



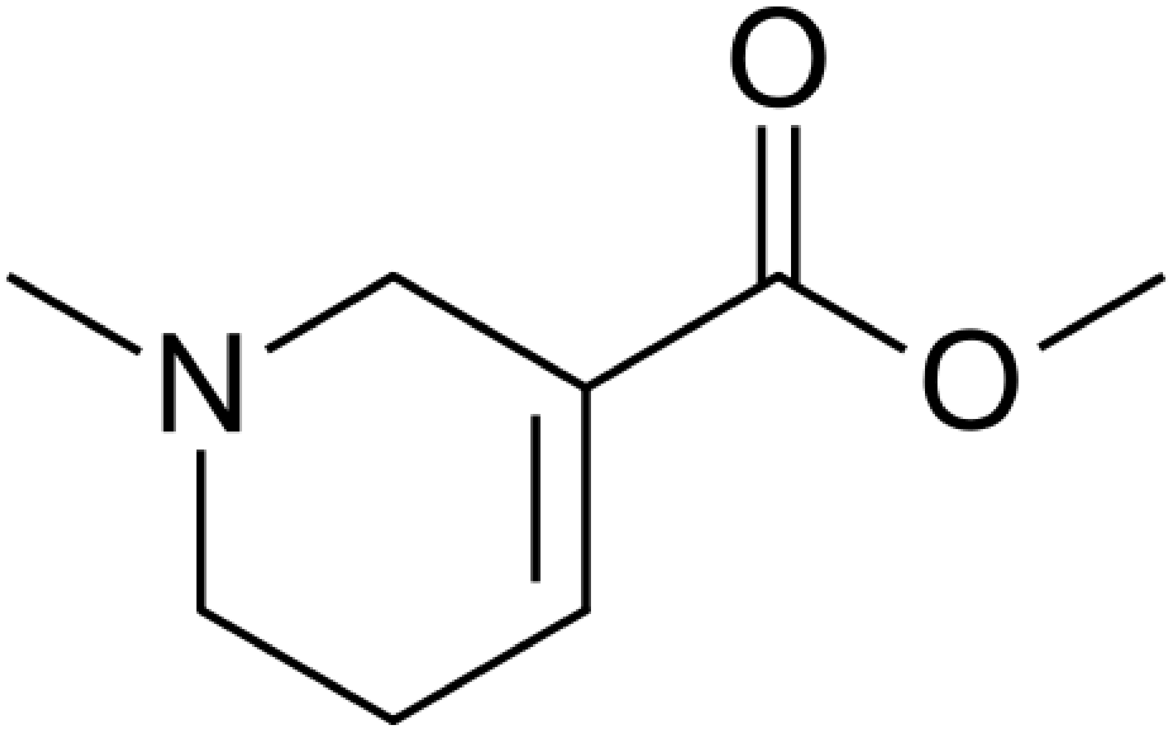
Areca nut, *Areca catechu*, Palmae, Southeast Asia

- Nuts are chewed with betle pepper (*Piper betle*, Piperaceae) leaves and slaked lime ($Ca(OH)_2$)

- Chemical reaction will free arecoline alkaloid (similar to nicotine), agonist of acetylcholine receptors

Areca nut vendor (Hainan, China)

Arecoline



Summary

- Most of stimulants / narcotics are analogs of neurotransmitters

For Further Reading

References

[1] A. Shipunov. *Ethnobotany* [Electronic resource]. 2011—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_310`

[2] Heinrich et al. 2012 (or 2004). *Fundamentals of Pharmacognosy and Phytotherapy.* Churchill Livingstone, Edinburgh. Mode of access: `http://ashipunov.info/shipunov/school/biol_310/heinrich2004_fund_pharm_part.pdf`

Outline

35 Pharmacognosy

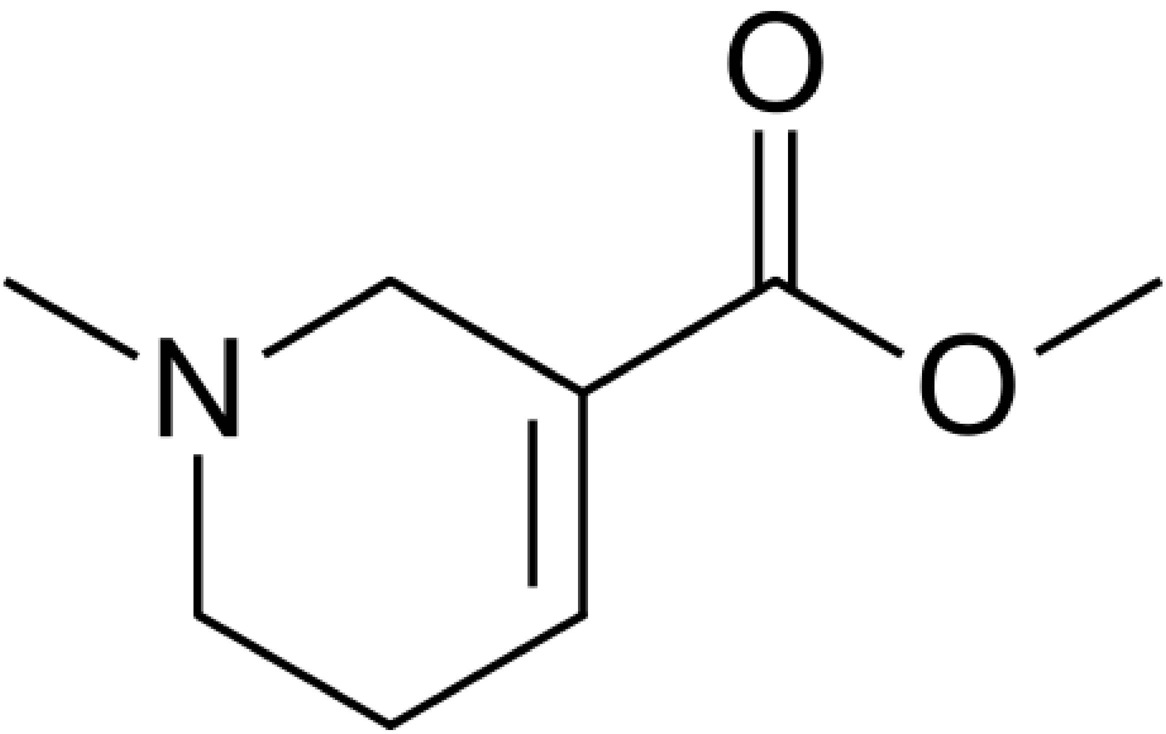
35.1 Plant remedies for nervous system; stimulants

Areca nut, *Areca catechu*, Palmae, Southeast Asia

- Nuts are chewed with betle pepper (*Piper betle*, Piperaceae) leaves and slaked lime ($Ca(OH)_2$)
- Chemical reaction will free arecoline alkaloid (similar to nicotine), agonist of acetylcholine receptors

Areca nut vendor (Hainan, China)

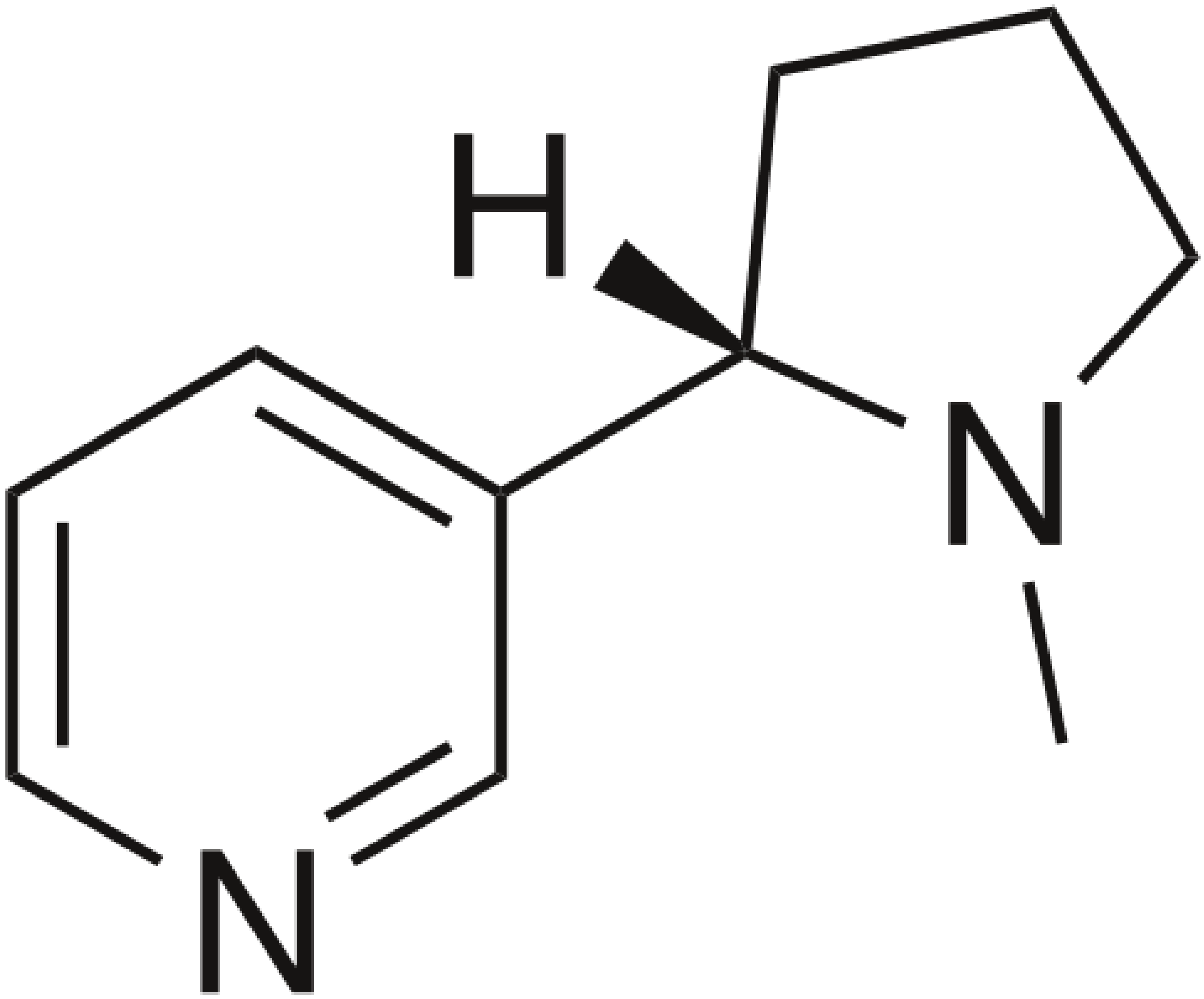
Arecoline



Tobacco, *Nicotiana tabacum*, Solanaceae, Central America

- Perennial herb with large glanduliferous leaves
- Contain alkaloid nicotine binding to acetylcholine receptors and (among other effects) increases the level of brain dopamine
- Nicotine is a also a well-known natural insecticide

Nicotine

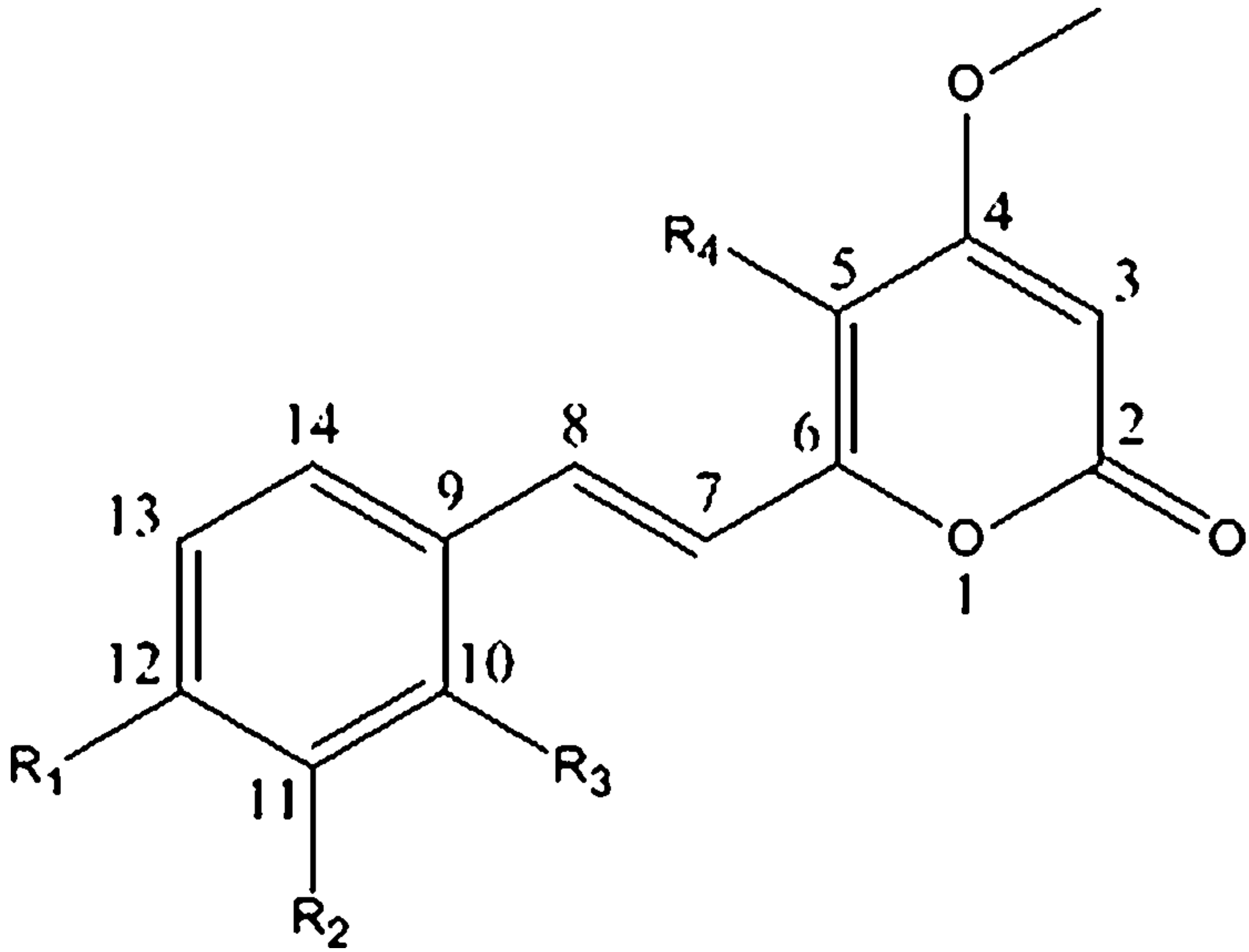


Kava, *Piper methysticum*, Piperaceae, Pacific

- Small shrub, roots are used to prepare sedative drink
- Active components are kavactones, stimulate inhibitory γ-aminobutyric GABA receptors

Kava

Kavactone



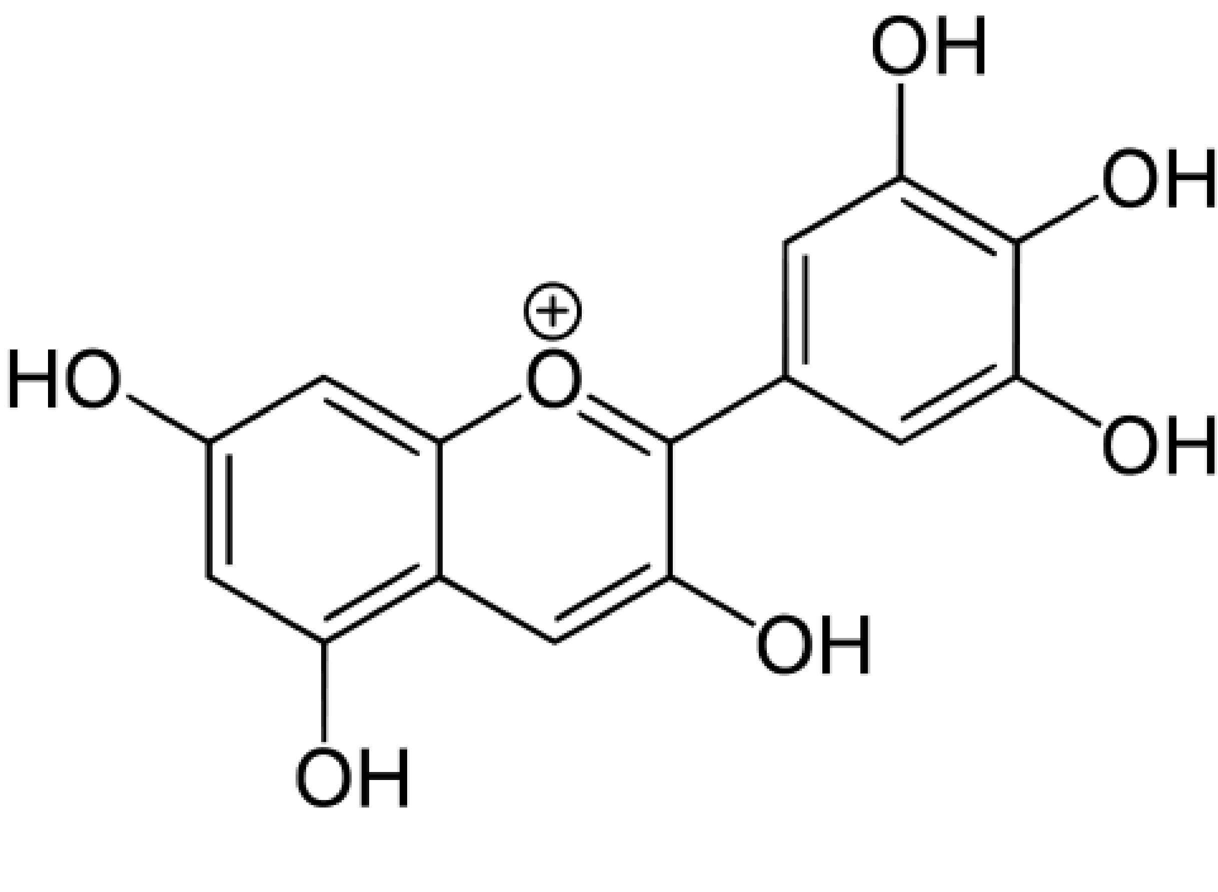
35.2 Other "teas"

Hibiscus tea, *Hibiscus sabdariffa*, Malvaceae, Mediterranean

- Flower calyces (sepals) are dried and boiled
- Contain flavonoids (e.g., anthocyanin deplhinidin) and organic acids with multiple medicinal effects, e.g., lowering blood pressure

Hibiscus tea plant

Delphinidin anthocyanide



Rooibos tea, *Aspalathus linearis*, Leguminosae, South Africa

- Small shrub of Cape province
- Leaves contain high level of antioxidants such as aspalathin and nothofagin, fermented similarly to tea or yerba mate

Rooibos

Boldo, *Peumus boldus*, Monimiaceae, South America

- Andean evergreen shrub
- Contains alkaloid boldine and multiple essential oils (e.g., with anthelmintic effect)
- Used as a tea in many South American countries, typically mixed with mate

35.3 Sedatives

Sedatives

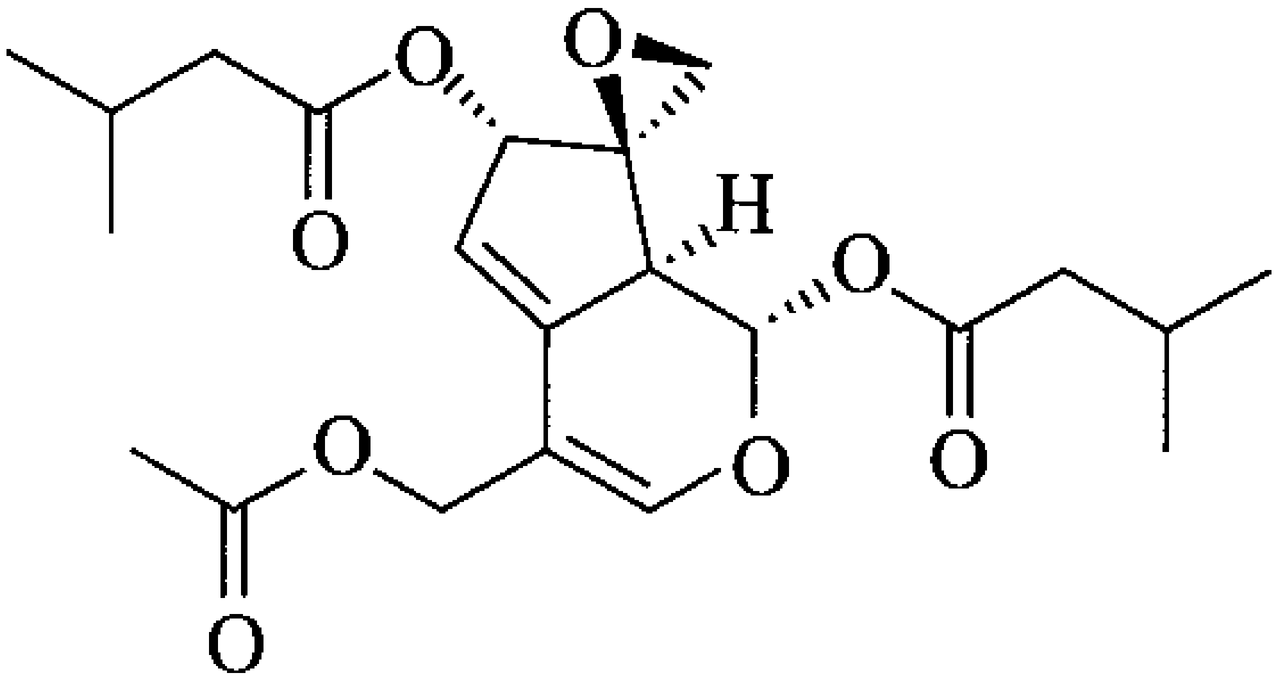
- Are often calling "hypnotics", difference is mainly in a dose
- Plant sedatives are much safer than synthetic

Valerian, *Valeriana officinalis*, Caprifoliaceae, Eurasia

- *Valerianae radix*
- Active components are valerian oils and iridoids valepotriates
- Interact with GABA receptors

Valerian

Valtrate valepotriate



Hops, *Humulus lupulus*, Cannabaceae, Eurasia

- *Lupuli flos*
- Active components are unusual organic acids humulone and lupulone and their derivatives
- Helps to normalize sleep, also have antibacterial effects

Hops (female inflorescences)

Lemon balm, *Melissa officinalis*, Labiatae, Eurasia

- *Melissae folium*
- Active components are multi-component volatile oils including aldehydes
- Improve nervous disorders and also gastrointestinal problems; has antibacterial effects

Melissa

Red passion flower, *Passiflora incarnata*, Passifloraceae, South America

- Dried leaves are used pharmaceutically
- Active components suspected to be flavonoids
- As effective as oxazepam (serax) in treating nervous disorders (e.g., hysteria)

Mandrake, *Mandragora officinarum*, Solanaceae, Central Asia

- Dried root contains atropine, scopolamine, hyoscyamine and podophyllin: all alkaloids
- Poisonous and hallucinogenic in large doses, hypnotic/sedative in small doses

Mandrake, from Tacuinum Sanitatis (1474)

Mandrake

Mandrake roots

35.4 Antidepressants

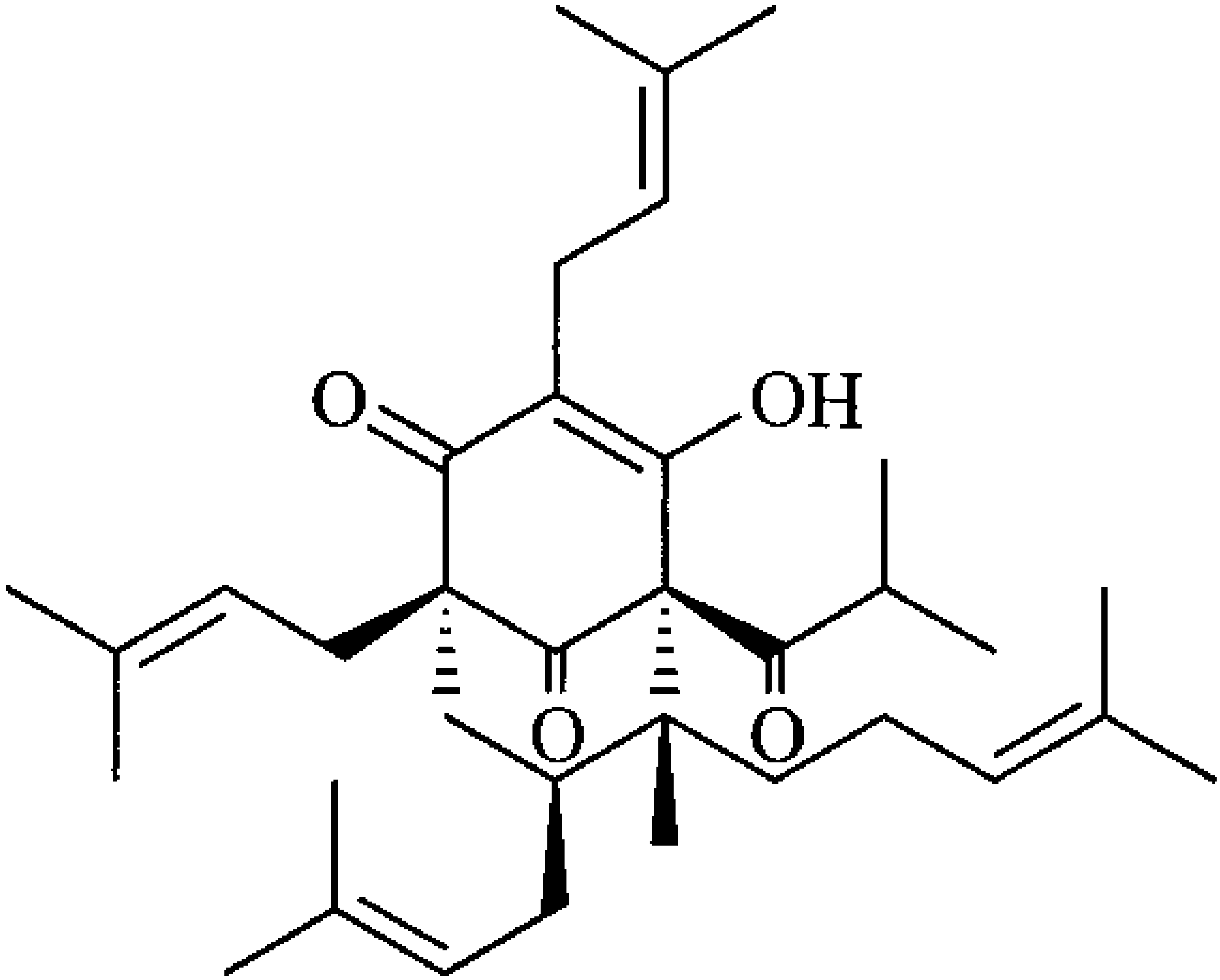
Antidepressants

- "Nerve tonics"
- Plants with anti-depressant activity are rare

St. John's wort, *Hypericum perforatum*, Hypericaceae, Eurasia

- *Hyperici herba*
- Hyperforin (derivative of terpenes) is the most active component
- Inhibition of synaptic uptake of several neurotransmitters: serotonin, dopamin, GABA etc.

Hyperforin



Hypericum perforatum

35.5 Analgesics

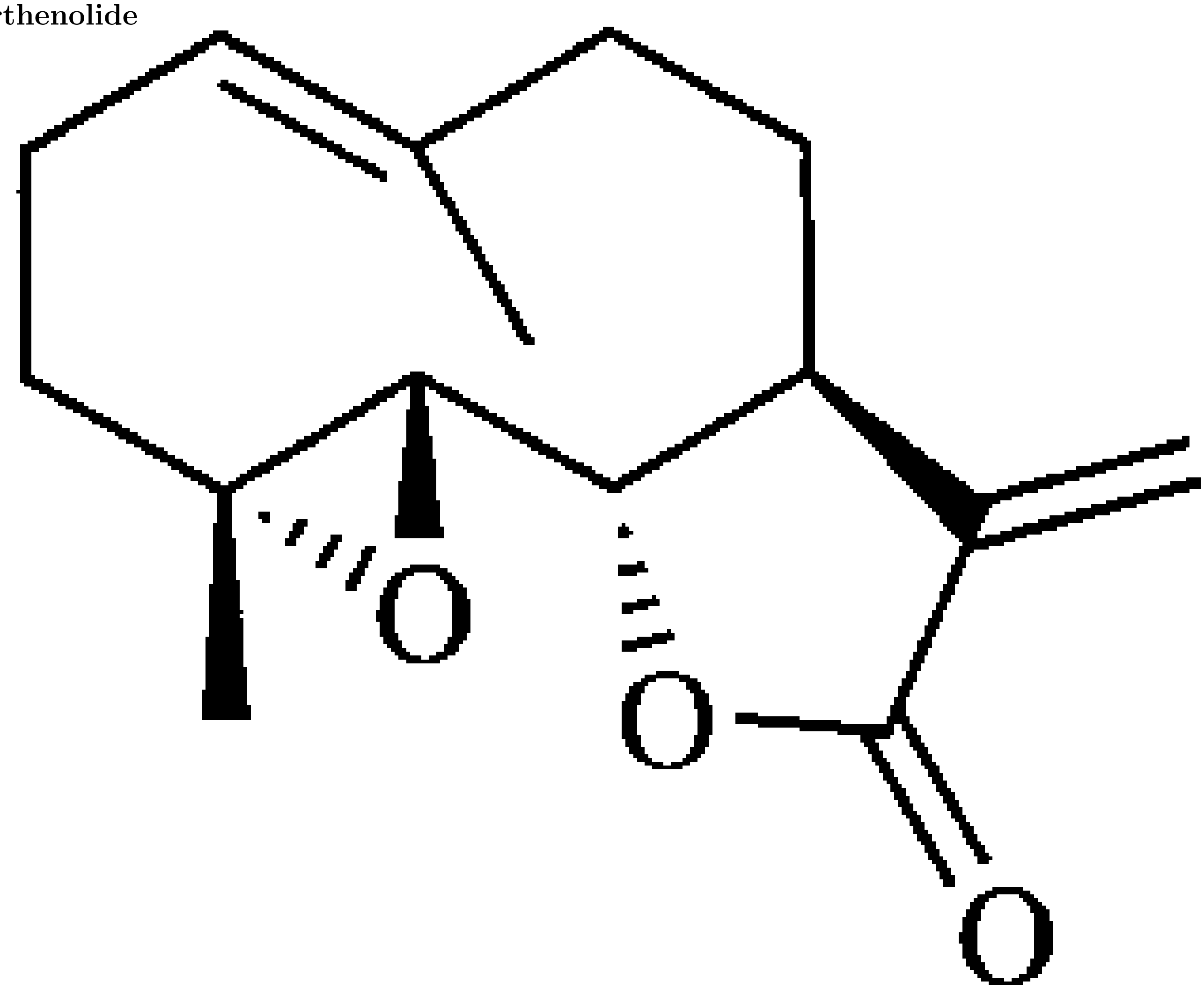
Analgesics

- Cocaine and morphines are sometimes used as analgesics
- Aspirin-related anti-inflammatory drugs will be covered later

Feverfew, *Tanacetum parthenicum*, Compositae, Eurasia

- *Tanaceti parthenii herba*
- Sesquiterpene lactones like parthenolide are responsible for the activity
- Suppress prostaglandine production

Parthenolide



Feverfew

35.6 Memory enhancement

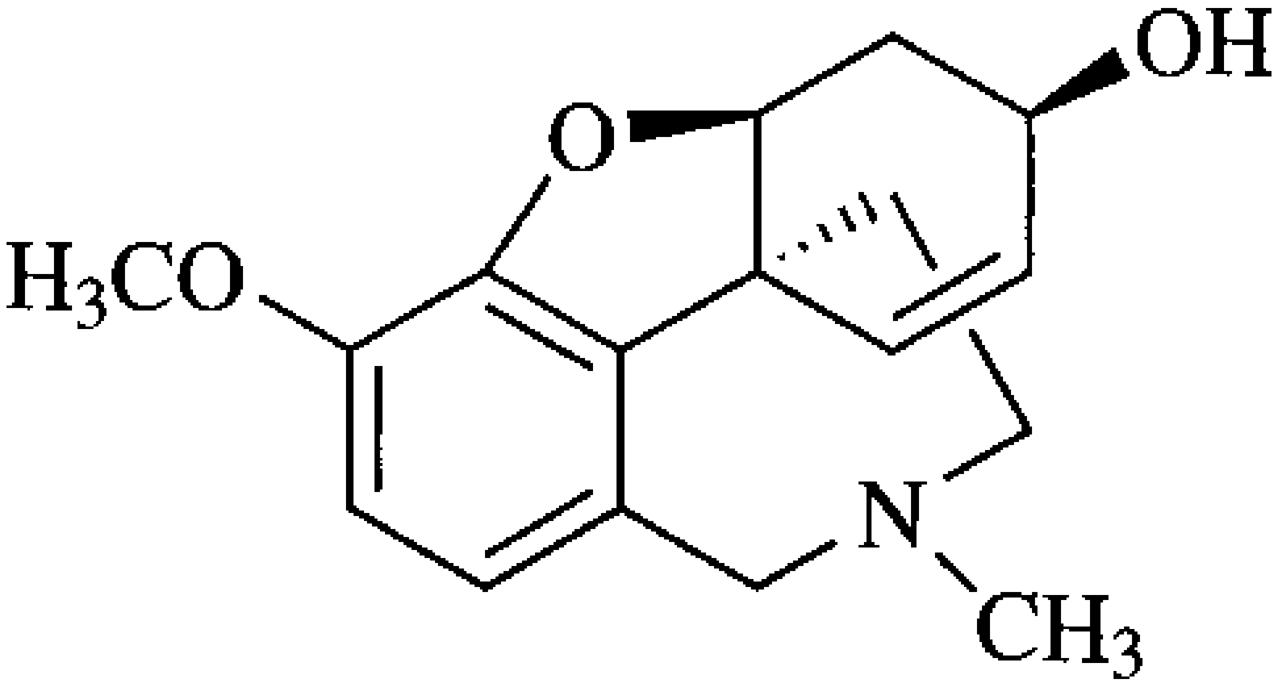
Memory enhancement

- Especially important in case of Altzheimer's disease (dementia)
- Often are inhibitors of acetylholinesterase

Snowdrop, *Galanthus nivalis*, Amaryllidaceae, Mediterranean

- Contains alkaloid galantamine
- Slow down the progression of Altzheimer's disease

Galanthamine



Snowdrop

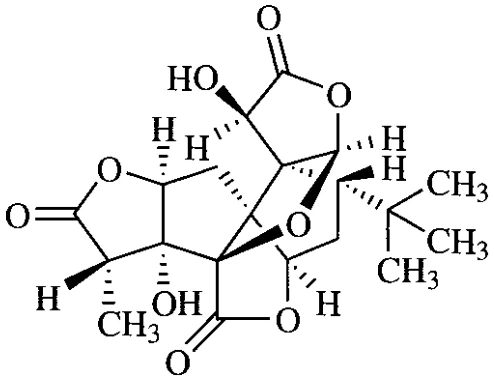
Ginkgo, *Ginkgo biloba*, Ginkgoaceae, China

- "Living fossil" from China, natural habitats are lost

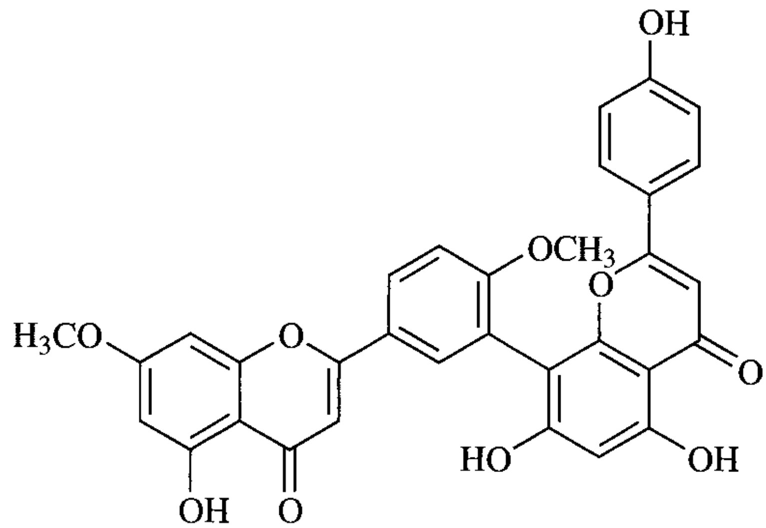
- Active components are diterpene lactones ginkgolides and glycosides such as ginkgetin
- Improve blood circulation in brain, have antioxidant effects, prevent degradation of synaptic receptors
- Also used to heal varicose veins

Ginkgo biloba

Ginkgolides and ginkgetins



Ginkgolide A



Ginkgetin

Summary

- Most of stimulants / narcotics are analogs of neurotransmitters
- Sedative and hypnotic chemicals are often non-alkaloids
- Mandrake is real!

For Further Reading

References

[1] A. Shipunov. *Ethnobotany* [Electronic resource]. 2011—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_310`

[2] Heinrich et al. 2012 (or 2004). *Fundamentals of Pharmacognosy and Phytotherapy.* Churchill Livingstone, Edinburgh. Mode of access: `http://ashipunov.info/shipunov/school/biol_310/heinrich2004_fund_pharm_part.pdf`

Outline

36 Pharmacognosy

36.1 Plant remedies for infectious and parasitic diseases

Antiprotozoal and antihelminth drugs

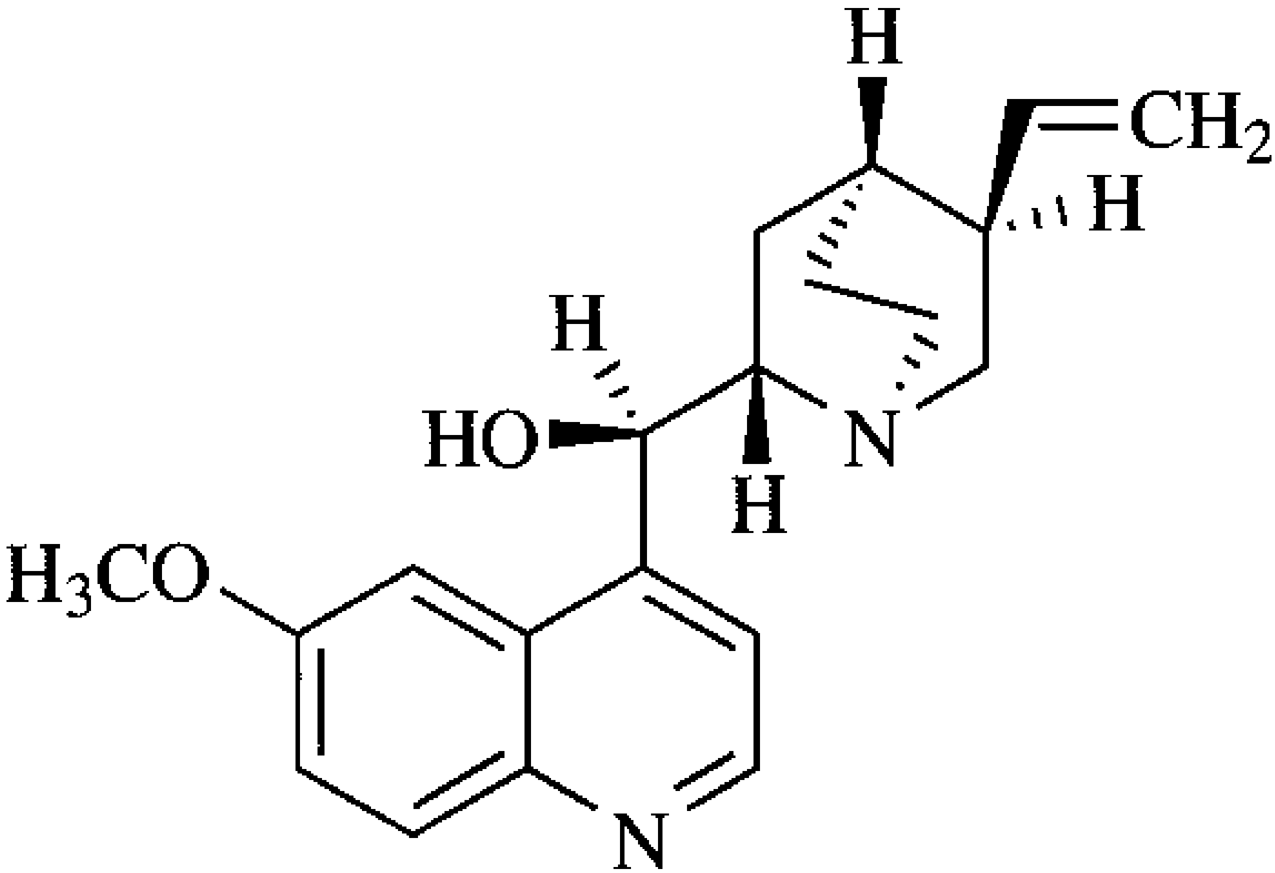
- Most of these diseases are restricted to tropics
- Sometimes, control on the transmission is much more effective than any treatments

Cinchona, *Cinhona* spp., Rubiaceae, South America

- *Cinchonae cortex*
- Quinoline alkaloids, such as quinine toxic to malarian parasite but in large doses also to humans
- Extremely bitter

Cinchona

Quinine

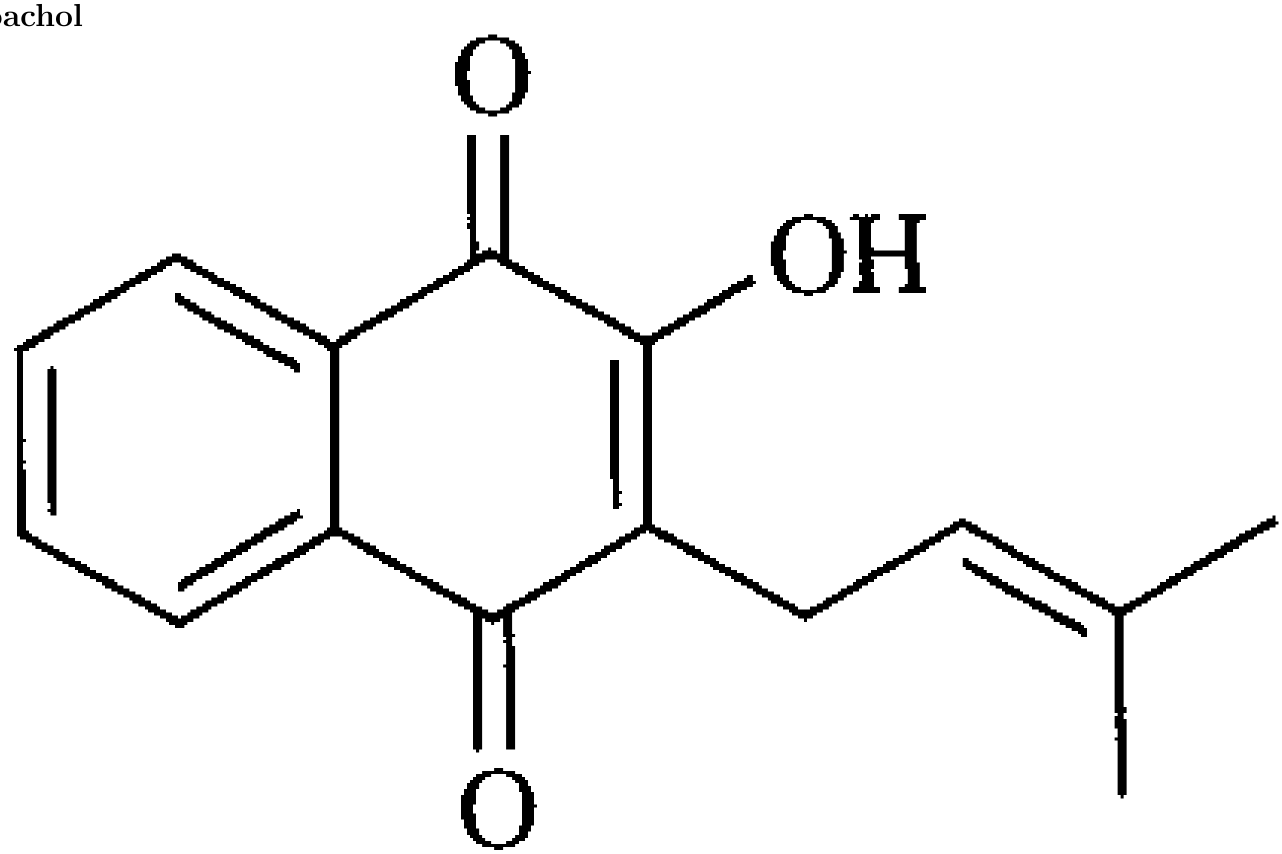


Lapacho, *Tabebuia* spp., Bignoniaceae, South America

- Large tropical trees, inner bark is used
- Napthoquinones, especially lapachol are active against multiple protozoan diseases and even cancers; cytotoxic in big doses

Tabebuia

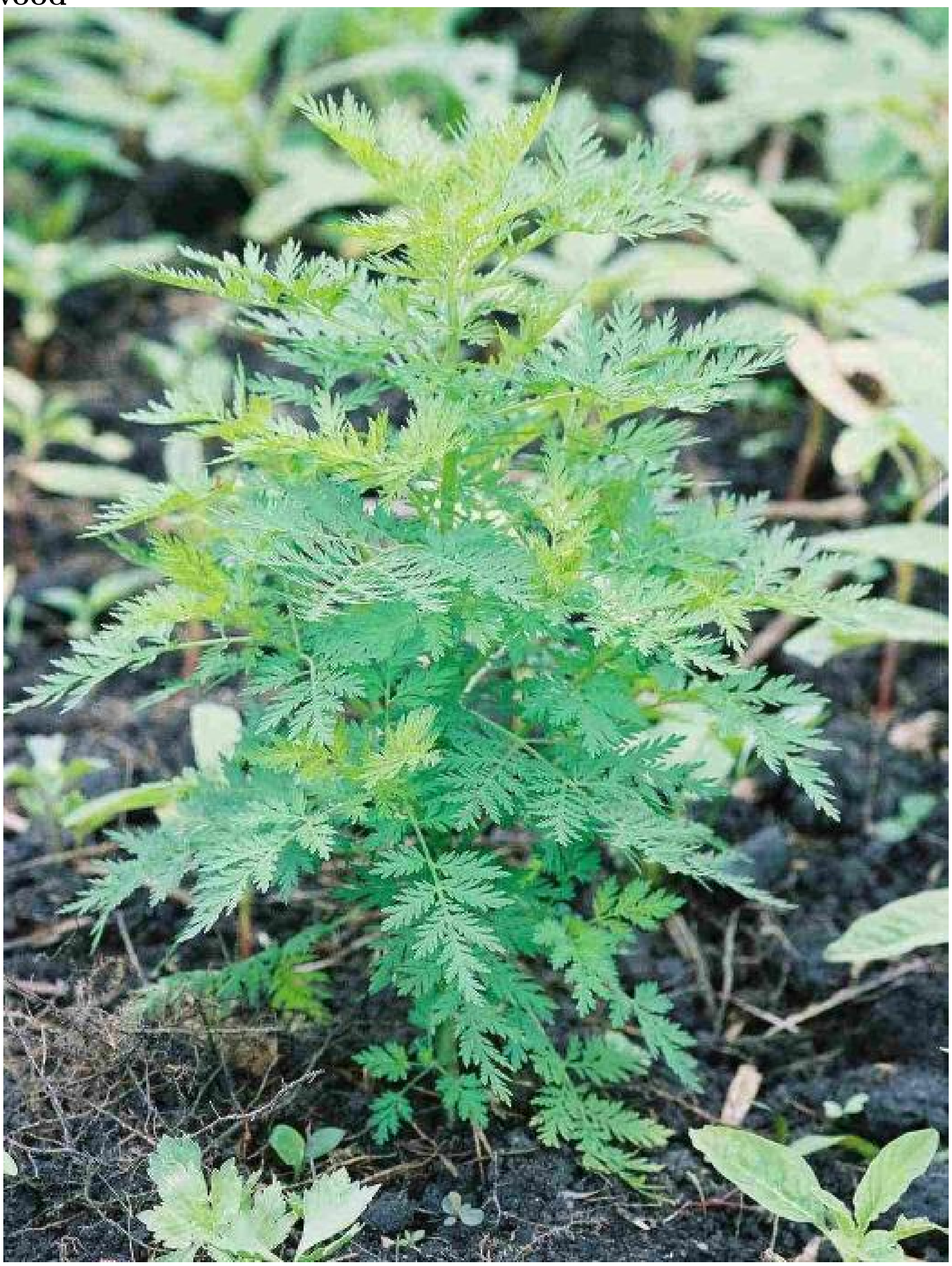
Lapachol



Sweet wormwood, *Artemisia annua*, Compositae, China

- Small annual herb, leaves and stems are used
- Sesquiterpenes like artemisinin are active against malarian parasite, *Plasmodium*
- Non-toxic (!)

Sweet wormwood



Moringa, *Moringa oleifera*, Moringaceae, South Asia

- Large tropical tree with edible leaves and oil-containing seeds
- Contains multiple active compounds like alkaloid spirochin with antibacterial and antihelminth effects

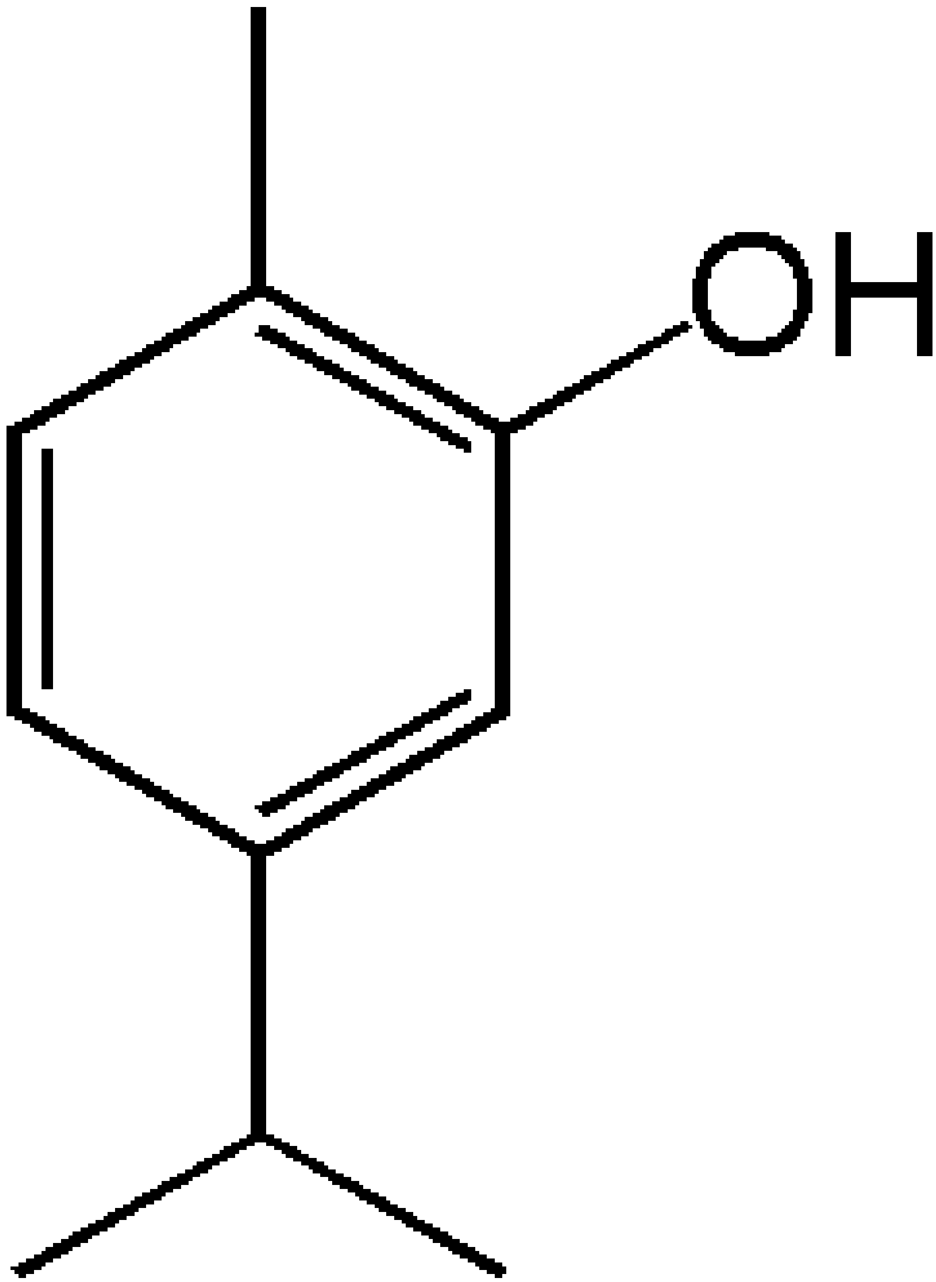
Moringa

Wild bergamot, *Monarda fistulosa*, Labiatae, North America

- Prairie herb with large clusters of flowers
- Contains rich set of essential oils: thymol, pinene, carvacrol, antibacterial and antihelminth

Wild bergamot

Carvacrol



Antiviral, antibacterial and antifungal agents

- Unlike antibiotics, have a broad spectrum of activity
- Most of them can be taken in form of herbal teas (like balm tea from *Melissa*)

Garlic, *Allium sativum*, Amaryllidaceae, Eurasia

- (Covered previously)
- Contains allicin, and different diallyls

Tea tree, *Melaleuca alternifolia*, Myrtaceae, Australia

- *Melaleucae atheroleum*
- Medium-sized tree from north-west coast of Australia
- Oils (in form of tea) are widely used as antiseptics: contain cineole and other essential oil monoterpenes

Melaleuca, tea tree

Urinary tract infections (cystitis)

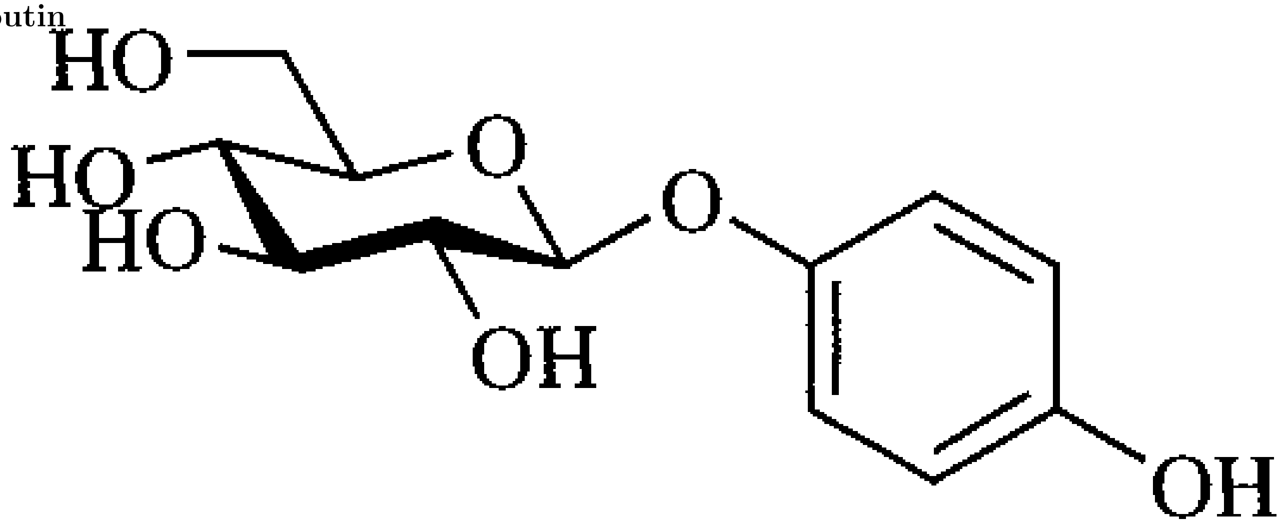
- Majority of women have some form of this infection
- Plant remedies are often work better because they do not have side effects (however, they are not recommended to patients with blood problems)

Bearberry, *Arctostaphylos uva-ursi*, Ericaceae, North Hemisphere

- *Uvae ursi folium*
- Small prostrate evergreen shrub
- Traditionaly used in cystitis; glycoside arbutin and its derivatives have stable antimicrobial activity

Bearberry

Arbutin



Cranberry, *Vaccinium macrocarpon*, Ericaceae, North America

- Minuscule shrub from bogs and coasts
- Contains anthocyanins which are suspected to be active compounds: cranberry juice suppresses urinary infections

Insecticidal agents

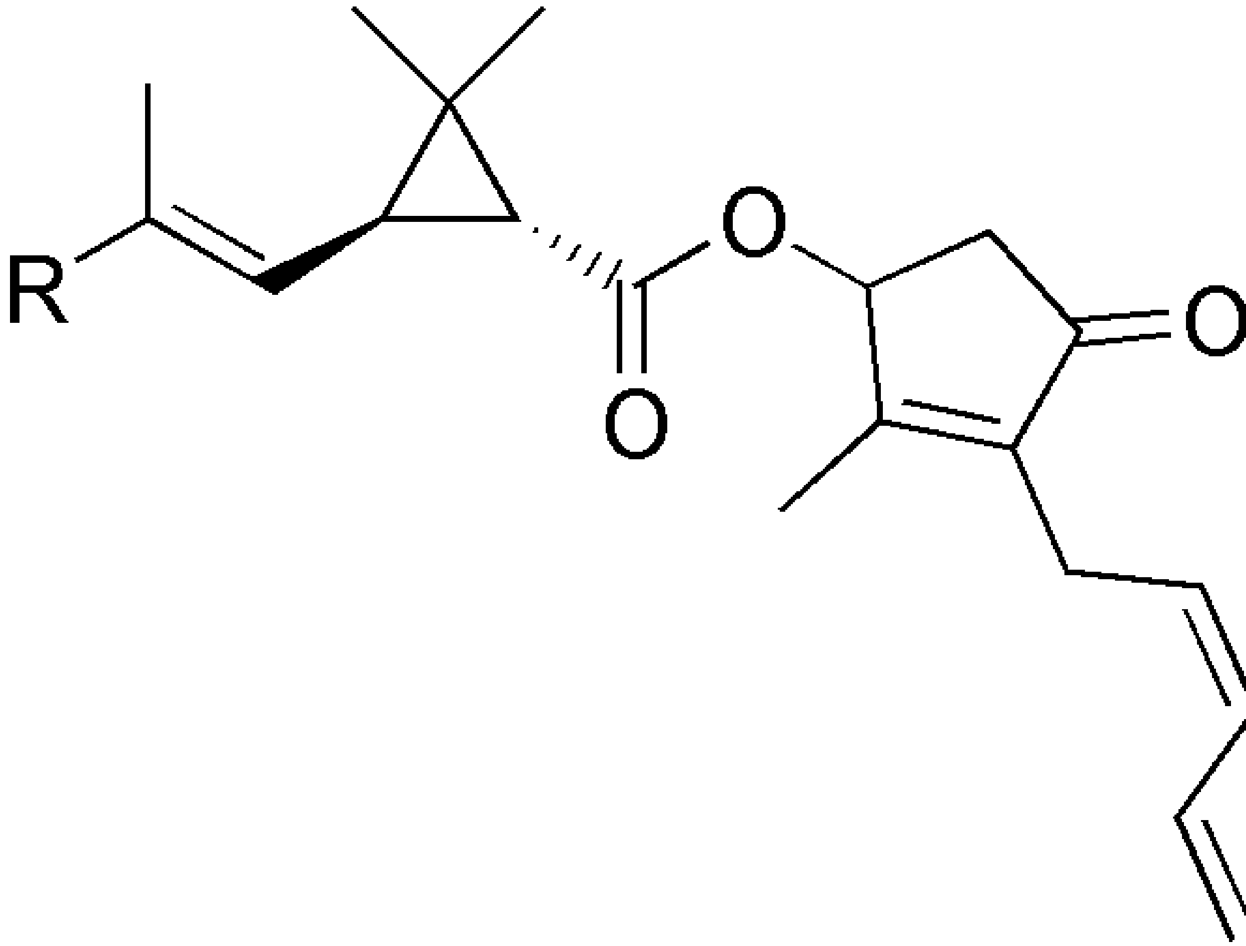
- Most derived from terpenoids and essential oils
- Alkaloids like veratridine (from *Veratrum* spp.) were used in the past but now abandoned due to toxicity

Pyrethrum, *Chrysanthemum/Tanacetum* spp., Compositae, North America

- Multiple herb species, all contain pyrethrin widely used as a spray, for fumigation etc.
- Synthetic pyrethrins are often subjects for increased resistance from insects

Pyrethrum

Pyrethrin

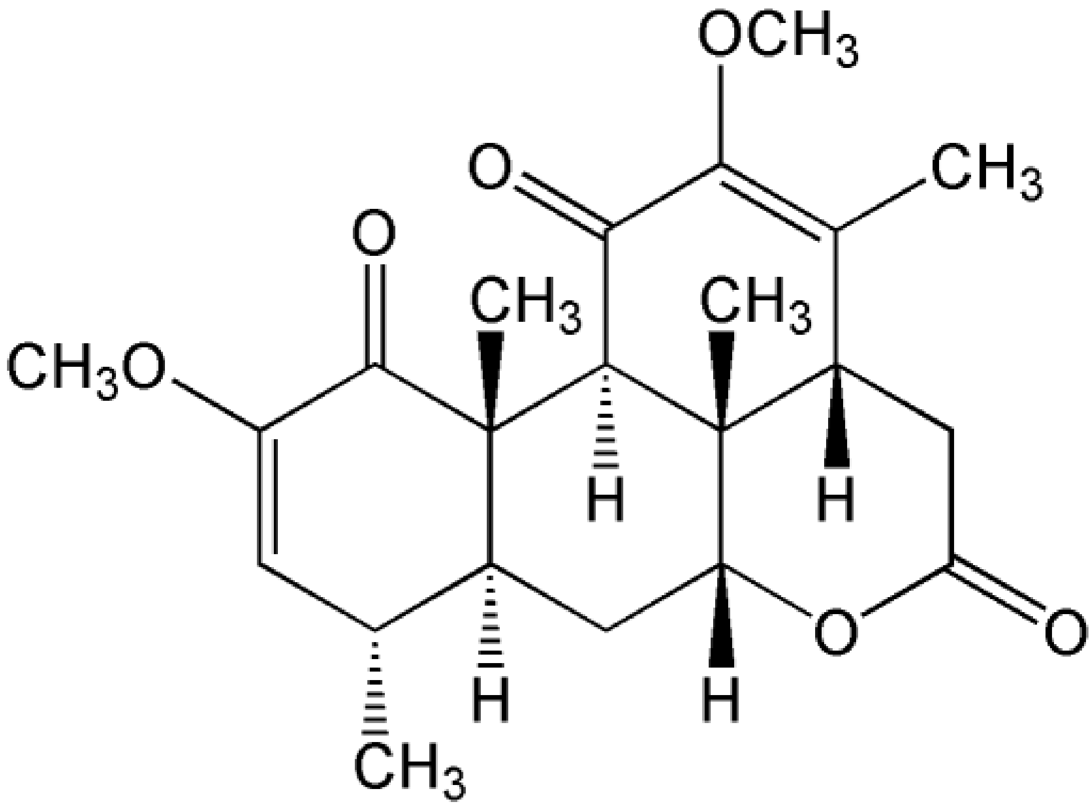


Quassia, *Picrasma excelsa* and *Quassia amara*, Simaroubaceae, Japan and Central America

- Wood of these trees is normally used (e.g., for smoke)
- Quassinoids like quassin are not only insecticides but also anthyheminth and antibacterial drugs

Quassia

Quassin



Summary

- Plant quinones and essential oils tend to be antimicrobial

For Further Reading

References

[1] A. Shipunov. *Ethnobotany* [Electronic resource]. 2011—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_310`

[2] Heinrich et al. 2012. *Fundamentals of Pharmacognosy and Phytotherapy*. Churchill Livingstone, Edinburgh.

Outline

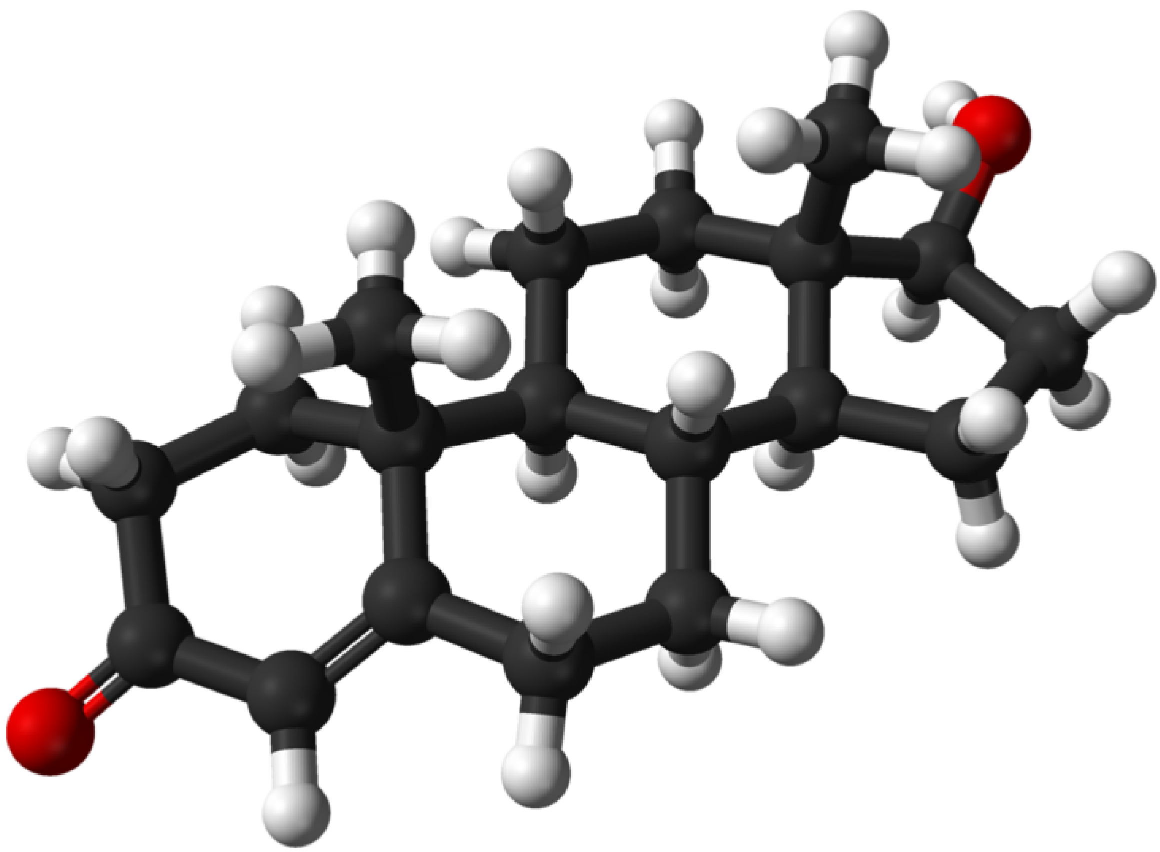
37 Pharmacognosy

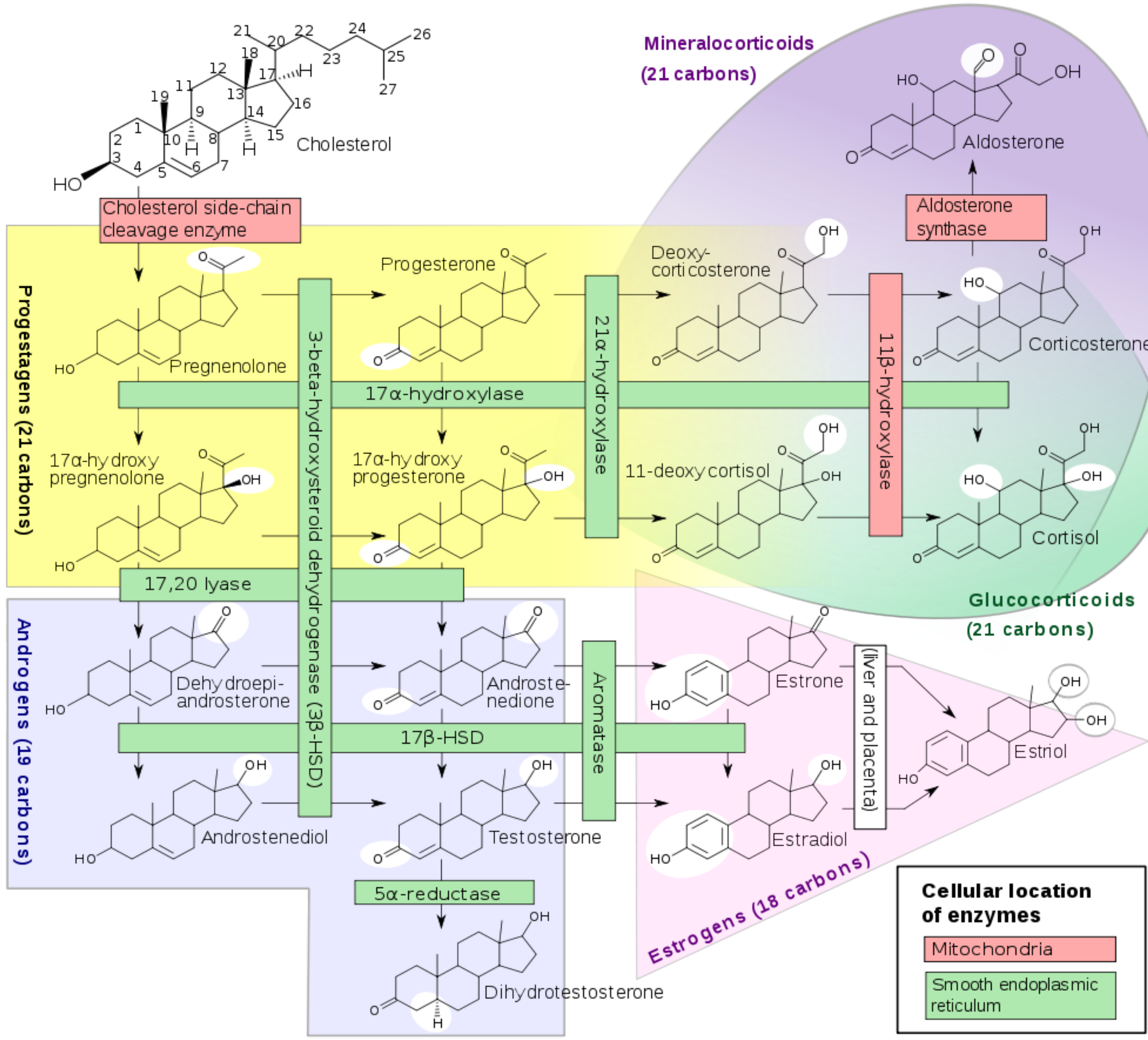
37.1 Plants curing hormone imbalance

Testosterone

- In prenatal development, induces gender identity
- Generally, promotes growth of muscle system through facilitation the synthesis of proteins
- Growth of muscle system stimulates growth of bones
- Has androgenic effects: secondary sex characteristics, sperm development
- Regulates fight-or-flight response, aggressive behavior and overall level of muscle energy
- Present in both males and females in 10:1 proportion

Testosteron

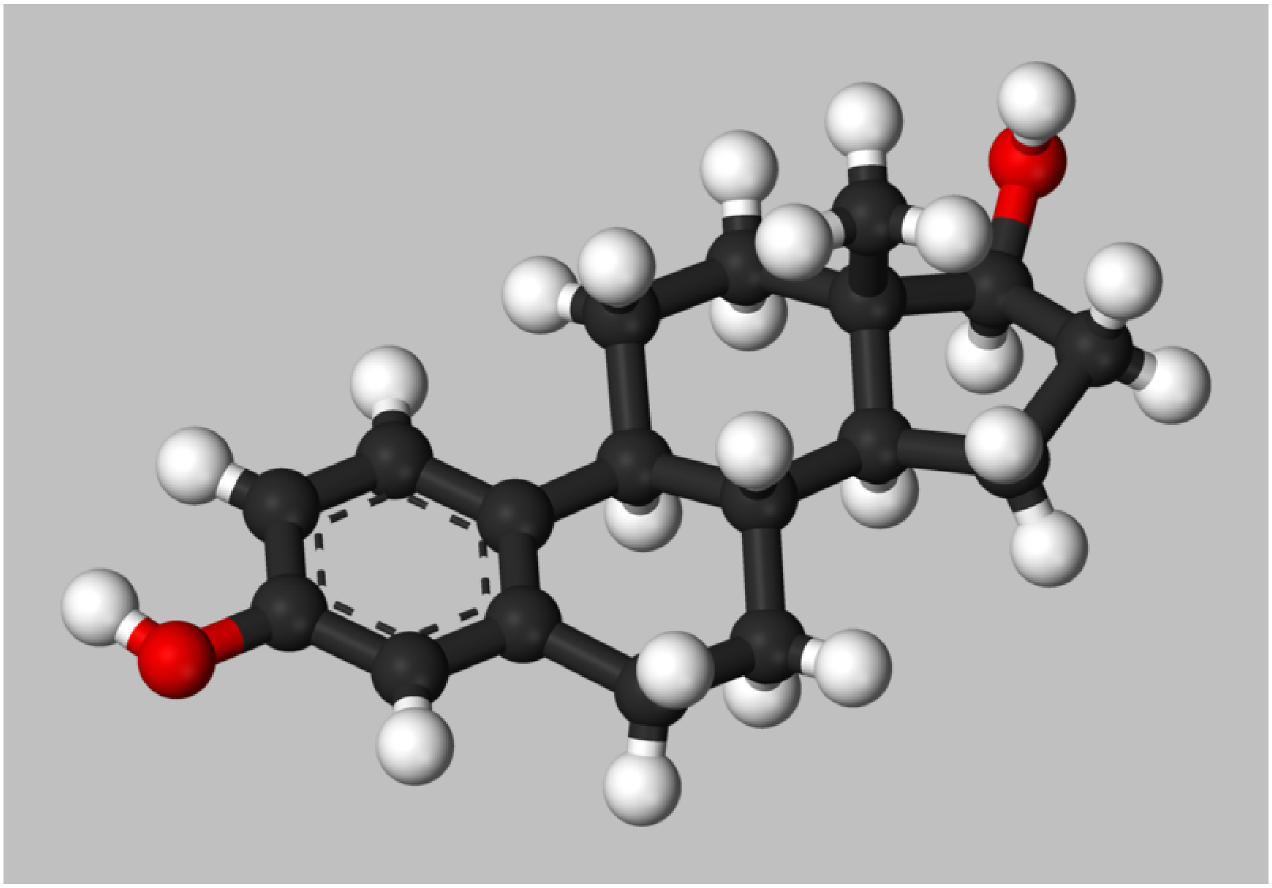




Estrogens

- Group of hormones, most important are estrone (E1) and estradiol (E2)
- Regulate female menstrual cycle
- Activate metabolism, reduce muscle mass, increase the level of fat storage, fasten cholesterol metabolism, promote female secondary sexual characteristics
- Rapid changes of estrogen levels reflects on mental health
- Promote development of some breast cancers
- Present in both males and females

Estradiol



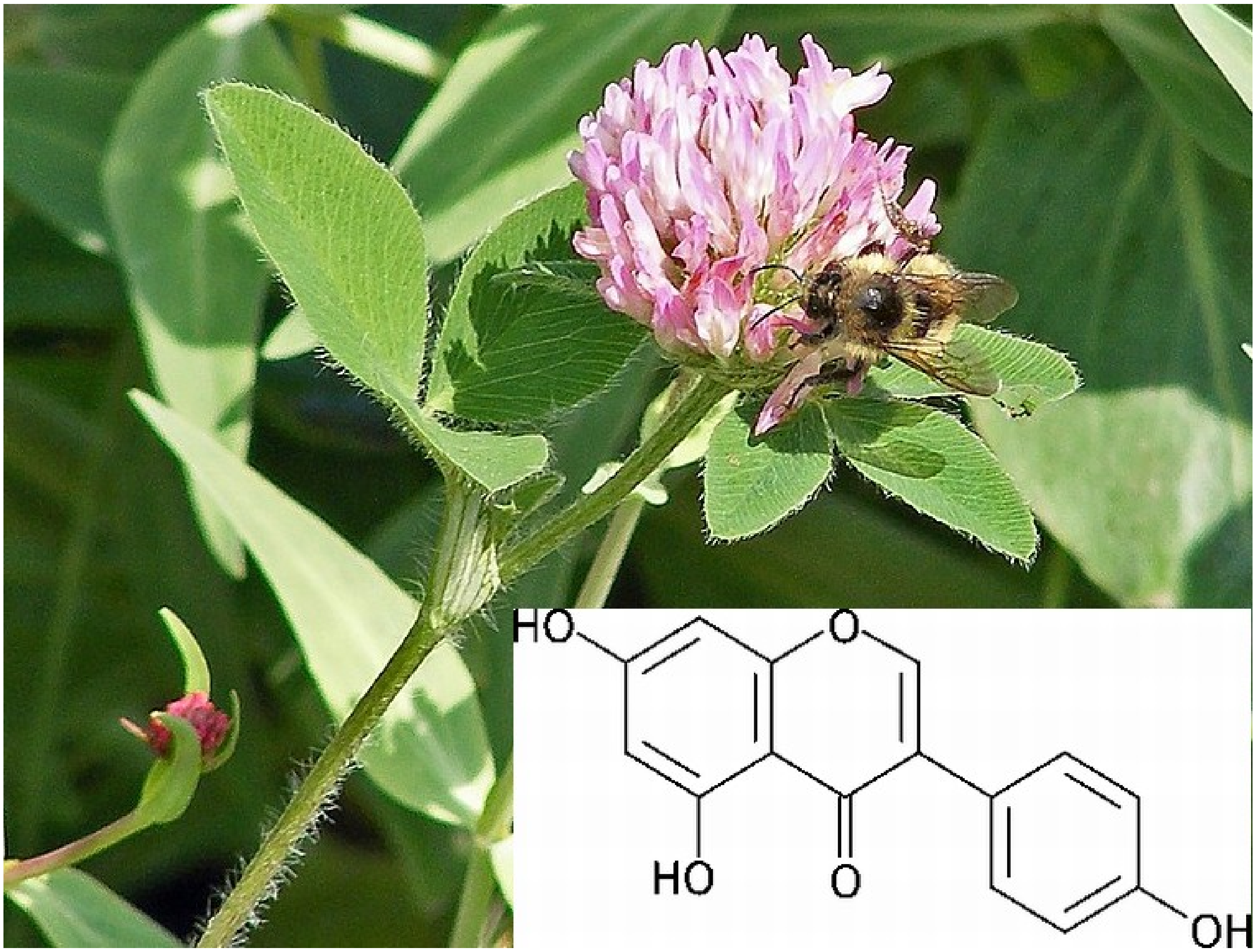
Phytoestrogens

- Plant analogs of steroids, “diet estrogens”
- Have both estrogen and anti-estrogen effects
- Soybeans contain significant amounts of phytoestrogens

Red clover, *Trifolium pratense*

- First spotted because of effect on grazing sheep fertility
- Plant belongs to legume family, Leguminosae
- Red, 2–3 cm diameter flower heads
- European plant, used as a forage and naturalized in North America

Red colver and genistein



Red clover clinical effects

- Genistein and coumestrol are two main components
- Traditionally used for treating skin diseases
- Now often used for a natural hormone therapy, decreases risks of some cancers

Black conosh, *Cicimifuga racemosa*

- Belongs to butterwort family, Ranunculaceae
- The other name is "squawroot" because of traditional use for female therapy
- Traditionally, also used for curing snake bites ("black snakeroot")

Black conosh clinical effects

- Glycosides cicimifugosides (e.g., actein) are main active components
- Improve menopausal symptoms, also affects menstrual cycle
- Lowering blood pressure

Black conosh and actein

Saw palmetto, *Serenoa serrulata*

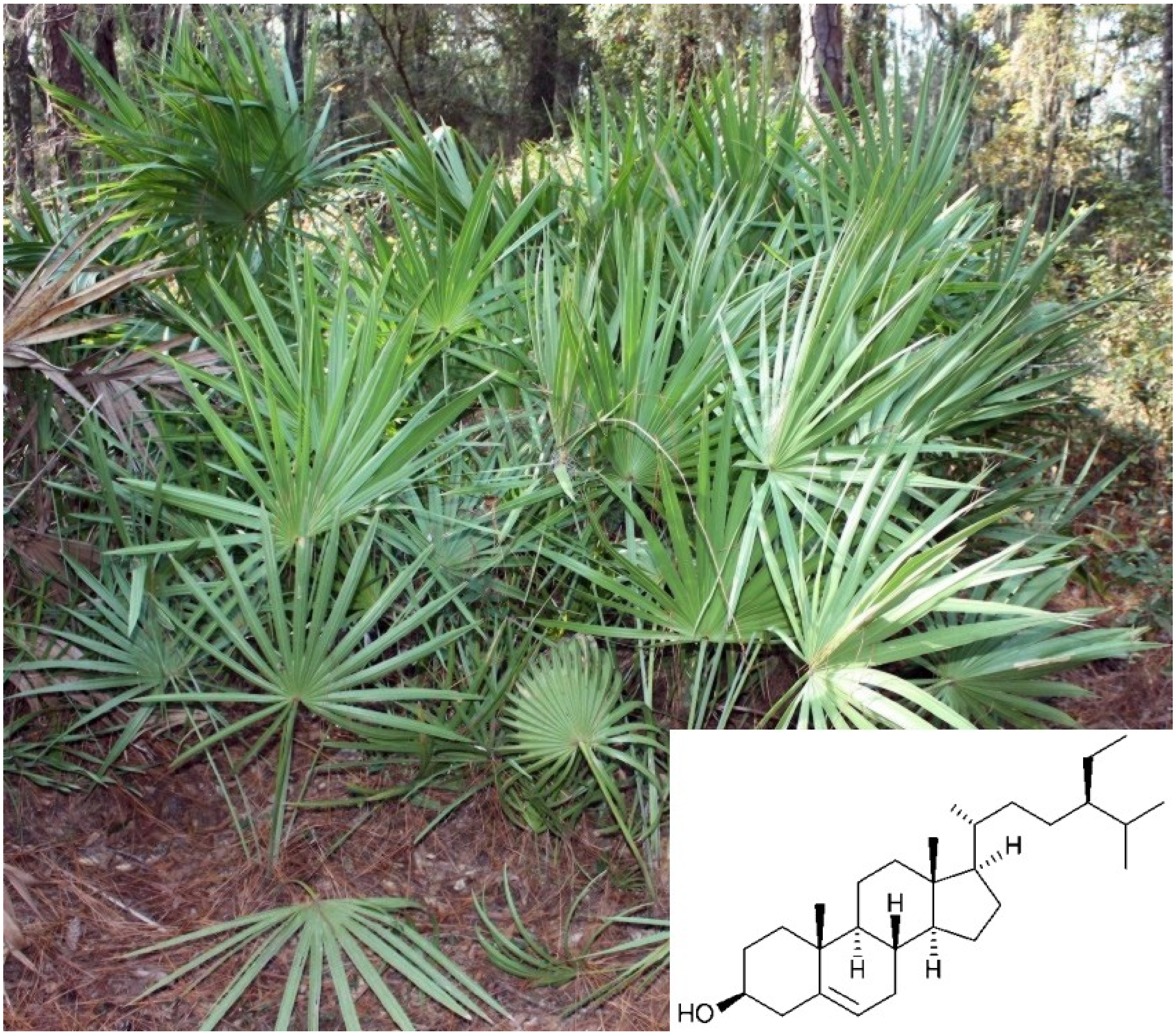
- Belongs to palm family, Palmae
- Important component of Florida forests
- Fruits are small black berries

Florida pine flatwood: saw palmetto and slash pine (*Pinus elliotii*)

Clinical effects of saw palmetto

- Contains multiple phytosterols (e.g., β-sitosterol) with estrogen effects
- Used mostly for treating prostate diseases in males

Saw palmetto and β-sitosterol

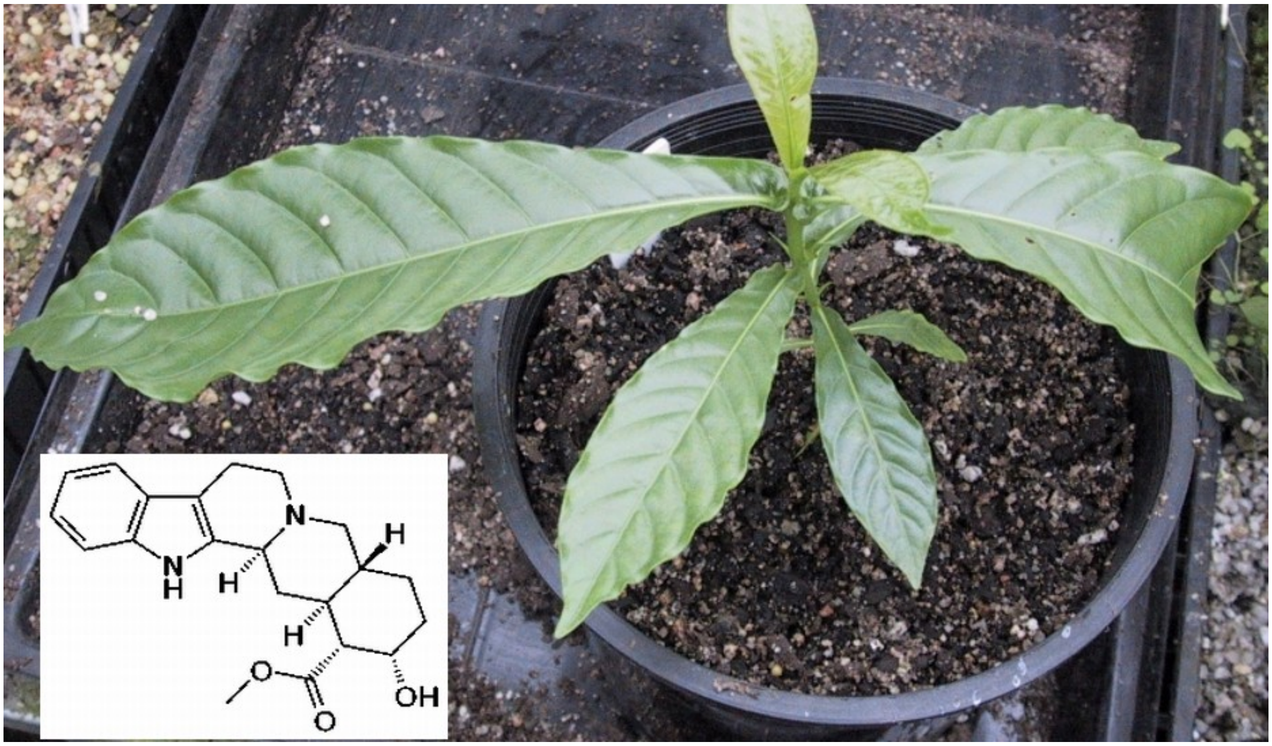


37.2 Plants curing sexual disorders: aphrodisiacs

African Yohimbe, *Pausinystalia yohimbe*

- Belongs to Rubiaceae family (which is rich of medicinal plants)
- Tall West African tree
- Bark is most rich of pharmaceutical components

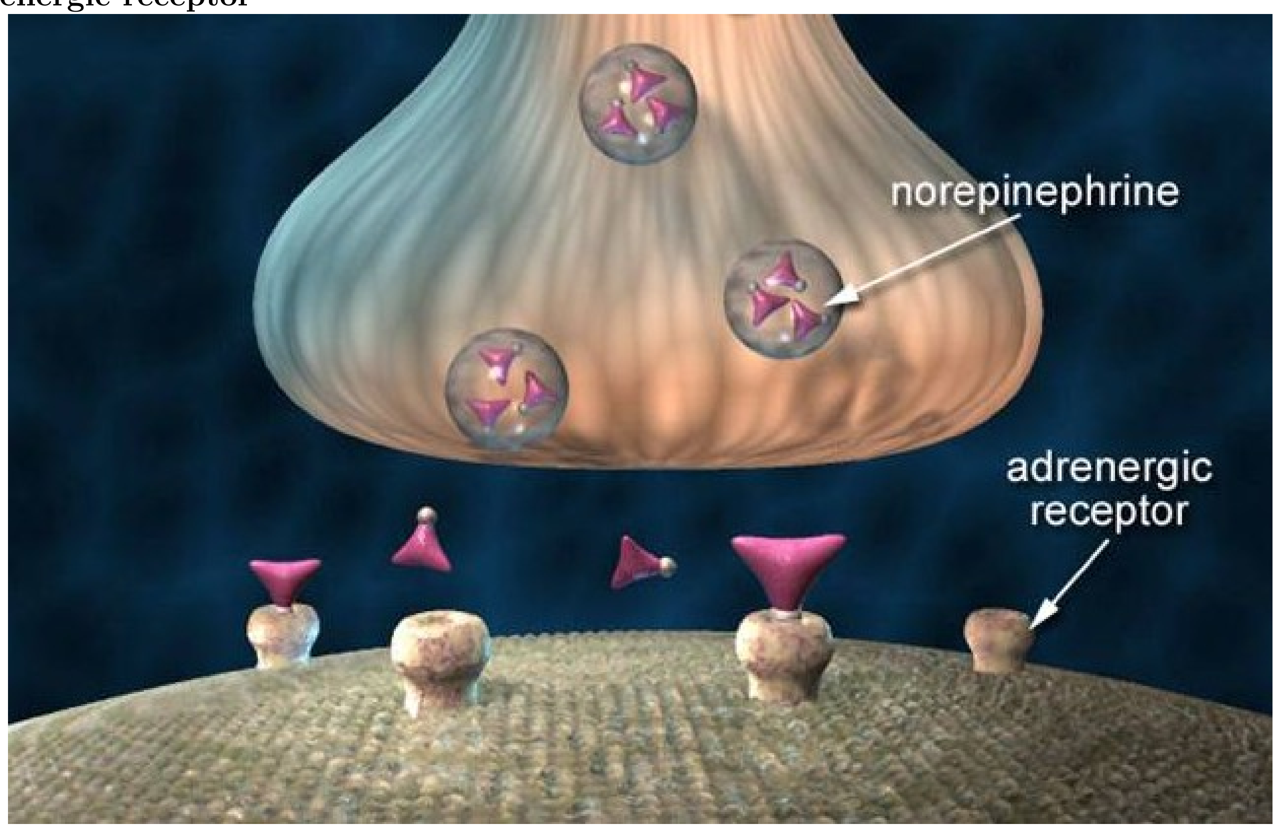
Yohimbe and yohimbine



Yohimbe pharmacological effects

- Contains multiple alkaloids, including yohimbine
- Alkaloid is α-adrenergic blocker, widely used as sexual stimulant

Adrenergic receptor



Mediterranean garden rocket, *Eruca sativa*

- Herbaceous plant from cabbage family, Cruciferae
- Used as leaf vegetable and as a sexual stimulant from Roman times
- Source of digestive alcohol, *rucolino*

Garden rocket and "Rucolino"

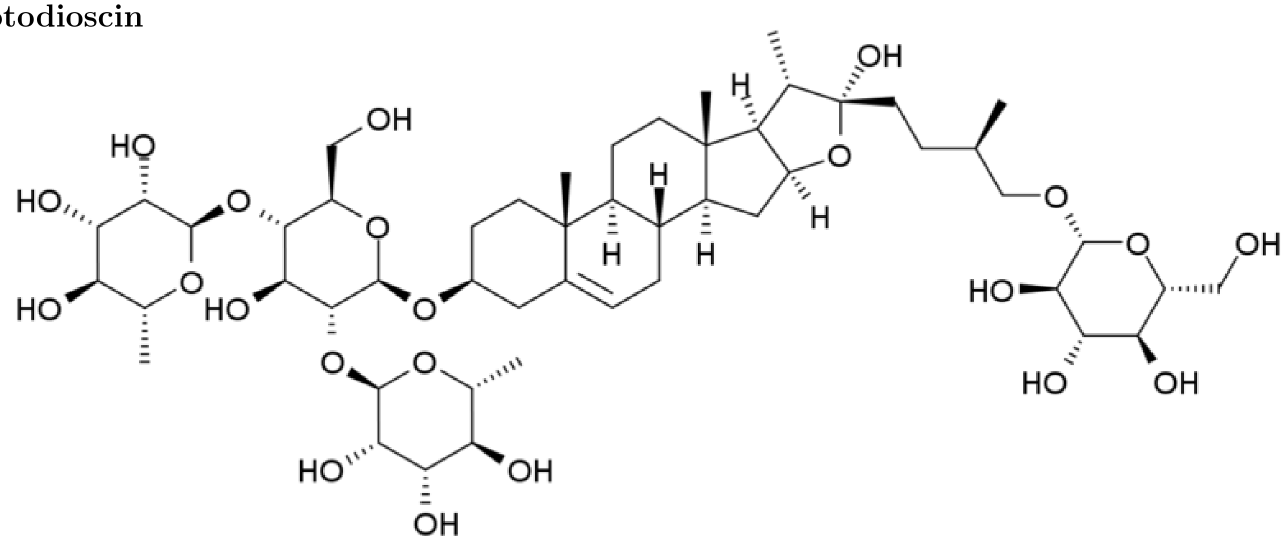
Indian gokharu, *Tribulus terrestris*

- Eurasian herbaceous creeping plant from Zygophyllaceae family, naturalized in U.S.
- Fruits have extremely large spines dangerous even to bicycles

- Important traditional part of Indian Ayurveda and Unani medicinal traditions
- Main component is steroidal protodioscin, increases the level of testosterone

Gokharu

Protodioscin



South Asian tonghat, *Auricoma longifolia*

- Small Indonesian tree from Simaroubaceae family

- Main active components are extremely bitter (50 times more than quinine) quassinoids (e.g., eurycomalactone) from tree roots
- It is shown that root extract increase sperm count, testosterone level, and even anti-cancer
- Now widely used as anabolic for bodybuilders

Tonghat and eurymalactone

Central American damiana, *Turnera diffusa*

- Shrub from Turneraceae family, native to southern U.S. and Mexico
- Native Americans prepared "damiana tea" as sexual stimulator
- It is shown that constituents may take part in estrogen metabolism

Damiana

Southern American walking palm, *Socratea exorrhiza*

- Small palm from Amazonian forests
- Widely known as “walking plant” because it constantly develops new stilt roots whereas older are decaying
- Inner parts of stilt roots are used as aphrodisiac

Walking palm

37.3 Plant remedies for endocrine and urinary diseases (the rest)

Antidiabetics

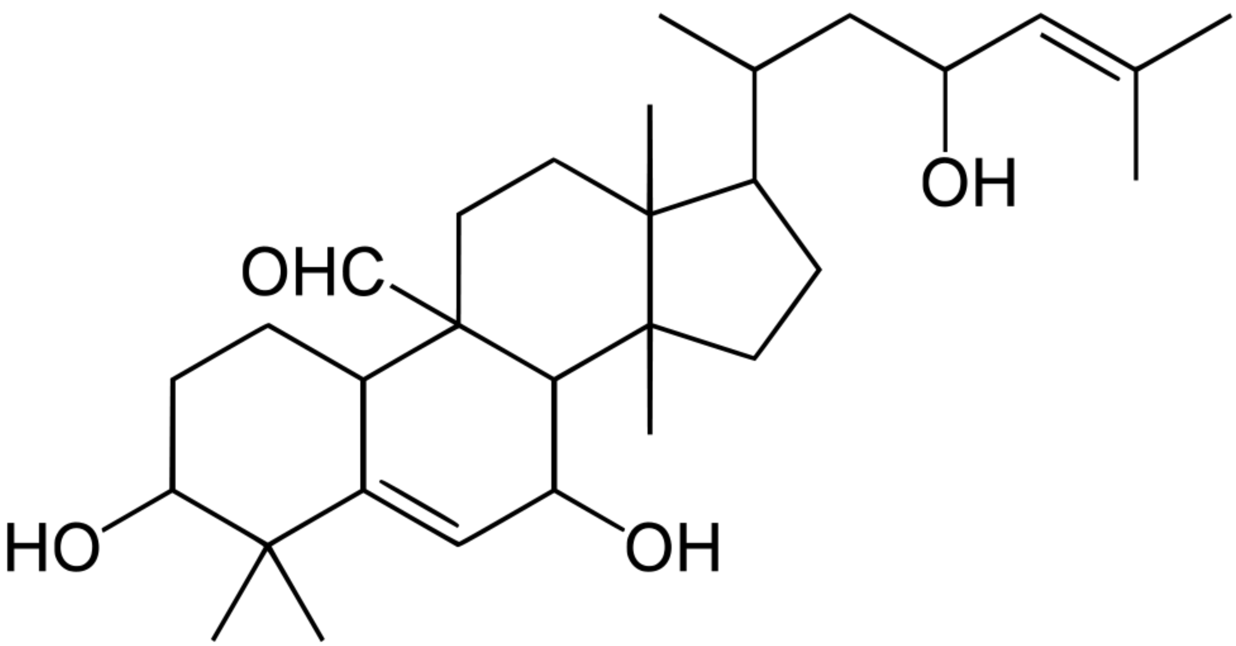
- Used for treatment in case of type 2 diabetes (non-insulin-dependent)
- Lower concentration of glucose in blood (hypoglycaemic effects)

Bitter melon, *Momordica charantia*, Cucurbitaceae, South Asia

- Leaves and fruits contain triterpene glycosides momordicosides
- Have hypoglycaemic effects

Bitter melon

Momordicin



Guar, *Cyamopsis tetragonolobus*, Leguminosae, Africa

- *Cyamopsidis seminis*
- Seeds are normally used, they contain galactose and mannose polymers which reduce absorption of glucose

Guar

Gymnema, *Gymnema sylvestris*, Apocynaceae, India

- (Covered previously)
- Large vine, leaves chewing results in temporary disappearance of sweet taste

Raspberry, *Rubus idaeus*, Rosaceae, North Hemisphere

- Tea from raspberry leaves was traditionally used to facilitate child birth
- Active components are most probably polypeptides and flavonoids

Raspberry leaves

37.4 Plants for musculosceletal system and skin

Arthritis, rheumatism and muscle pain

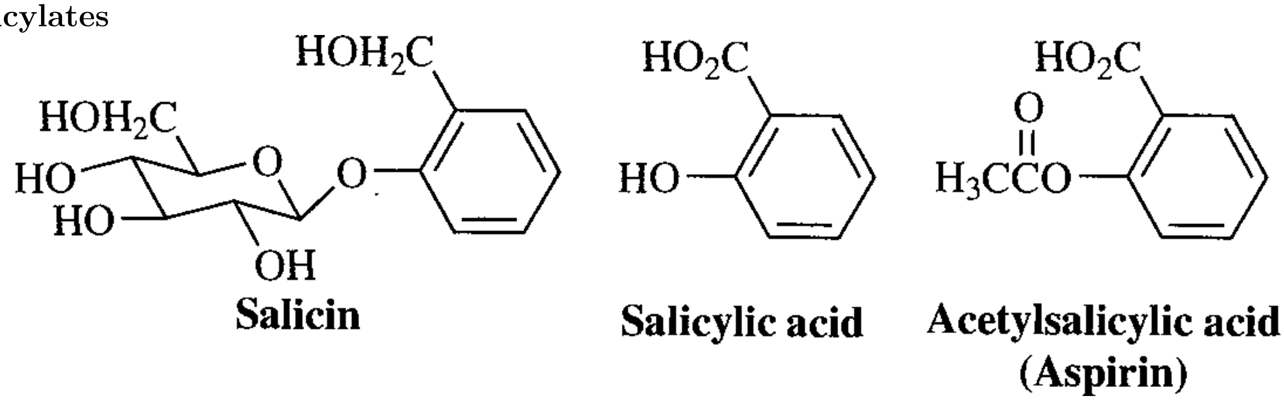
- Numerous unrelated diseases, from infections to psychological
- As a result, no general treatment available
- Main synthetic non-steroidal anti-inflammatory drug (NSAIDs: aspirin, ibuprofen) are cyclo-oxygenases which inhibit prostaglandin synthase enzymes

Willows, *Salix* spp., Salicaceae, Northern Hemisphere

- *Salicis cortex*
- Contains salicylic acid
- Work much better with stomach than pure salicylis or acetylsalicylis acids (aspirin)

Willow

Salicylates



Meadowsweet, *Filipendula ulmaria*, Rosaceae, Eurasia

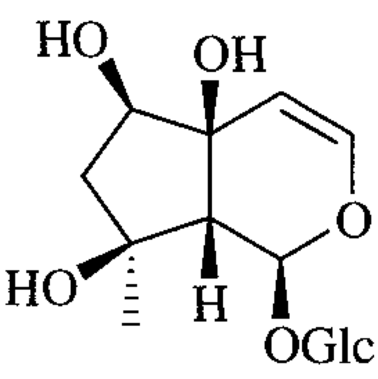
- Perennial herb growing in wet places; leaves and flowers are used
- Contain high amounts of salicylic acid, “aspirin” is a derivative from old name of plant, “spiraea”

Meadowsweet

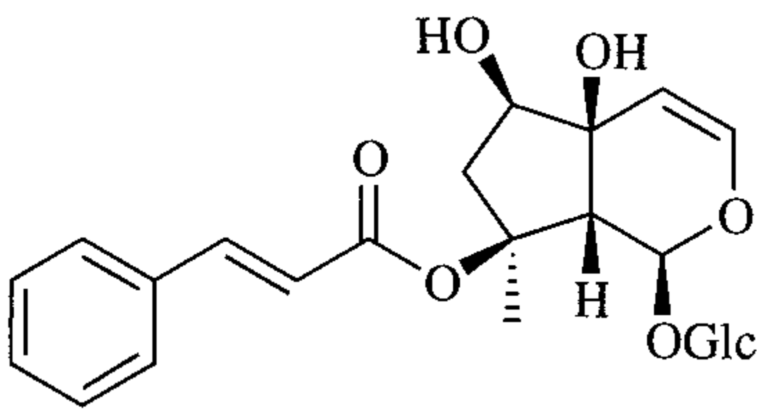
Devil’s claw, *Harpagophytum procumbens*, Pedaliaceae, South Africa

- *Harpagophyti radix*
- Plant with extremely spiny fruits; roots are collected
- Contains bitter iridoids harpagide and harpagoside working well in arthritis

Devil’s claw



Harpagide



Harpagoside

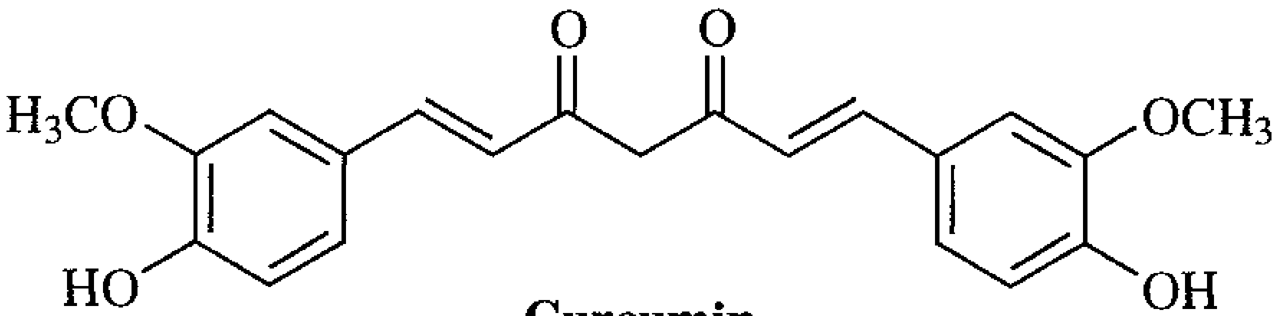
Turmeric, *Curcuma domestica*, Zingiberaceae, South Asia

- *Curcumae domestuicae rhizoma*

- Herbaceous plant similar to ginger, rhizomes are used
- Plant came from Ayurveda and TCM
- Curcuminoid phenolic compounds are active, antagonist of some inflammatory factors

Turmeric

Curcumin



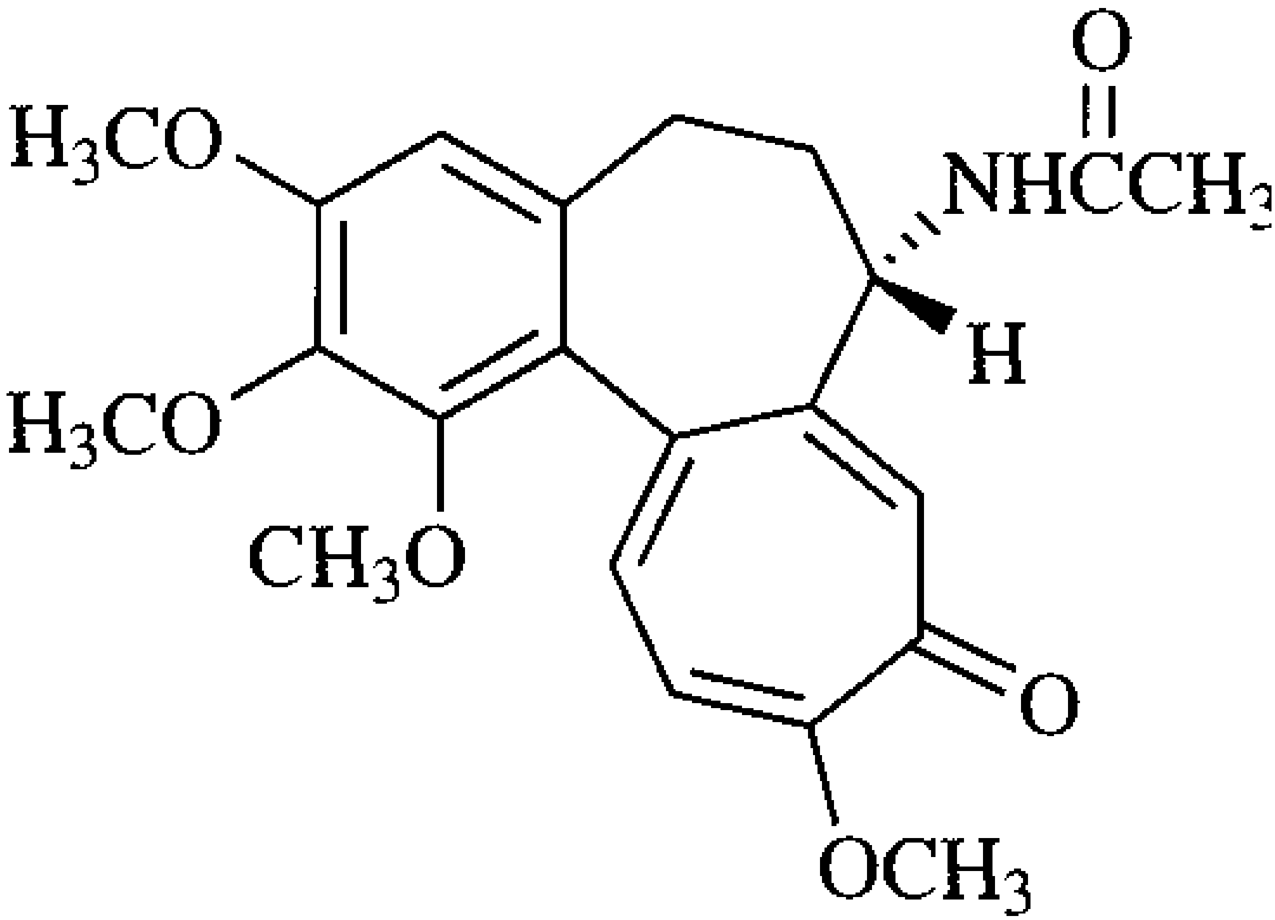
Curcumin

Autumn crocus, *Colchicum autumnale*, Colchicaceae, Eurasia

- Used against gout: severe inflammation of foot joints caused by formation of uric crystals
- Colchicine is an active compound; extremely toxic!
- Also, used as anti-cancer

Autumn crocus

Colchicine



Cold and influenza

- Mixture of diseases, anti-inflammatory, antiviral drugs and immunostimulants are used
- Demulcents and emollients used for symptomatic treatment

Linden, *Tilia* spp., Malvaceae, North Hemisphere

- *Tiliae flos*
- Deciduous trees with insect-pollinated, fragrant flowers
- Active components are different essential oils, polysaccharides; some are capable to bind with inhibitory GABA receptors

Linden

Coltsfoot, *Tussilago farfara*, Compositae, Eurasia

- Herb with dimorphic leaves and early flowering (both flowers and leaves are used)
- Main active components are acidic polysaccharides

Coltsfoot

Common marshmallow, *Althaea officinalis*, Malvaceae, Eurasia

- *Althaeae radix*
- High herbaceous perennial plant
- Tissues are rich of mucilage polysaccharides and flavonoids

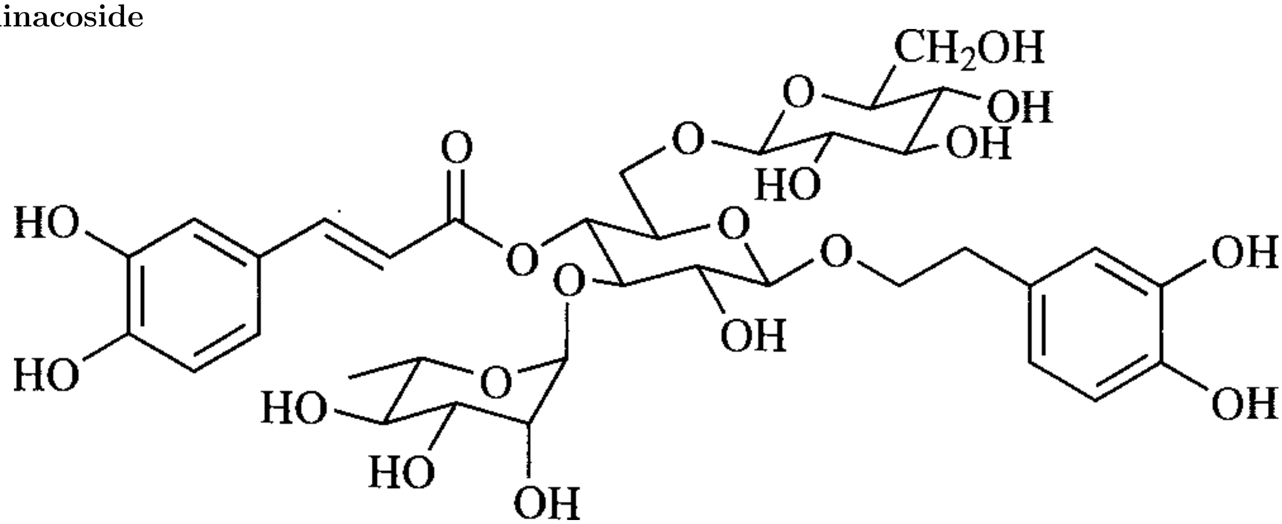
Marshmallow

Echinacea, *Echinacea purpurea* and other species, Compositae, North America

- Perennial herb, widely used by native tribes
- Contain numerous glycosides and other compounds, e.g., echinacoside
- Immunostimulant and anti-allergic plant, often combined with garlic

Echinacea

Echinacoside



Wintergreen, *Gaultheria procumbens*, Ericaceae, North America

- Leaves and stems contain oils rich of methyl salicylates
- Often used topically, e.g., for many kinds of muscular pains

Wintergreen

Red pepper, *Capsicum* spp., Solanaceae, Central America

- (Already covered)
- Provides the revulsive effect

Skin diseases

- Eczema, dry skin, infectious diseases, local inflammation etc.
- Anti-inflammatory, antimicrobial and some specific drugs are used

Yarrow, *Achillea millefolium*, Compositae, Eurasia

- Perennial plant with dissected leaves, all parts are used
- Essential oils and tannins are responsible for anti-inflammatory and astringent effects

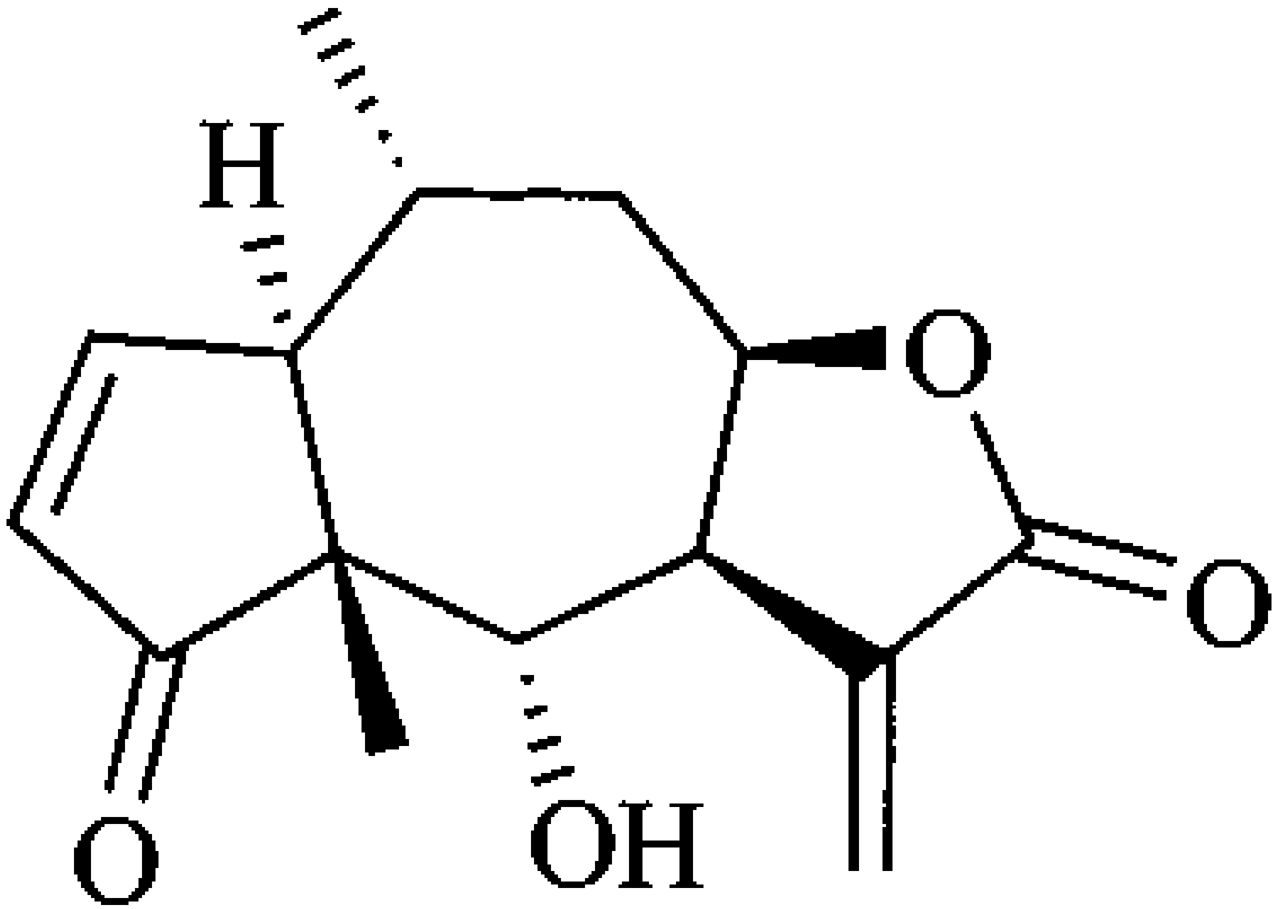
Yarrow

Arnica, *Arnica montana*, Compositae, Eurasia

- Perennial mountainous plant from Alps
- Contain a rich combination of active compounds: proteins, essential oils, sesquiterpene lactones (e.g., helenalin)

Arnica

Helenalin



***Aloë vera*, Asparagaceae, Africa**

- African tree with succulent leaves
- Mixture of different components with antibacterial, anti-inflammatory and other effects

Aloë vera

Calendula, *Calendula officinalis*, Asteraceae, Eurasia

- Herbaceous plant with bright yellow or orange inflorescences
- Oils, polysaccharides, saponins (like calenduladiol), carotenes—with anti-inflammatory and antiseptic effects

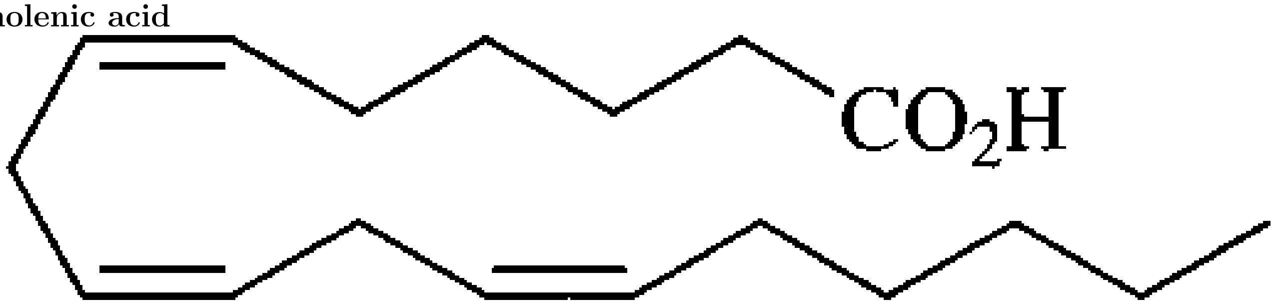
Calendula

Evening primrose, *Oenothera* spp., Onagraceae, North America

- Used by local tribes
- Active is γ-linolenic acid which has topical anti-inflammatory and anti-eczematic effects

Evening primrose

γ-linolenic acid



Witch hazel, *Hamamelis virginiana*, Hamamelidaceae, North America

- Shrub with hazel-like leaves and extremely early (or late) flowering
- Leaves and bark contain tannins with positive astringent effects to skin

Witch hazel

37.5 Plants for eye, ear, nose and pharynx

Eyebright, *Euphrasia* spp., Orobanchaceae, Eurasia

- Traditional European plant remedy
- Active components are iridoid glycosides: aucubin, euphroside etc., lignans and tannins
- Helps in conjunctivitis

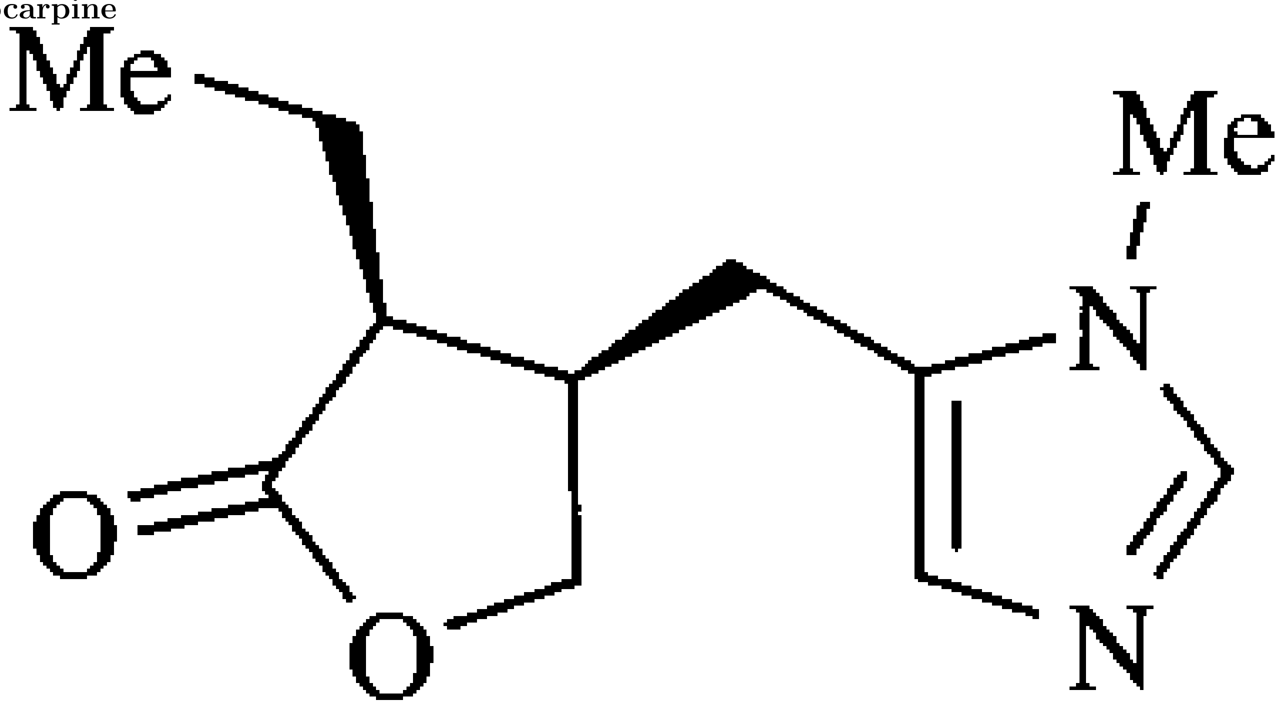
Eyebright

Jaborandi leaf, *Pilocarpus* spp., Rutaceae, South America

- Contains alkaloid pilocarpine
- Stimulating eye muscles, contracting pupils after atropine; used against glaucoma

Jaborandi leaf

Pilocarpine

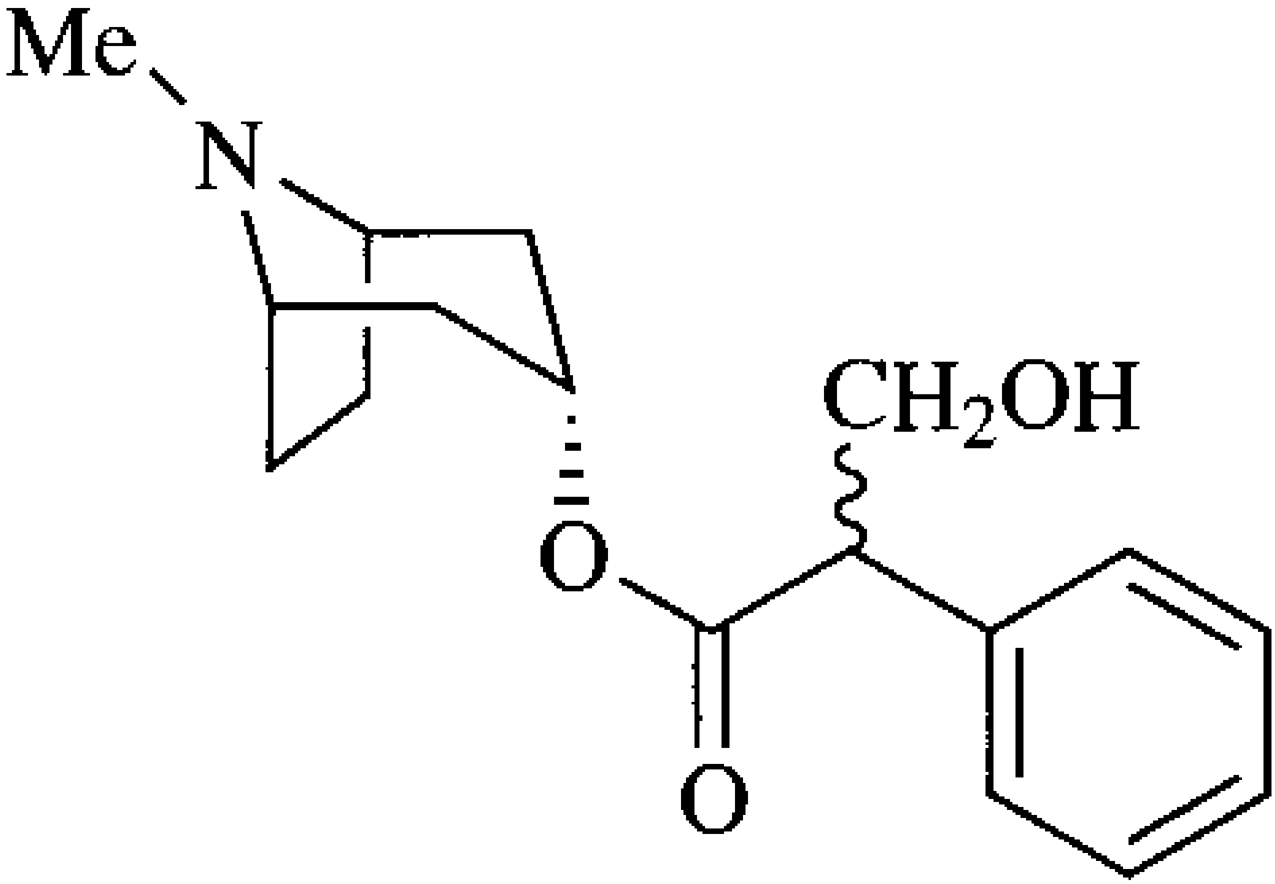


Deadly nightshade, *Atropa belladonna*, Solanaceae, Mediterranean

- Contains alkaloid atropine
- Used for medical examination to open iris

Deadly nightshade

Atropine



Essential oil plants for nose and orthopharynx

- Essential oils are using as antiseptic and anti-inflammatory agents
- Sage (*Salvia officinalis*), eucalyptus (*Eucalyptus* spp.) and peppermint (*Mentha* × *piperita*) are most frequently used

Clove, *Syzygium aromaticum*, Myrtaceae, Southwest Asia

- *Caryophylli flos*
- Flower buds extremely rich of eugenol
- Used also as a culinary spice

Clove

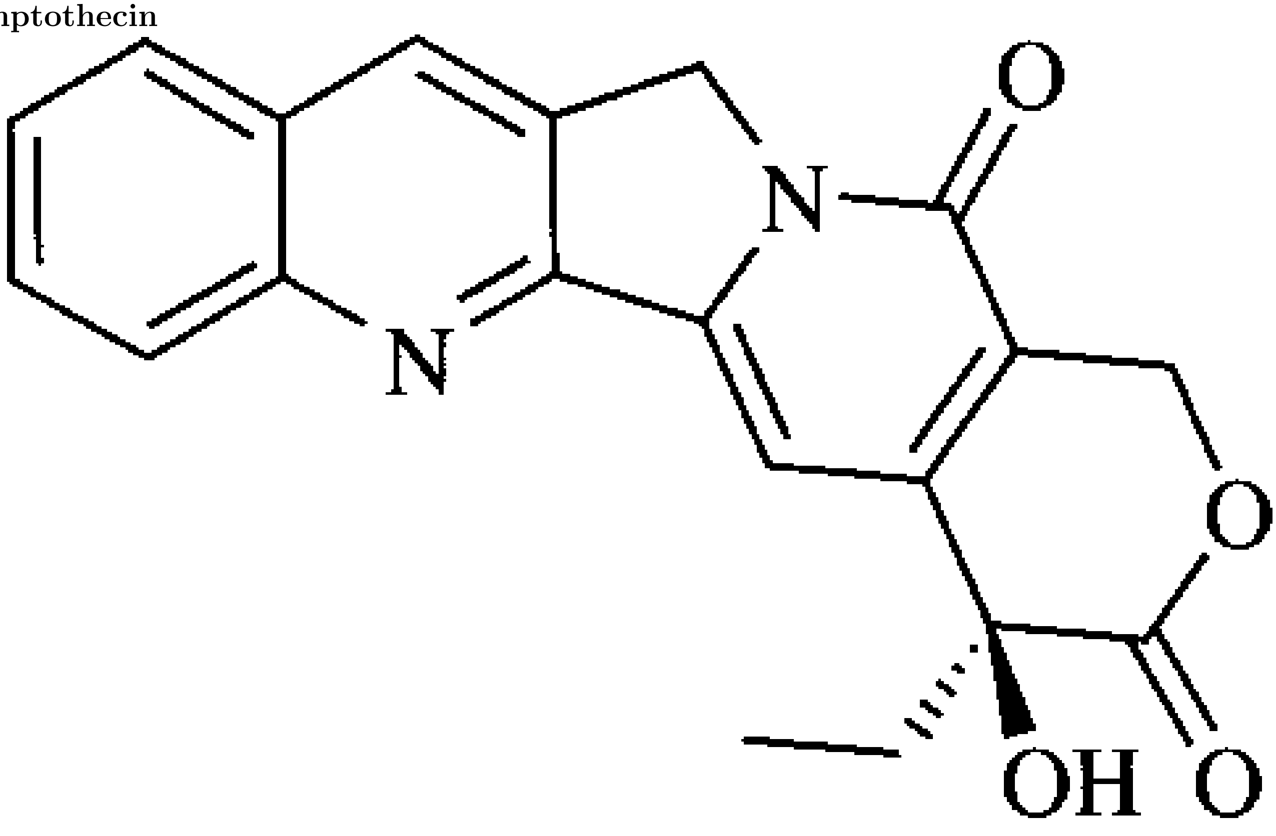
37.6 Anti-cancer plants

***Camptotheca acuminata*, Cornaceae, East Asia**

- TCM plant
- Study started in the end of 1950s
- Wood and bark contain camptothecin, highly unsaturated alkaloid (toxic!)
- Active against gastrointestinal tumors of short duration

Camptotheca acuminata

Camptothecin

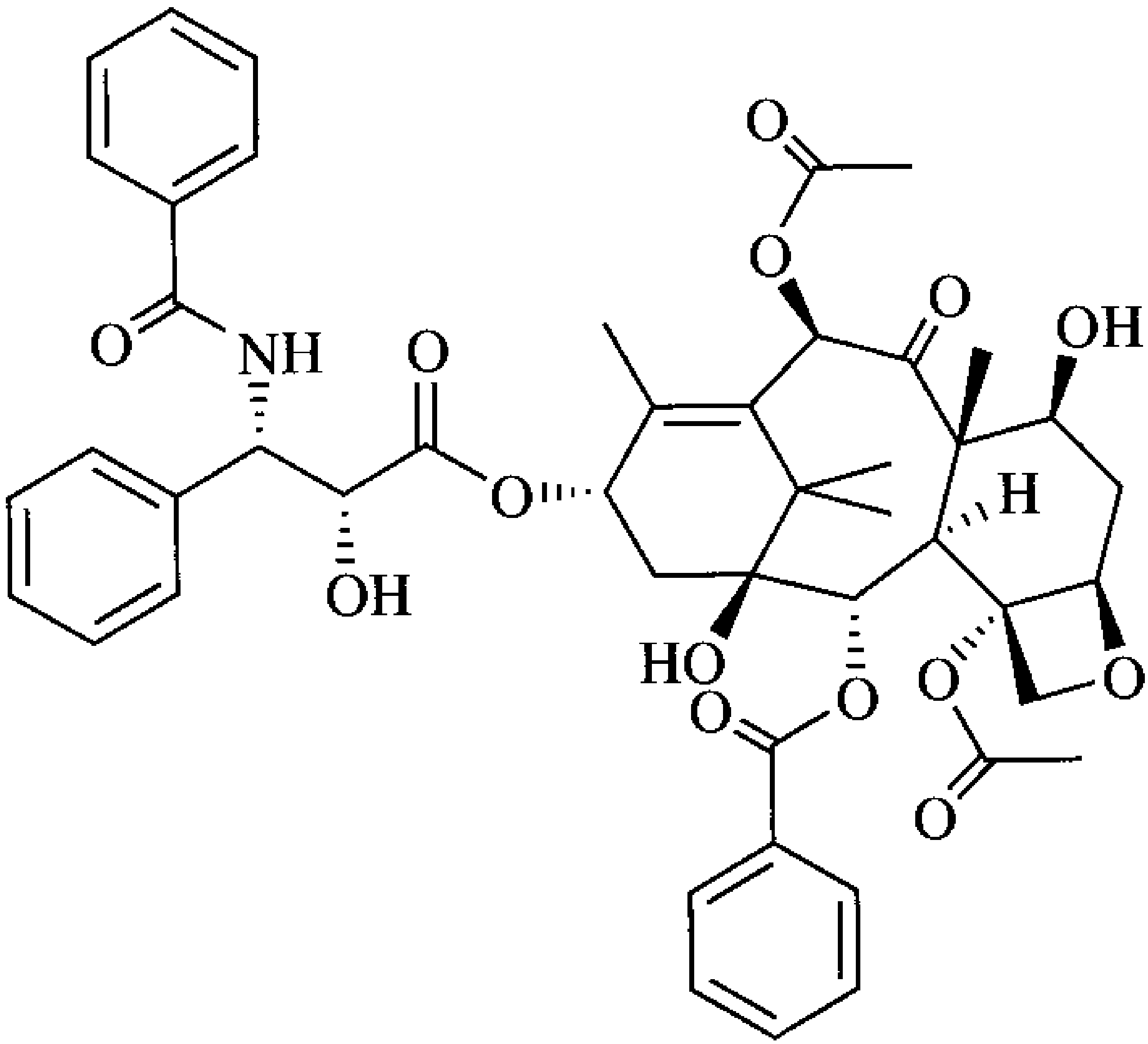


Pacific yew, *Taxus brevifolia*, Taxaceae, North America

- Conifer tree with berry-like cones
- Contains taxol which is active against leukemia: it stops mitosis due to inhibition of tubulin depolymerisation
- Actually, taxol is produced mostly by yew fungal symbiont, *Taxomyces*

Yew

Taxol

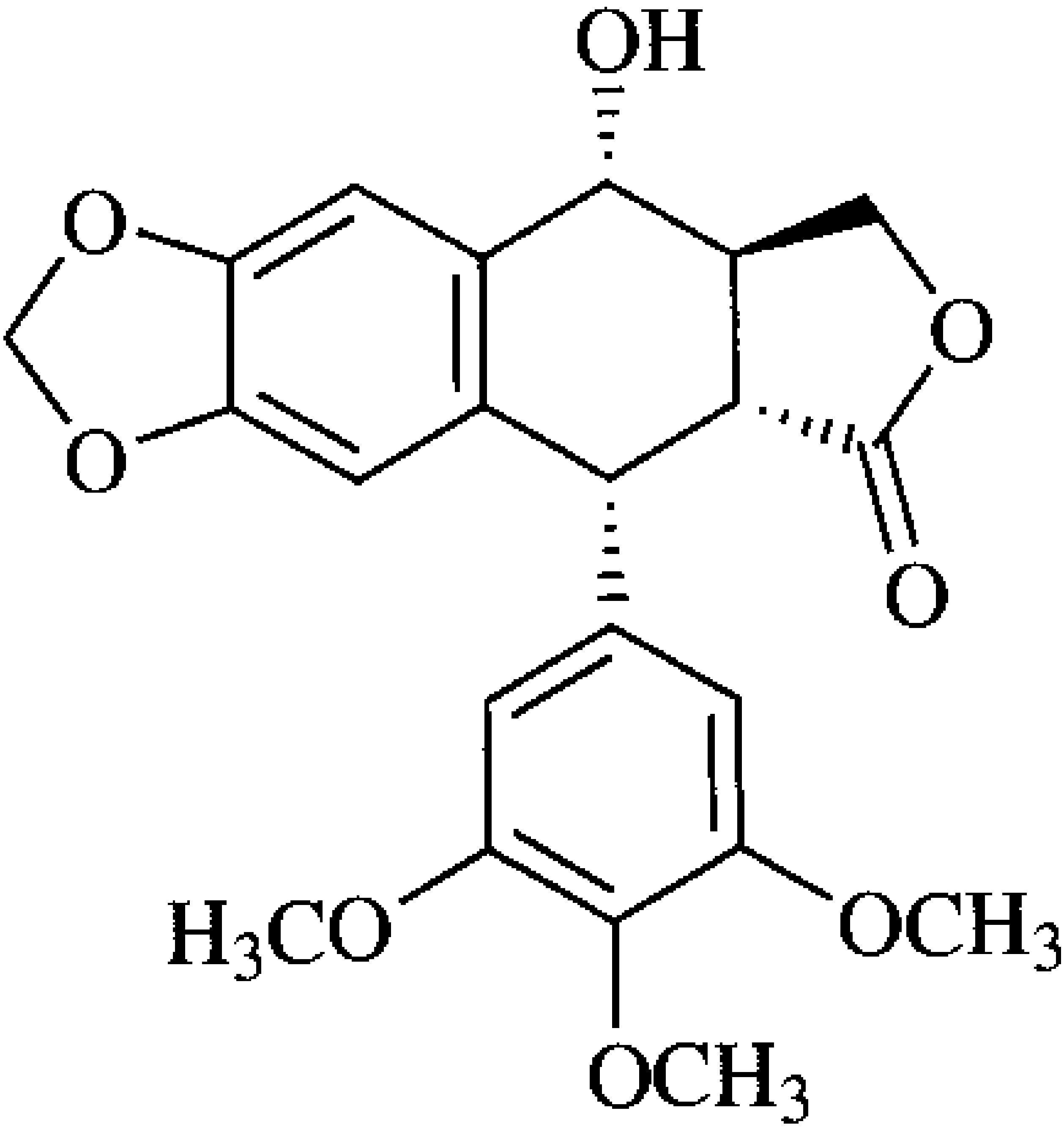


Mayapple, *Podophyllum peltatum*, Berberidaceae, North America

- Rhizomes contain cytotoxic glycoside podophyllotoxin
- Working similarly to colchicine: binds to tubulin and prevents microtubule formation

Mayapple

Podophyllotoxin



White birch, *Betula alba*, Betulaceae, Eurasia

- Betulinic acid (almost non-toxic!) is shown to have inhibiting effect on several tumor cell lines
- It is believed that birch canker fungus ("chaga") also contains anti-cancer agents

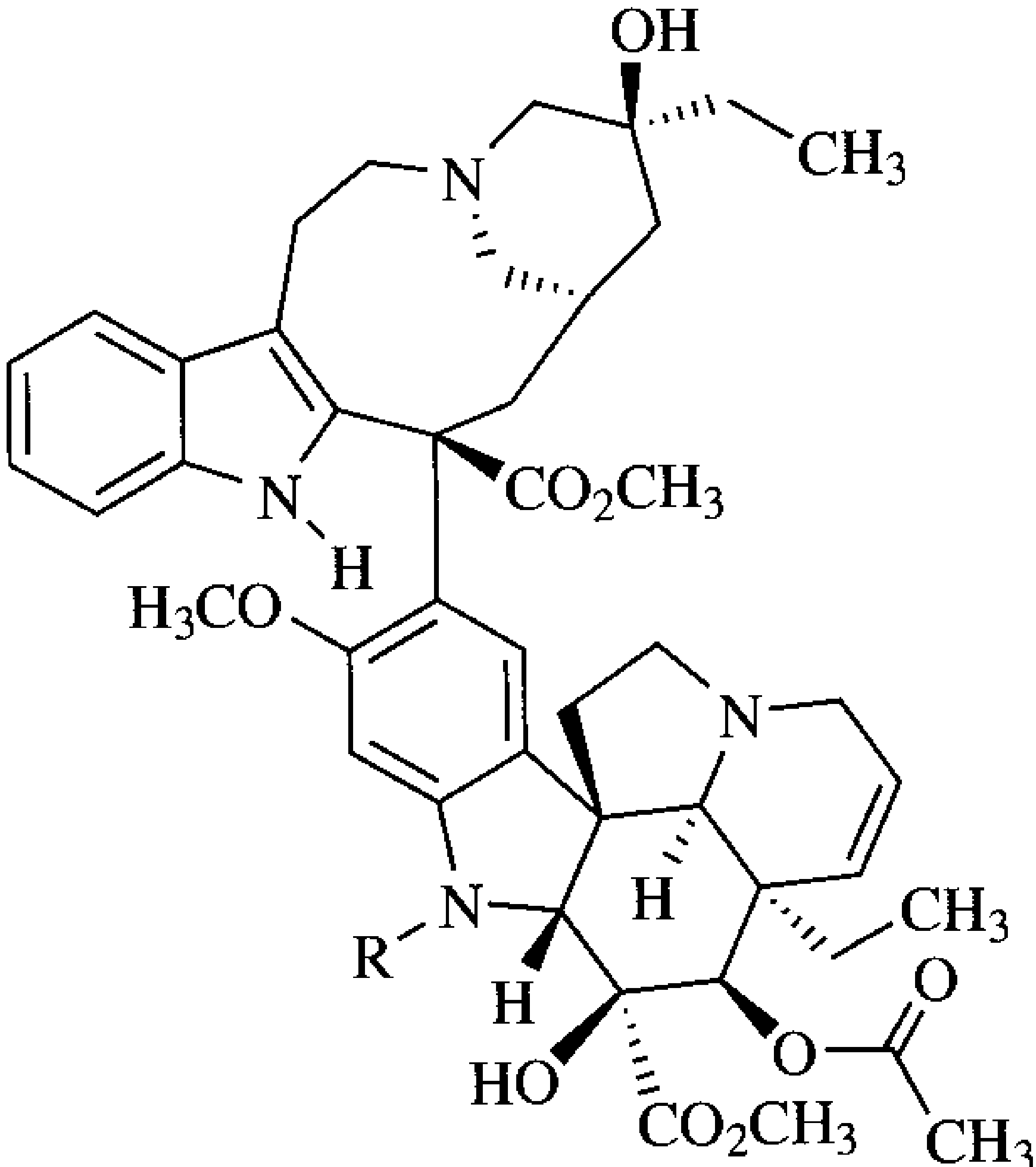
Birch canker

Madagascar periwinkle, *Catharanthus roseus*, Apocynaceae, Madagascar

- Has multiple effects, long believed to be a “magic plant”
- Multiple indole alkaloids like vincristine inhibit cell division in many cancer lines, especially sarcomas

Madagascar periwinkle

Vincristine

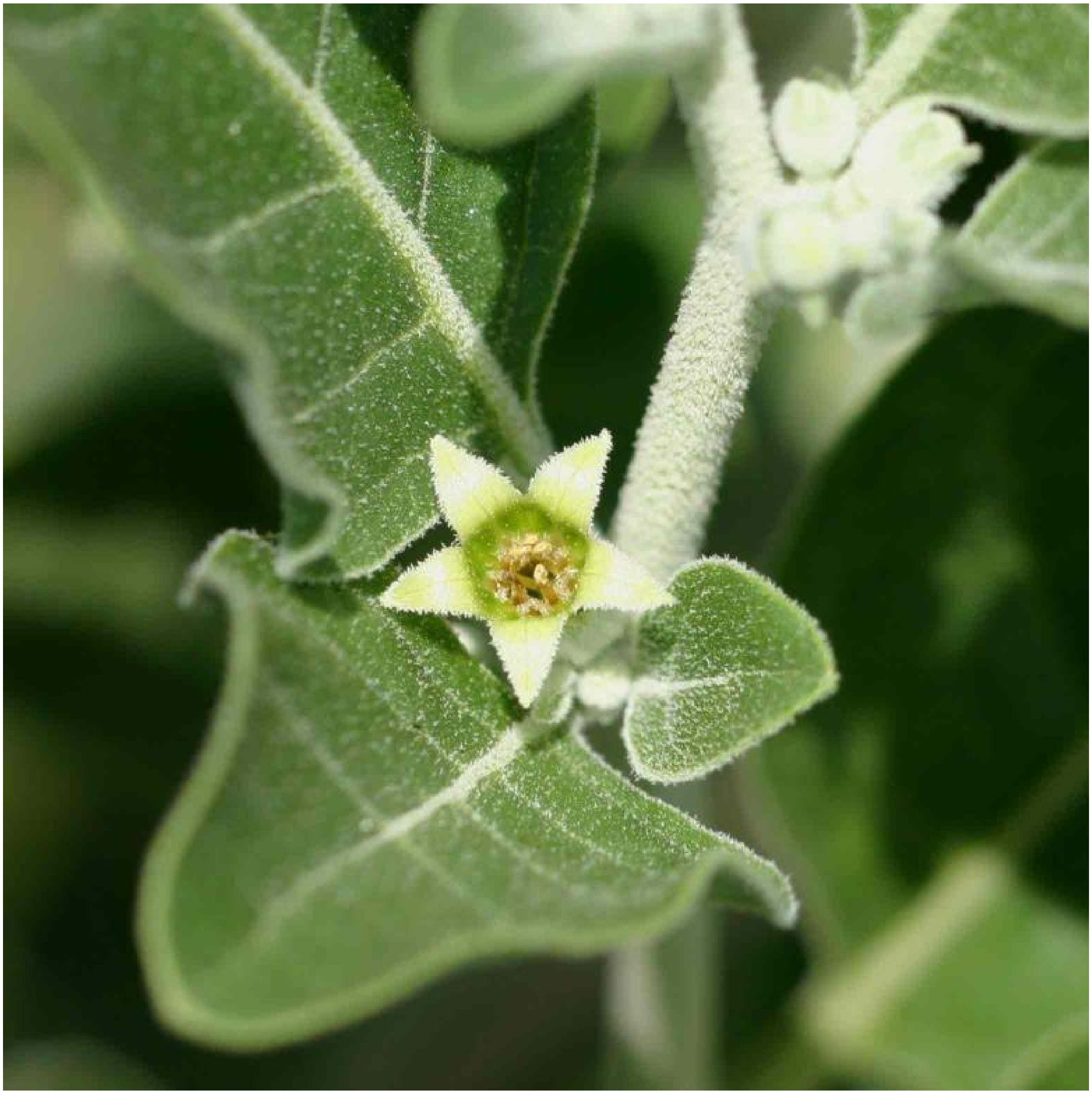


37.7 Plants for supportive therapy

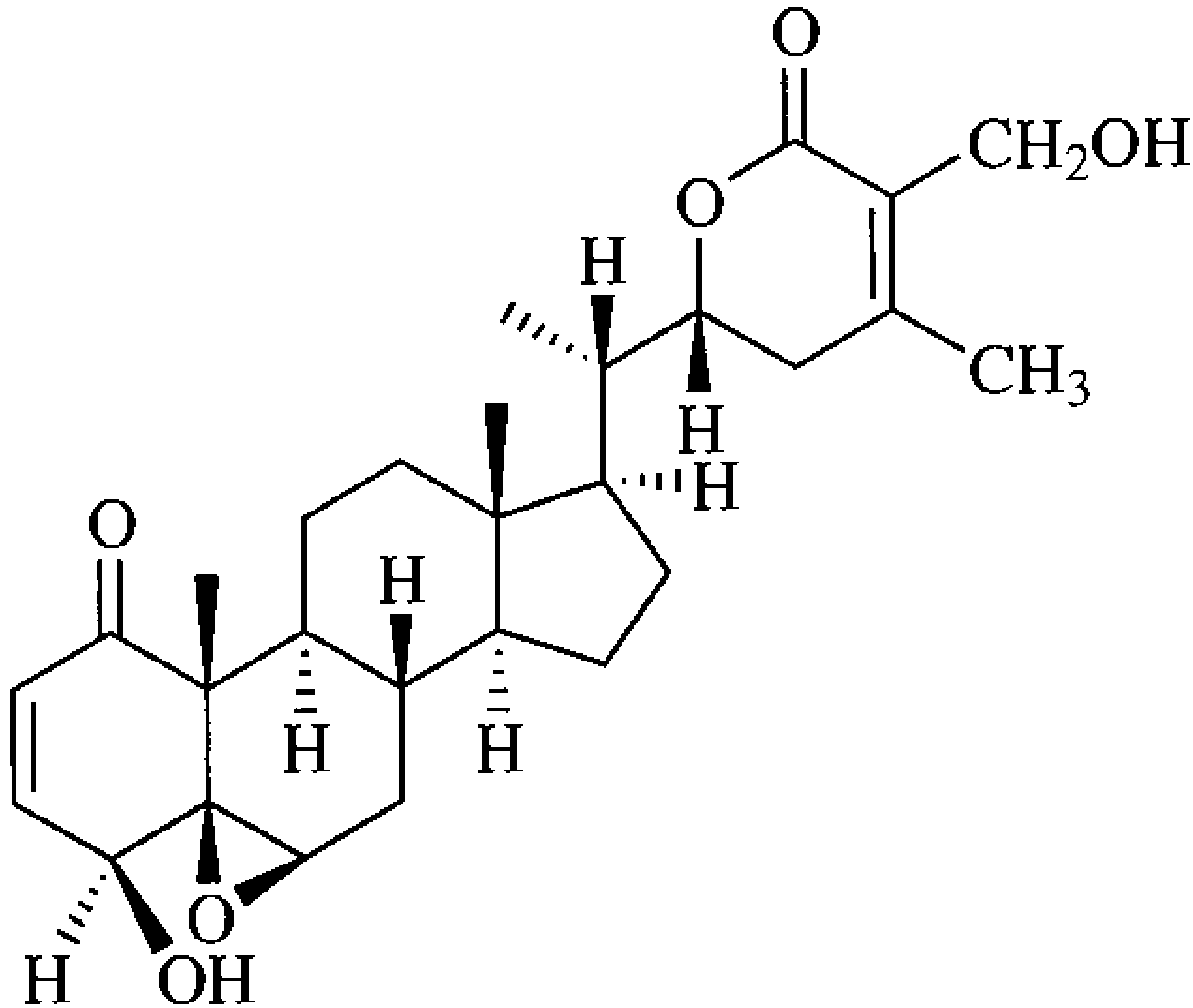
Ashwaganandha, *Withania somniferum*, Solanaceae, South Asia

- Roots are used in Ayurveda from more than 4,000 years
- Contain different steroidal lactones and alkaloids like withaferin
- Effects are still under research, plant is believed to have sedative and immunostimulating, adaptogene and anti-stress properties

Ashwaganandha



Withaferin

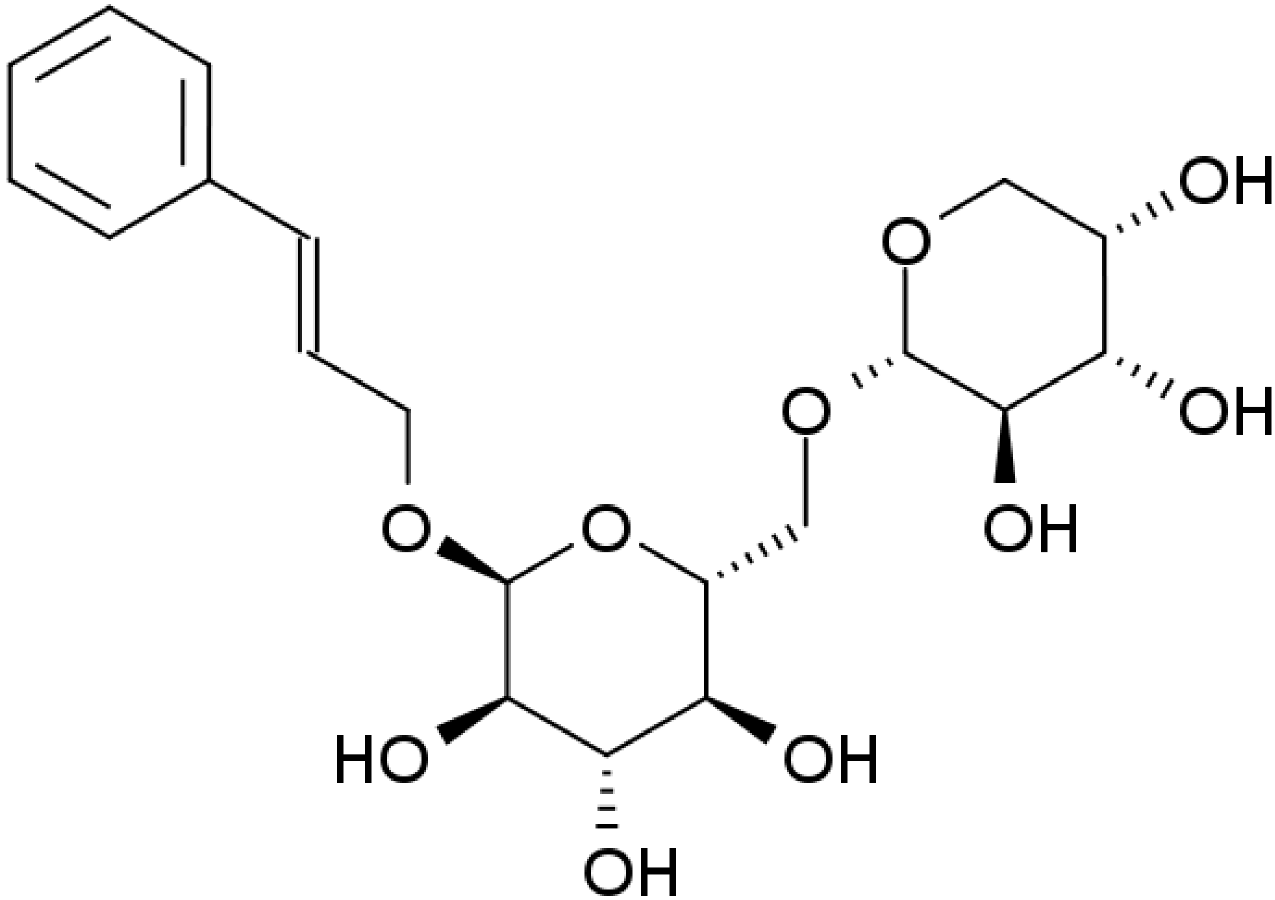


Golden root, *Rhodiola rosea*, Crassulaceae, North Hemisphere

- Traditional plant in Siberian medicine, went to Europe and to TCM
- Roots contain rosavin glycosides
- Have anti-stress, stimulating and adaptogene properties

Golden root

Rosavin

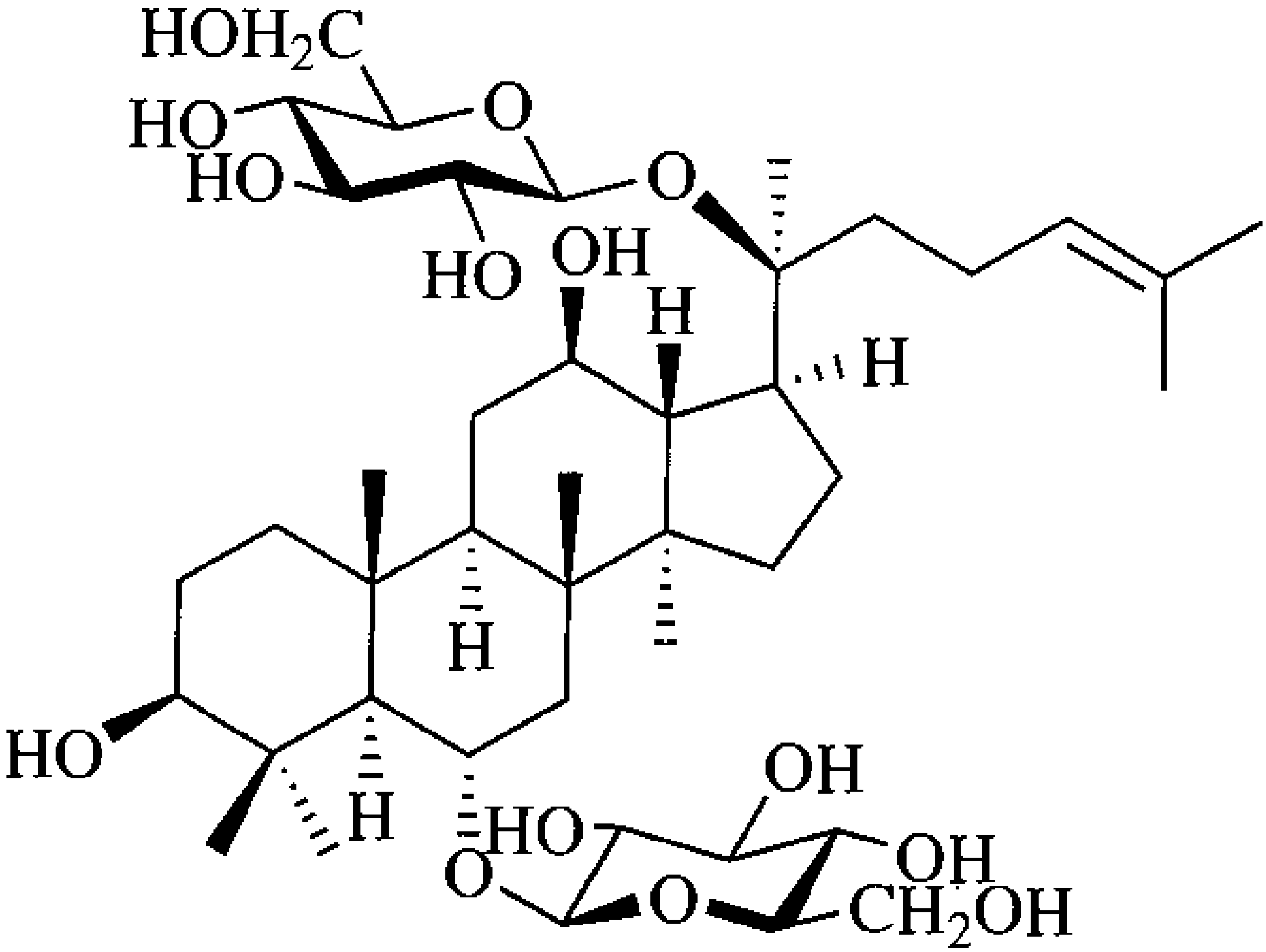


Ginseng, *Panax ginseng*, Araliaceae, East Asia

- Extremely important TCM plant
- Active components are ginsenosides
- Facilitate metabolism, improve concentration, increase level of adaptation, etc. etc.
- American ginseng (*Panax quinquefolius*) and Siberian ginseng (*Eleuterococcus senticosus*) contain similar compounds

American ginseng

Ginsenoside



Gotu kola, *Centella asiatica*, Araliaceae, South Asia

- Traditional Ayurveda plant, belongs to “rasayana”
- Contains multiple glycosides (centelloside etc.) which have immunostimulatory and sedative effects

Gotu kola

Maca, *Lepidium meyeri*, Cruciferae, South America

- Also called "Peruvian ginseng"
- Contains multiple benzyl glucosinolates and polyphenols with stimulatory and sexual enhancement effects
- There is a possibility (small though as maca roots are boilde and/or dried) that some harmful compounds present, it is not recommended to eat it fresh

Maca

Reishi (Lingzhi) mushroom, *Ganoderma* spp., Polyporaceae, East Asia

- Important component of TCM, "fungus of immortals"
- Triterpenes (like ganoderic acids) have general tonic and cholesterol-lowering effects

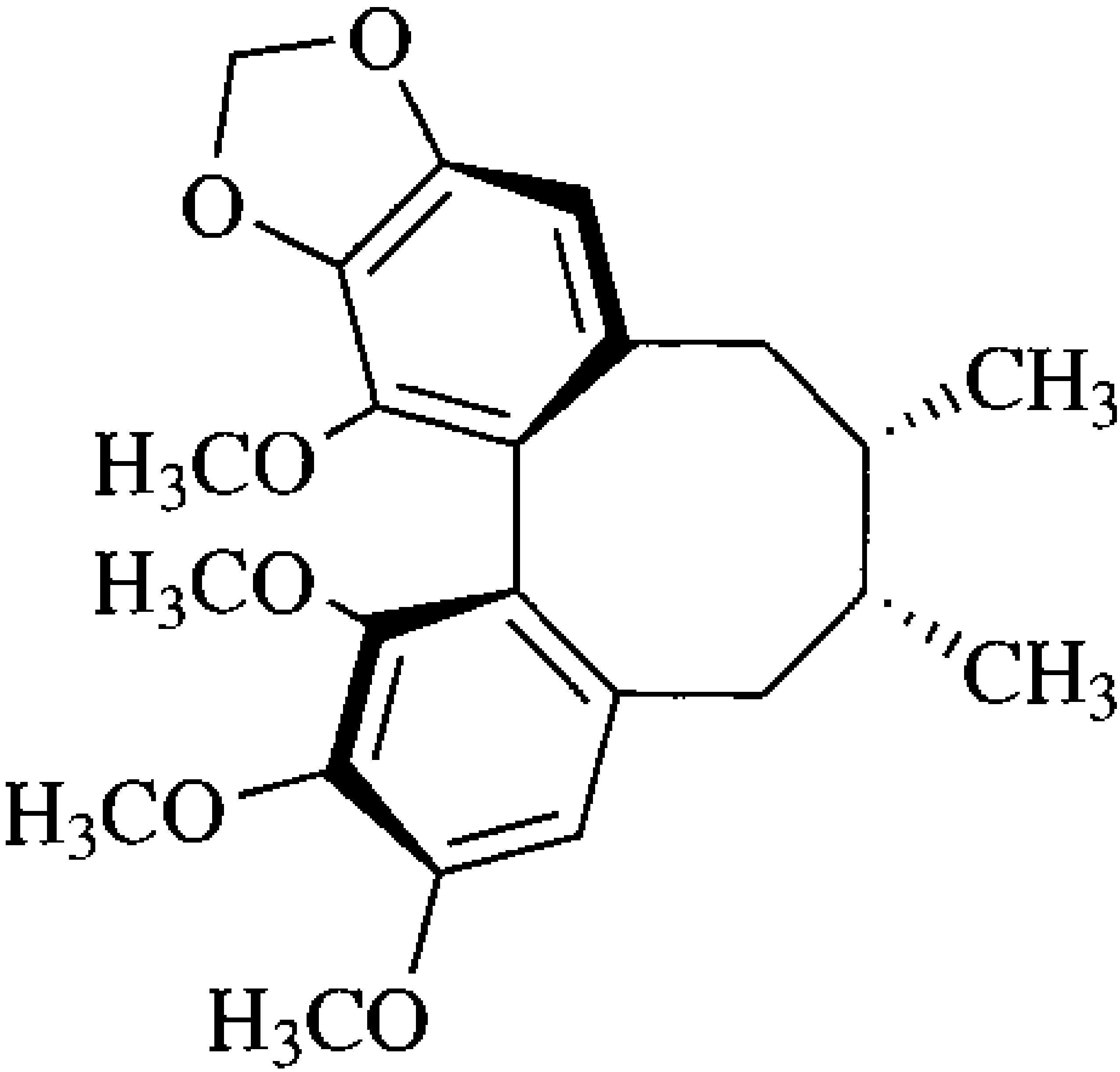
Lingzhi

Magnolia vine, *Schisandra sinensis*, Schisandraceae, East Asia

- Berries contain lignans like schizandrin
- In TCM, it is believed to prolong life via increasing the "vital energy"
- Clinical investigations provide some support for antioxidative, brain-stimulating and even anti-cancer activities

Magnolia vine

Schizandrin



Summary

- Anti-cancer plant compounds often suppress cell division
- Many supportive plants are still waiting for the scientific evidence of their effects
- Anti-inflammatory, antibacterial and astringent compounds are most important for treating cold and skin diseases
- Plant quinones and essential oils tend to be antimicrobial

For Further Reading

References

[1] A. Shipunov. *Ethnobotany* [Electronic resource]. 2011—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_310`

[2] Heinrich et al. 2012 (or 2004). *Fundamentals of Pharmacognosy and Phytotherapy.* Churchill Livingstone, Edinburgh. Mode of access: `http://ashipunov.info/shipunov/school/biol_310/heinrich2004_fund_pharm_part.pdf`

Outline

38 Fruits and vegetables

38.1 Introduction

Fruits—and vegetables

- The main "common sense" difference is the low amounts of sugars in vegetables, plus tree origin of fruits
- However, there are multiple exceptions: beet, avocado, plantains etc.
- In addition, pumpkins and relatives (melon, watermelon, squashes) normally treated as separate group
- Morphologically, fruits are fruits (and sometimes seeds like litchi or pomegranate, or riped inflorescences like pineapple or fig), and vegetables are everything else

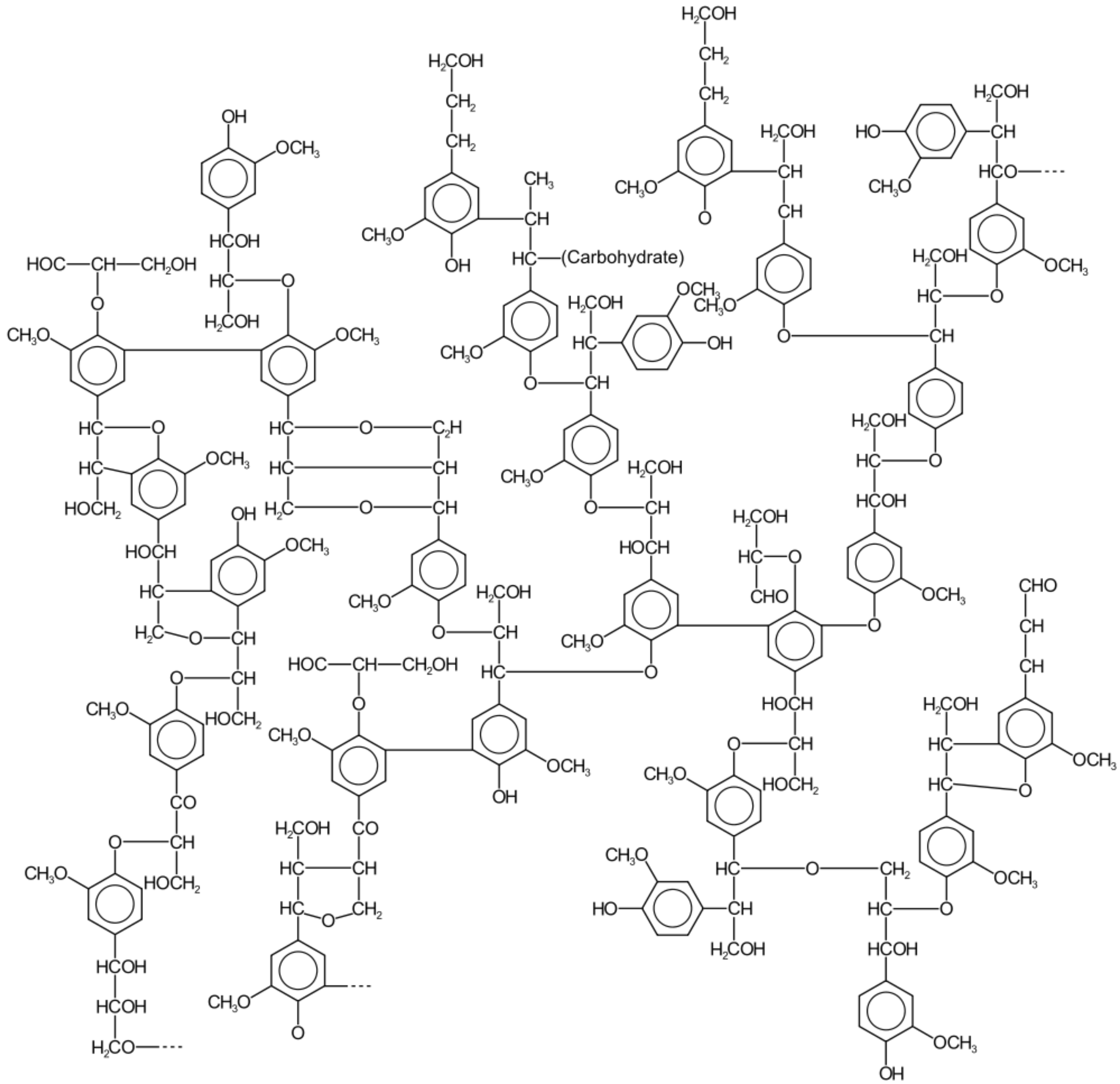
Main components of fruits

- Water
- Dietary fiber
- Sugars
- Organic acids
- Vitamins

Dietary fiber

- Polysaccharides
- Lignin
- Other constituents of plant cell walls (glycoproteides etc.)
- Improve intestinal transit, lowering the risk of colorectal cancer

Lignin



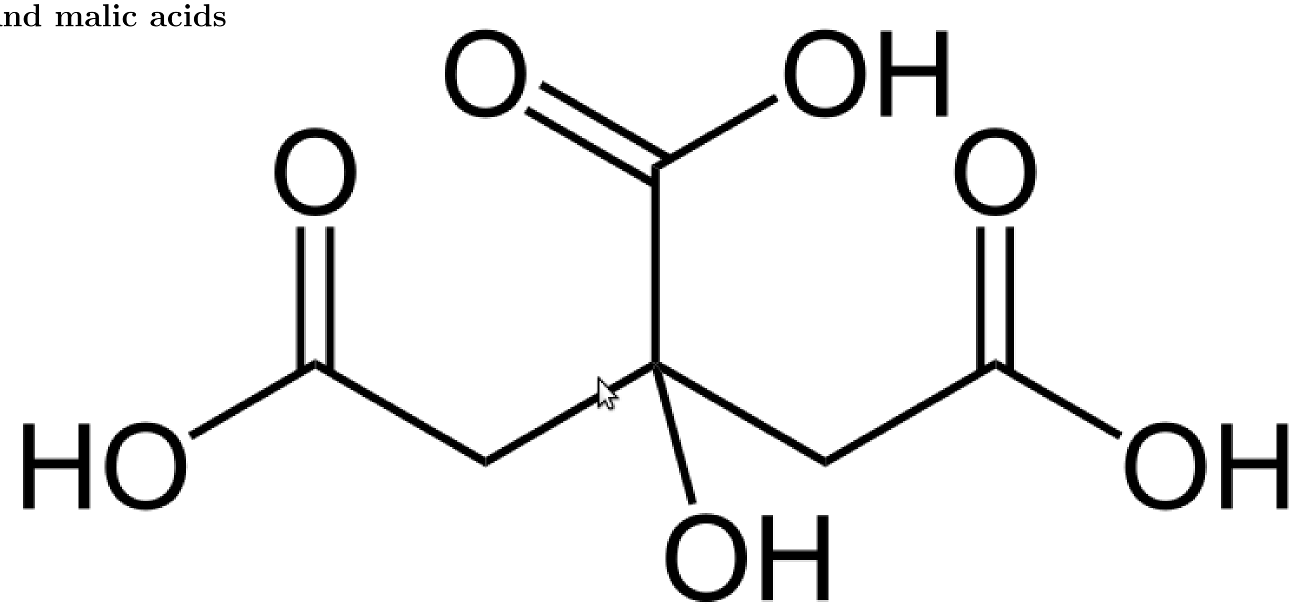
Fruit sugars

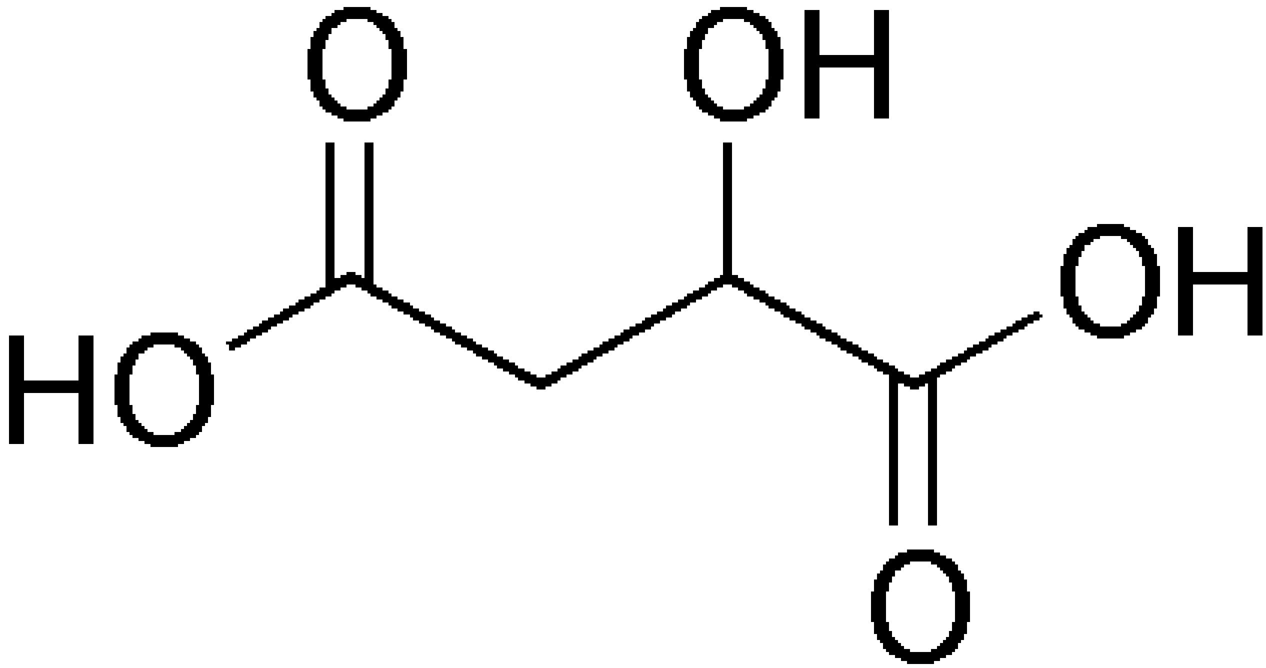
- Mostly fructose and its derivatives (kestoses)
- Sweeter 1.7 times more than sucrose, but only at room temperature

Organic acids

- Malic (*Pyrus malus*, apple and other Rosaceae fruits)
- Citric (*Citrus* fruits etc.)
- Tartaric (e.g., in wine)
- Are good antioxidants

Citric and malic acids

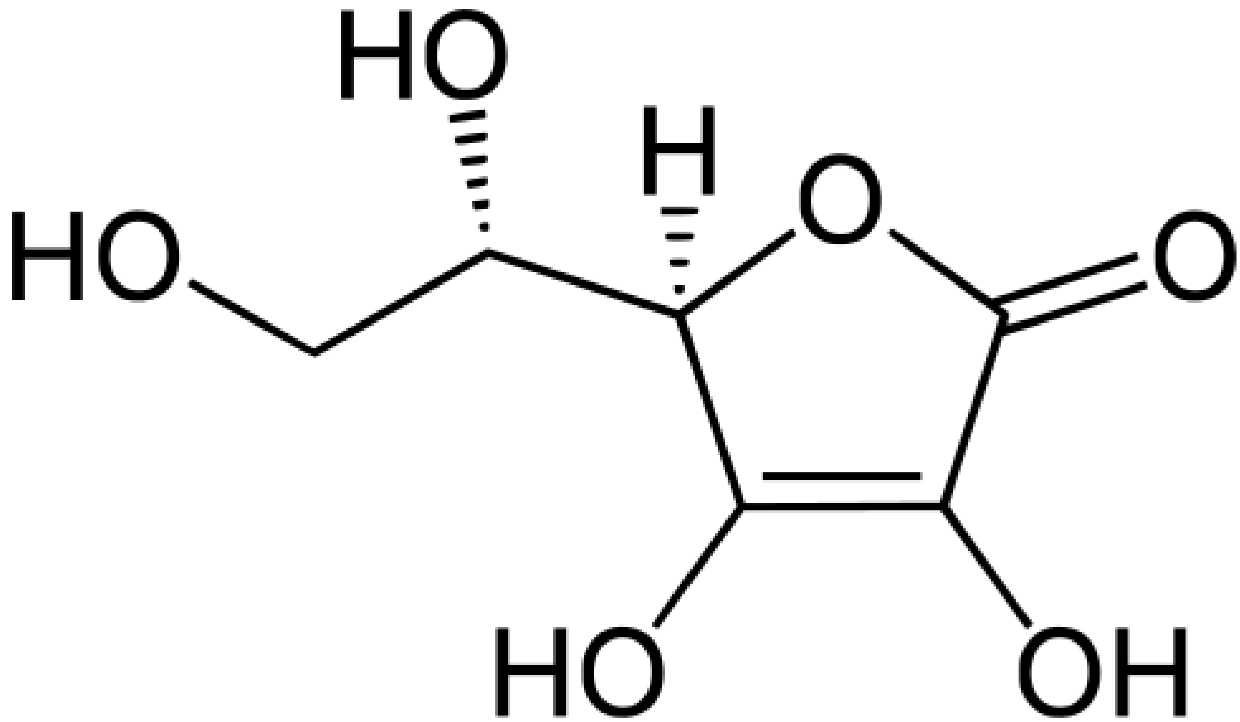


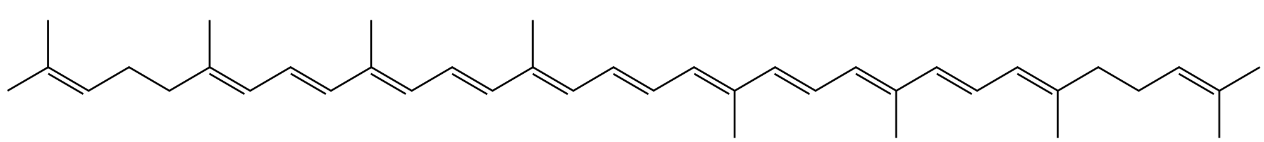


Fruit vitamins

- Vitamin C (ascorbic acid)
- Pro-vitamin A (β-carotene)
- Other carotenes (lycopene etc.)

Ascorbic acid and lycopene

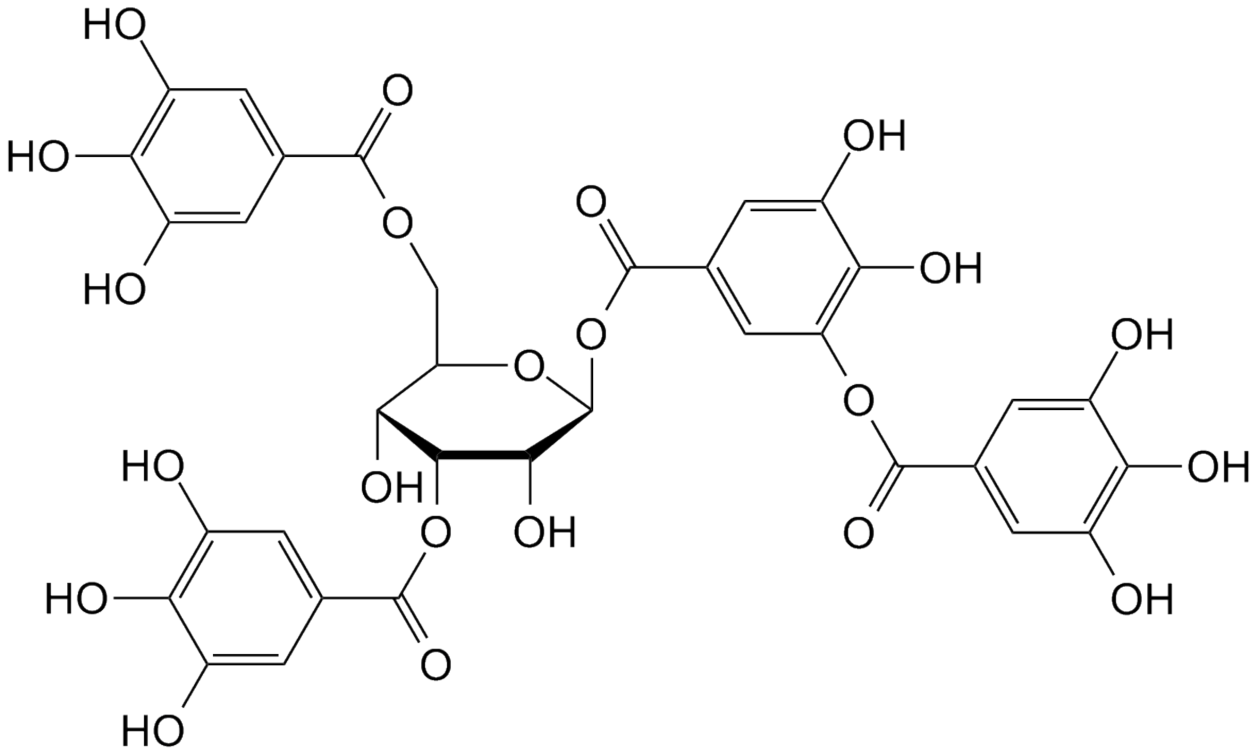




Specific components which are restricted to few species

- Lipids
- Starch
- Gums, mucilages, pectins
- Astringent chemicals (e.g., tannic acid)
- Aroma compounds
- Other secondary* metabolites (latex, alkaloids, glycosides)

Tannic acid



38.2 Rosaceae fruits

Rosaceae in general

- Medium-sized family (≈3,000 species) of small trees, shrubs and herbs from subtropical and temperate regions
- Flower contains numerous stamens (secondary multiplied), free pistils and hypanthium: modified receptacle
- Fruit is mostly fleshy

Rosaceae groups

- Rosoideae—herbs or shrubs, leaves often compound, receptacle large, fruit aggregate
- Spiraeoideae—shrubs or trees, leaves simple, receptacle small, fruit often monomerous
- Maloideae—trees, leaves simple, receptacle and pistils fused

38.3 Rosaceae with multiple fruits

Rosaceae with multiple (aggregate) fruits

- Most primitive group
- Tangled genetic systems: apomixis, polyploidy and permanent odd pentaploidy ($2n = 35$ in *Rosa canina*)
- *Rosa* is ornamental and medicine plant with
- *Rubus* and *Fragaria* are also widely cultivated

Rubus

- Biennial semi-shrubs, sometimes herbs
- Multiple wild species, only two are widely cultivated: raspberry (*Rubus idaeus*) and blackberry, *Rubus caesius* forms and hybrids

Rubus idaeus from Koehler's "Medizinal Pflanzen"

Rubus features

- Two aboveground stem types: primocane and floricane, plus underground rhizomes
- Fruits contain (among other) salycilic acid and different antioxidants

Blackberries on the different stages or ripening

***Fragaria* $\times$*ananassa*, strawberry**

- Octoploid ($2n = 56$) hybrid species of two other octoploid strawberries, *Fragaria virginiana* from North America and *F. chiloensis* from Chile.
- Garden hybrid, first occurrences are in France from ≈1740
- Herb with runner stems and accessory multiple nut fruit (the edible part is a receptacle)

Strawberry features

- Susceptible to multiple diseases, often cultivated in semi-artificial conditions as plasticulture
- Cultivated as annual or perennial
- Long-day cultivars flower early in May and capable to produce fruits in June

Plasticulture of strawberries

***Rubus chamaemorus*, cloudberry**

- One of the northernmost berry plants
- Semi-shrub; the only dioecious *Rubus*
- Food of many Arctic mammals and birds, e.g. reindeer
- When ripe (yellow), have a creamy texture and tart taste
- Contains benzoic acid content acting as a natural preservative: stays all winter without additional preparations
- Rich of vitamin C: used against scurvy

Rubus chamaemorus

Roses as food plants

- Roses (*Rosa* spp. including North Dakota state flower, *Rosa arkansana*) are edible plants.
- Hypanthium is rich of vitamins, especially vitamin C. Typically, accessibility of vitamins from fruits are higher than from synthetic products.

38.4 Rosaceae with stone fruits

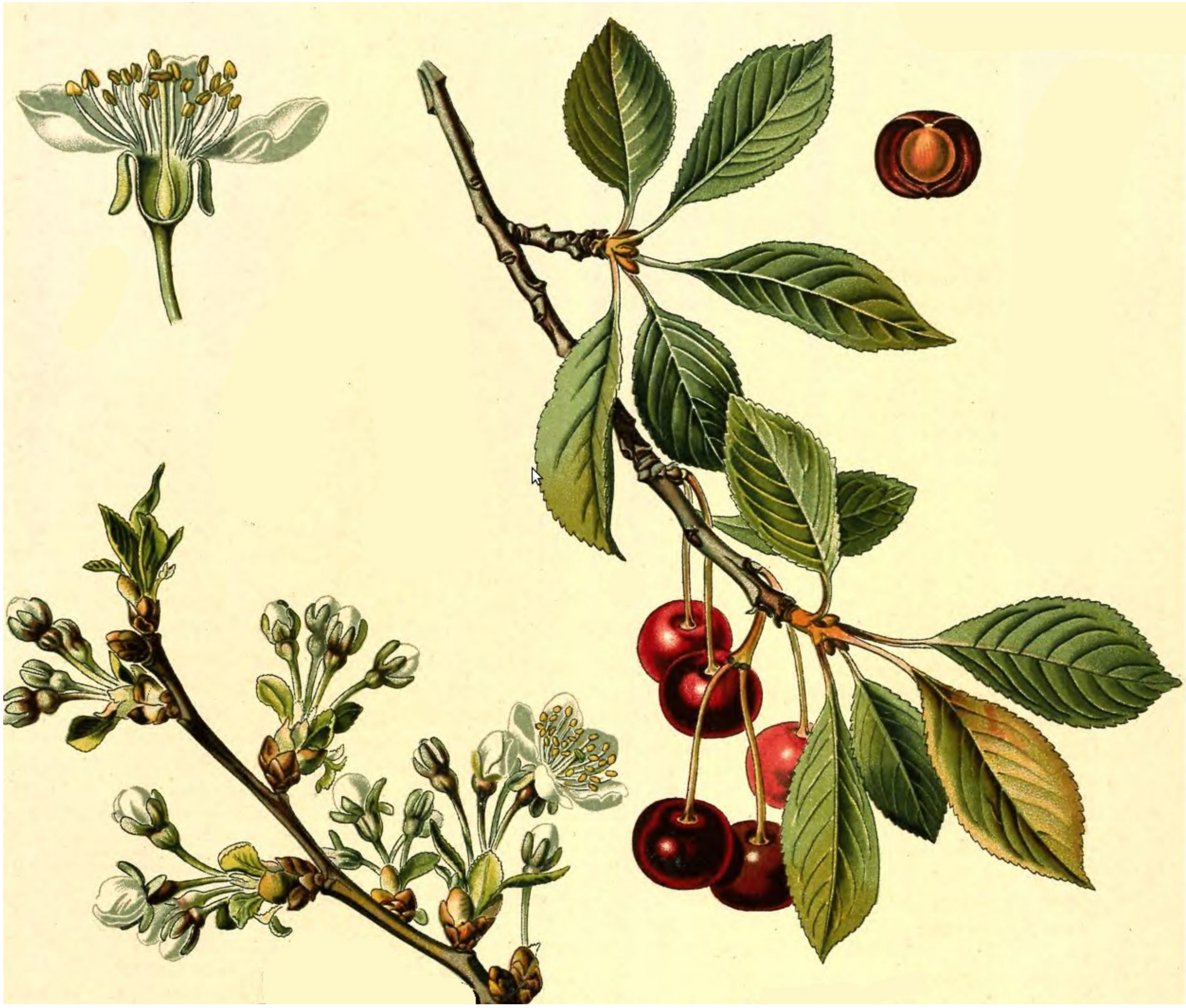
Rosaceae with stone fruits, *Prunus*

- Multiple (≈430) species often separated in different genera on the base of fruit morphology
- Often hairy exocarp, juicy mesocarp and stone endocarp
- Distributed almost equally among Eurasia and North America
- Flower before appearance of leaves, inflorescences are umbels

***Prunus avium*, cherry**

- Mediterranean tree, cultivated from Roman times
- Used also as timber and ornamental plant
- All parts except "berries" (drupes) contain cyanogenic glycosides
- Sweet/early and sour/late groups of cultivars.

Prunus



Cherry

Other cherries

- Black cherry (*Prunus serotina*) and choke cherry (*Prunus virginiana*) are two frequently cultivated North American species
- Choke cherry is a state fruit of North Dakota
- It is also a hosts of tent caterpillar, *Malacosoma* sp.

Choke cherry

“Nest” of tent caterpillars

***Prunus armeniaca*, apricot**

- Old culture of Central Asian origin, later spread into China and Europe
- Dry fruits were traditionally used as sugar source (along with melon)
- Fruits contain oil of cooking quality
- Biggest producer is Turkey

Drying apricots in Cappadocia, Turkey

Prunus ×domestica, plum

- Hybrid hexaploid ($2n = 48$) species, originated from cherry plum *Prunus divaricata* ($2n = 16$) and blackthorn *P. spinosa* ($2n = 32$)
- Probably of Caucasian origin, contemporary cultivars are even more complicated hybrids
- Well-known laxative fruit
- Chinese "plum" is a separate species, *Prunus mume*—kind of intermediate between apricot and plum

Plums

Blackthorn

Cherry plum

Chinese plum drawing

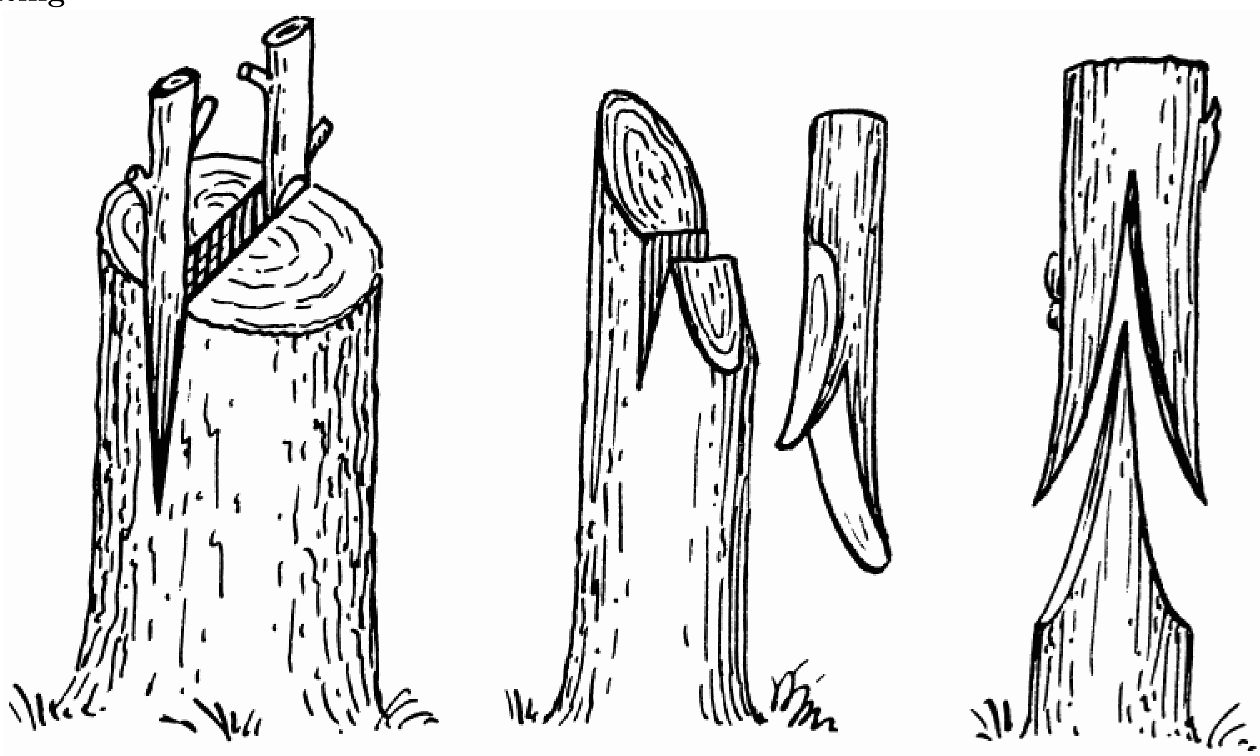
Prunus mume

Prunus persica, peach

- Tree of Chinese origin, cultivated from 1,100 BC and spread to Europe with Alexander the Great army
- Multiple cultivars including nectarines (result of bud sport mutation) and Chinese flat peaches
- Propagated mostly by grafting on adequate rootstocks (many other *Prunus* species)
- China is still a biggest producer

Chinese flat peach

Grafting



38.5 Rosaceae with pome fruits

Pome fruits

- Result of fusion between hypanthium and pistils
- The edible part is a hypanthium wall

Pyrus malus, apple

- Sometimes treated as separate genus *Malus*, in this case species has a name *Malus domestica*
- Eurasian origin, common forest plant in Europe
- Eastern Turkey is the center of species diversity

Malus

Apple features and history

- Old culture, cultivation started in pre-Roman times
- Brought to North America in 1625 (first apple tree near Boston)
- Massive mythological background
- Temperate culture; in tropics, leaves should be removed if flowering required on next year
- Biggest producers are China, U.S. and Iran

Apple pollination

***Pyrus communis*, pear**

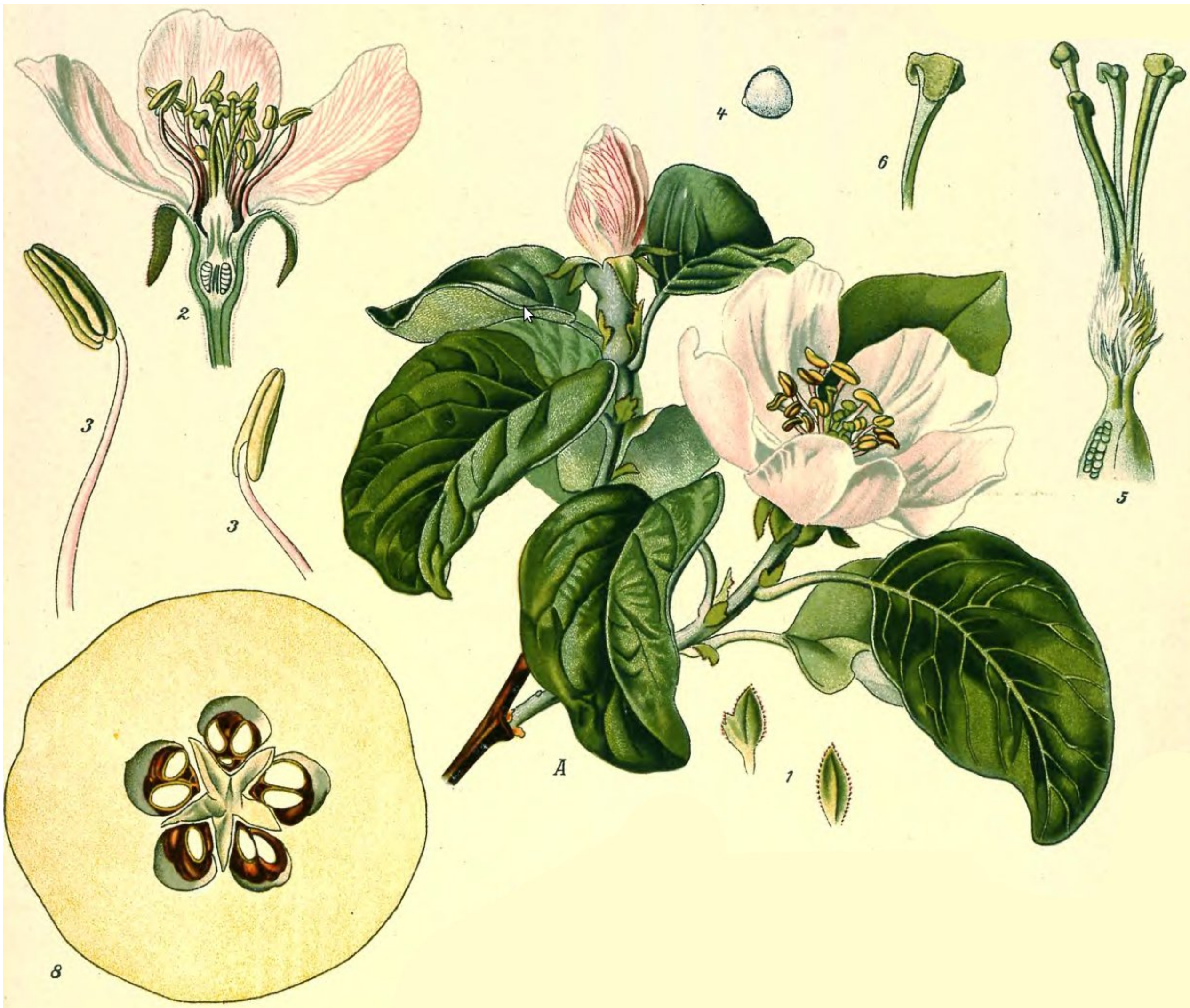
- Some branches transform to thorns
- Chinese origin, cultivation started there before 1,000 BC
- Went to Europe in ancient Greek times
- *Pyrus pyrifolia* is a close species—Asian pear

Asian pear, *Pyrus pyrifolia*

***Cydonia oblonga*, quince**

- Caucasian origin, spread to the cultivation in Balkans
- Rich of microelements
- Used mostly for jams and jellies

Cydonia



Quince flowers

Quince fruits

***Chaenomeles japonica* and hybrids, Japanese Quince**

- East Asian deciduous spiny shrubs, usually small
- Red flowers and relatively big, hard fruits
- Fruits are edible after frost ("bletted")
- Have more vitamin C than lemons (up to 150 mg/100 g)

Japanese Quince, *Chaenomeles*

***Mespilus germanica*, medlar**

- Caucasian hardy culture
- Contains significant amounts of pectins, used for jams and jellies

Medlar fruits

***Eriobotrya japonica*, loquat**

- Evergreen tree from central China
- Flowering in November, has fruits in April and May
- Cultivated also as ornamental plant

Loquat flowers

Loquat fruits

Aronia spp., chokeberries

- North American genus with 2–3 species, grows well in North Dakota
- Fruits are rich of antioxidants
- Used also as ornamental
- In Russia, cultivated hybrid (origin is still unclear, but probably with European common white-beam, *Sorbus aria*) *Aronia* ×*mitschurinii* is one of the northernmost fruit plants

Aronia ×*mitschurinii*

***Amelanchier* spp., serviceberry, juneberry**

- North American genus with ≈20 species, some are cultivating
- Fruits are rich of vitamins (A, C and even E) and minerals
- Grows well on poor soils and dry conditions, recommended for prairie cultivation

Serviceberry

Sorbus spp., mountain ash

- Large (up to 200 species) genus occurred in North America and Eurasia
- Most species have edible fruits
- European rowan (*Sorbus aucuparia*), and common whitebeam (*Sorbus aria*) are main cultivated species (also as ornamentals)
- Fruits are mostly used for wines, jams and jellies; bitter taste is normally gone after first frosts

European rowan, _Sorbus aucuparia_

Common whitebeam, *Sorbus aria*

***Crataegus* spp., hawthorn**

- More than 200 species of shrubs ans small trees from Eurasia and North America
- Many species are cultivated for their fruits and also as ornamentals, for aroma compounds and/or as tea surrogate
- Used in multiple traditional medicine practices, one proven use is treating chronic heart diseases

Hawthorn fruits

Summary

- The main "common sense" difference of vegetables is the low amounts of sugars, most vegetables are also herbs
- Most of fruits are sources of water, sugars, organic acids and plant vitamins
- Rosaceae is one of the most important temperate fruit families
- Most of Rosaceae cultivated fruits are result of long selection involved multiple hybridization
- Most of Rosaceae cultivated fruits are propagated by grafting on appropriate rootstocks

38.6 Citrus and related genera

***Citrus* and related genera**

- Belong to Rutaceae, ruta family, often treated as separate subfamily, Aurantioideae
- East Asian and/or Indonesian origin
- Have specific **hesperidium** fruit with flavedo exocarp, albedo mesocarp and membrane endocarp covered with juicy hairs

Trifoliate, *Poncirus*

- Spiny, hardy citrus, with compound leaves, growing even in warm temperate regions
- Used as a rootstock for grafting other species
- Fruits are bitter but contain vitamins and microelements

Poncirus trifoliata

Orange, *Citrus sinensis*

- All *Citrus* have unifoliate leaves but with a strip between petiole and leaf blade (remained from compound leaf)
- Chinese origin, before the Age of Discovery was known in Europe mostly as a legend about "golden apples"
- Mostly subtropical (not tropical) culture
- Also used as a rootstock for other species (e.g., grapefruit)

Lemon, *Citrus limon*

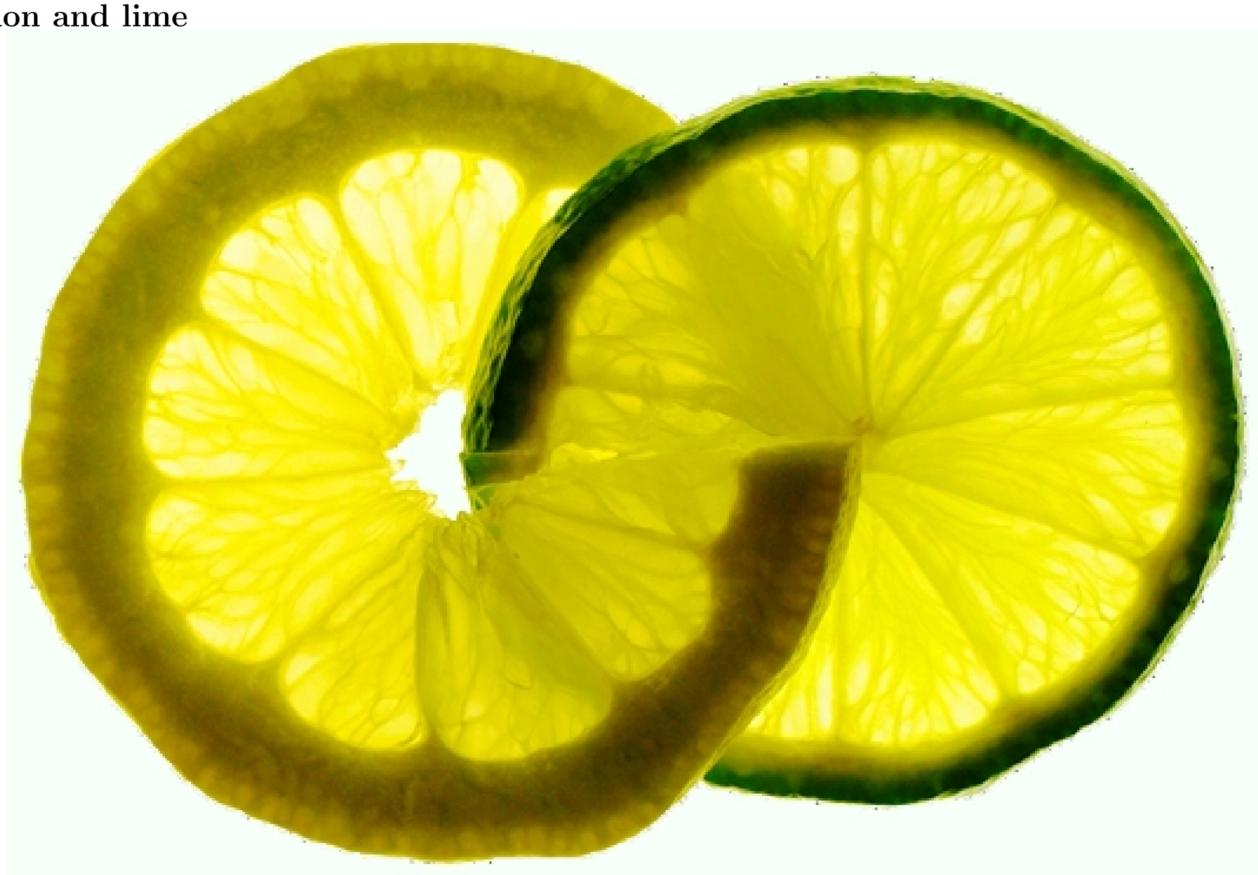
- Relatively big (4–6 m) spiny trees
- Flowers continuously
- Sour citrus, fruits contain up to 8% of lemon acid

- Introduced to Europe in 1000s
- There are cultivars for home growth

Lime, *Citrus aurantifolia*

- Pure tropical culture, damaged even with small frost
- Originated from Malaysia, but culture started in Caribbean
- Flavedo is green and thin; aroma compounds different from lemon

Lemon and lime



Mandarin, *Citrus reticulata*

- Extremely variable species, with multiple cultivars and hybrids
- Multiple names: tangerine, clementine, satsuma, unshiu
- Small trees or even shrubs with big leaves, some forms (unshiu) are hardy; all require humid climate

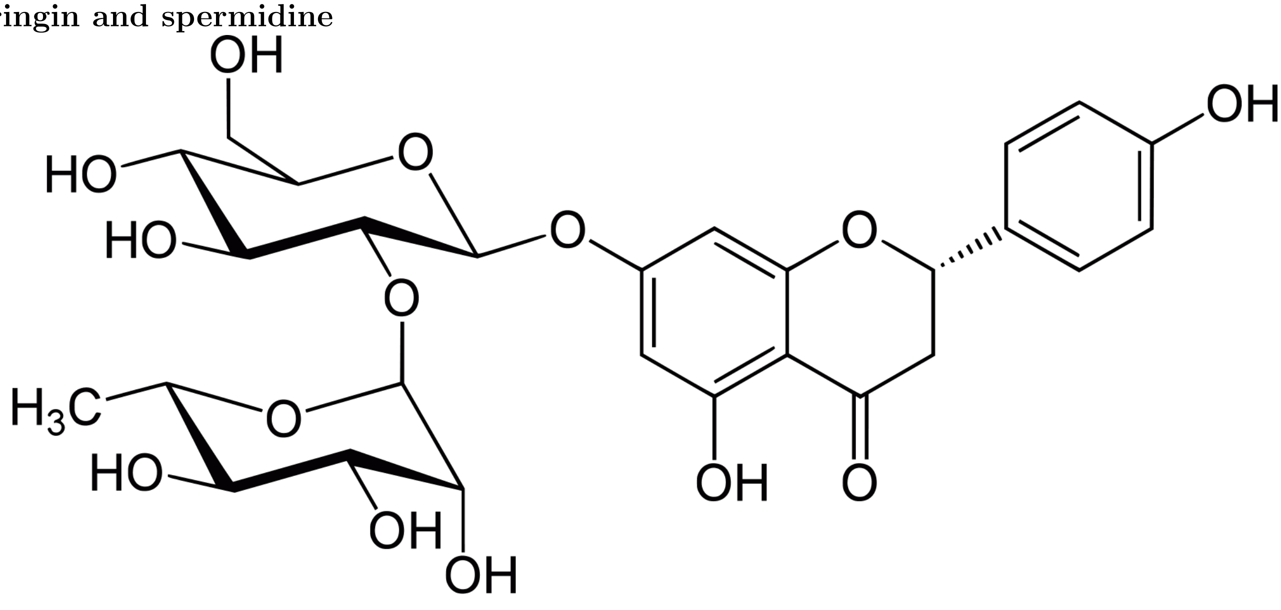
Mandarin

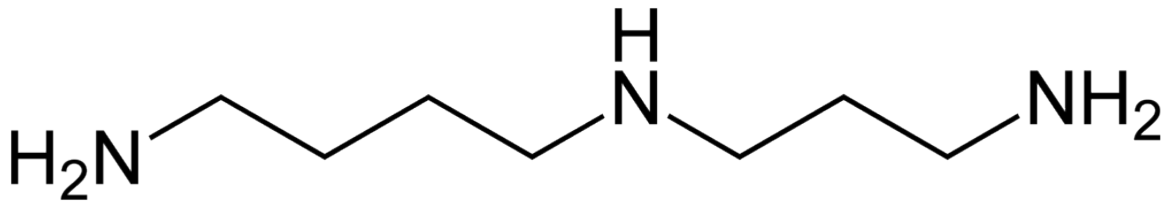
Grapefruit, *Citrus ×paradisi*

- Originated in 1750 in Barbados, most probably as a unique (!) hybrid between orange and pomelo (*Citrus maxima*)
- Cultivated mostly in USA and Caribbean countries
- Big tree, fruits larger than orange, with bitter taste due to **naringin**, the glycoside with digestive, tonic and anti-atherosclerotic effects
- Also contains significant amounts of vitamins B and polyamine spermidin (which is known to increase lifespan of different laboratory animals)

Grapefruit

Naringin and spermidine





Pomelo, ***Citrus maxima***

- Pomelo, shaddock (by name of captain Shaddock who brought it to Caribbean) is widely cultivated in Thailand and neighboring countries
- Largest citrus (up to 15 m), fruits also large, up to 3 kg, contain naringin
- Tropical culture, may be cultivated even on seashores

Pomelo

Bitter orange, bergamot orange, ***Citrus aurantium***

- Used mostly as a source of strong aroma compounds
- Also known as appetite suppressant
- Component of different liquors and Earl Gray tea

Bitter orange

Citron, *Citrus medica*

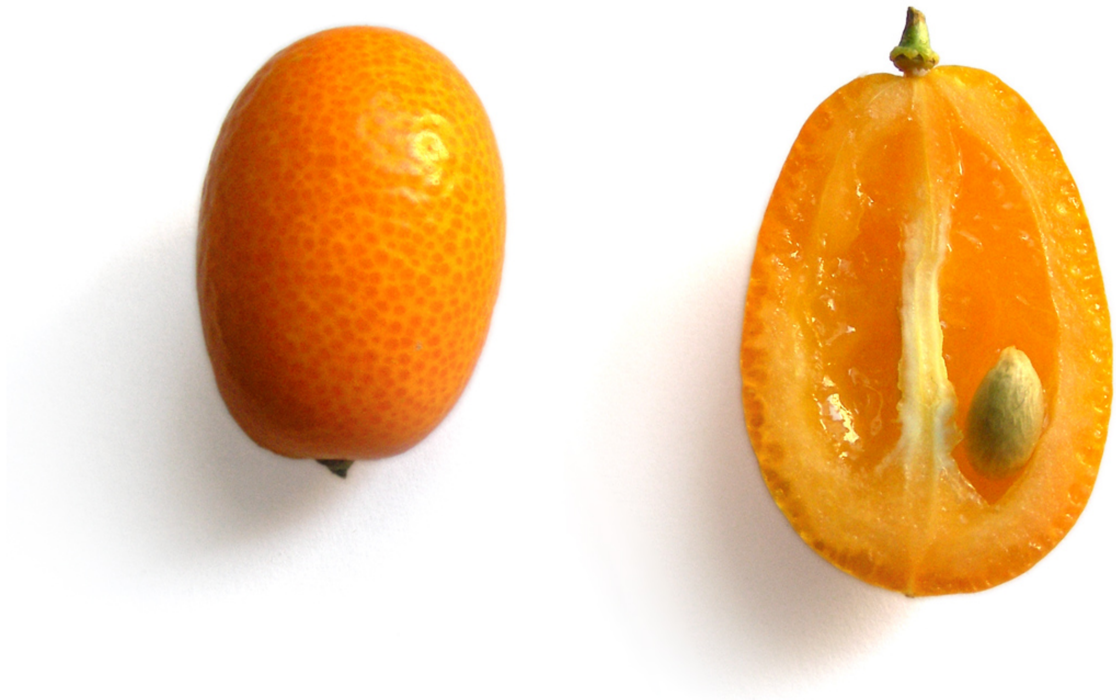
- Have large but somewhat bitter fruits
- Flavedo is thick, used raw and for candies
- Historically, was first citrus cultivated in Europe
- Famous "Buddha's hand" is *Citrus medica* var. *sarcodactylis*

"Buddha's hand" citron

Kumquat, *Fortunella* spp.

- Small evergreen trees from other genus (*Fortunella*) and 4 cultivated species, all from East Asia
- Sour fruit with sweet skin
- Widely hybridize with other citrus species

Kumquat



38.7 Important tropical fruits

Banana, *Musa acuminata*

- Belongs to Musaceae family of monocots
- Genus contains 11–13 species, all tropical
- Cultivated forms are seedless triploids with AAB genome, where "A" is a wild *Musa acuminata*, and "B" is *M. balbisiana*
- Fruits are rich of carbohydrates, vitamins of B group, iron and potassium

Wild diploid banana with seeds

Banana biology

- Perennial herbaceous (!) plant with large underground rhizome
- Rhizome produce groups of leaves with connected petioles (pseudo-stem)
- Inflorescence will grow through pseudo-stem and produce up to 3,000 flowers, male and female
- Wild forms are often bird-pollinated, cultivated forms are parthenocarpic

Banana corms

Banana flowers

Banana agriculture

- Propagated with slices of rhizome (corms)
- Initial growth of pseudo-stem is 5–6 months, then fruits appear after 2–3 month
- Critical to humidity (must be high) and soil richness (planted often on burnt forest plantations)

Banana plantation

Banana history

- Probably originated in southeast Asia and then distributed across the world before age of exploration
- Two main cultivar groups selected: fruit bananas and plantains (vegetable, starch-containing bananas)
- Biggest producers are India, Philippines and China

Summary

- *Citrus* is a group of genera with no wild species; different species and even genera can hybridize almost freely
- Banana is a giant perennial herbaceous plant with no true aboveground stem

Pineapple, *Ananas comosa*

- The only fruit from Bromeliaceae family
- Herbaceous plant
- "Fruit" is a riped inflorescence (infructescence, pseudocarp)

Pineapple biology

- Perennial herb with rigid, spiny, succulent leaves
- Leaf rosette serves as reservoir for water
- Inflorescence is a dense spike, where all flowers are fused

Pineapple flower

Pineapple agriculture

- Needs semi-dry tropical climate and lots of fertilizers
- Flowering is normally being induced by sodium acetylide and water reaction, resulted ethyne acts as a flower-stimulated hormone
- Harvesting is dangerous due to presence of protein-digesting enzyme bromelain

Pineapple field

Pineapple history

- Pineapples are extremely rich of sugars, vitamin C and essential mineral manganese (Mn)
- Originated in South America, probably near contemporary Paraguay, wild relatives are unknown
- Cultivated in greenhouses in XVIII-XIX centuries, burning dung was typically used as a source of ethyne
- Thailand and Brazil are biggest producers now

Mango, *Mangifera indica*

- Evergreen massive tree from sumac (Anacardiaceae) family. Cultivated in most tropical countries, especially in Africa and South Asia.
- Low fertilization rate, from hundreds of flowers only few produce fruits
- Plant of monsoon climate: requires both dry and humid season
- Dwarf mango, Ataulfo mango = *Mangifera indica* 'Mango Ataulfo'
- Manual planting, pruning, harvesting but may give fruits for 300 years
- Rich of vitamin C, A and antioxidants; known to prevent colon cancer

Mango flowers

Papaya, *Carica papaya*

- Belongs to small family Caricaceae (close to Cruciferae)
- One of the most widely cultivated tropical plants

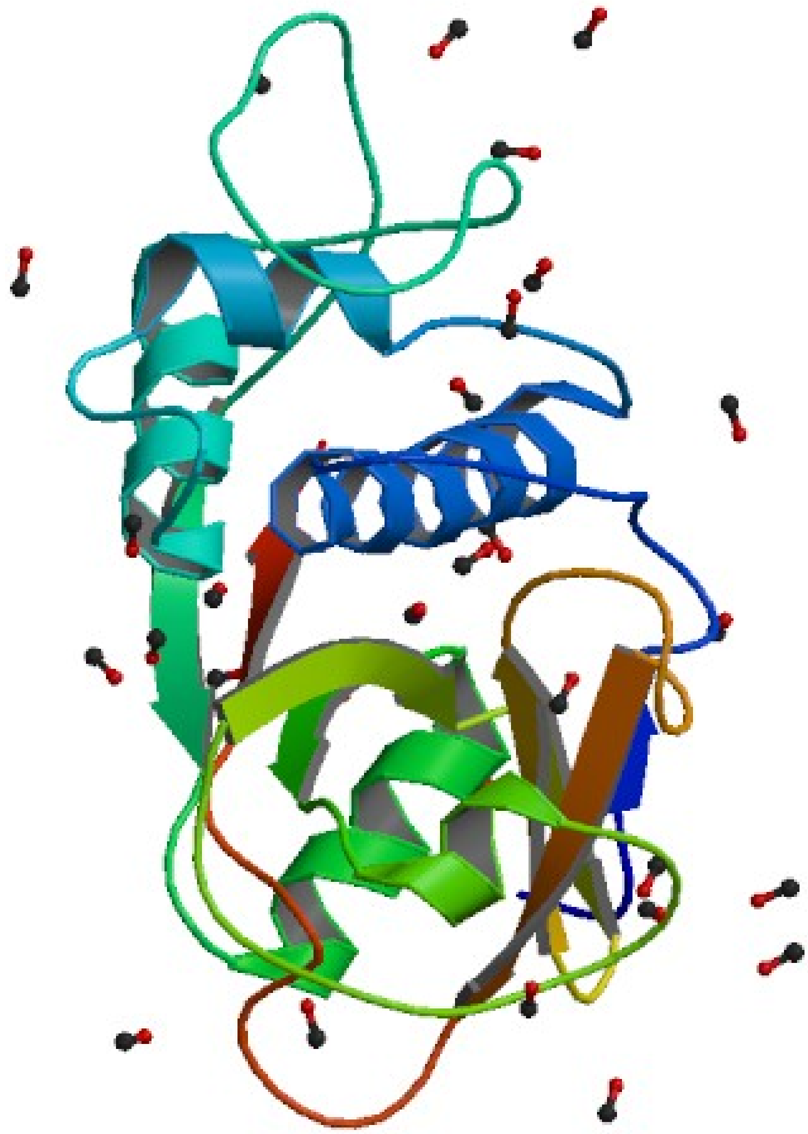
Papaya biology

- Fast growing, palm-like tree with short lifespan ($<$ 20 years)
- Flowers of three kinds: male, female and hermaphroditic, there are $\approx$50 sexual forms
- Fruits contain seeds rich of mustard oils (like in cabbage family); fruits themselves are rich of starch, sugars, vitamin A and lycopene, and also of papain, peptidase enzyme

Papaya plantation

Papaya flower

Papain enzyme



Papaya history

- Domesticated in southern Mexico in Aztec time
- It is still unclear if papaya occurred in south-west Asia before the age of exploration
- Culture of wet tropical climate, Brazil is the biggest producer

Avocado, *Persea americana*

- Representative of Lauraceae family
- Fruits are rich of fats (14%, mostly monounsaturated) and poor of sugars ($< 1\%$)
- Also contain vitamins B (including folate, B_9), A, K and potassium

Avocado biology

- Medium-sized evergreen tree
- Flowers are cross-pollinated, there are morning-female (A) and day-female (B) races
- Cultivars are mostly propagated by grafting
- Seeds are easy to germinate

Avocado tree

Avocado flowers

Avocado pollination

Avocado seedling

Avocado history

- Domesticated in Central America (Mayan civilization)
- Spread in many other places, including California
- Was first fruit of aircraft delivery
- Mexico and China are now biggest producers

Passion fruit, *Passiflora edulis*

- Other names: maracuja, granadilla
- Belongs to Passifloraceae family and passionflower genus, *Passiflora*
- Amazingly complex flower structure

Passionflower

Passionfruit

Passion fruit features

- Perennial vine, flowering twice a year
- Pollinated with birds and big insects
- Extremely rich of vitamin C

Litchi, lychee, *Litchi sinensis*

- Evergreen tree from Sapindaceae family
- Old traditional Chinese culture, cultivation started 2,000 BC

Litchi

Litchi seeds

Litchi features

- Edible part of litchi fruit is seed aril (seed attachment)
- Contain significant amounts of minerals like phosphorous and copper
- Mycorrhizal tree
- Fruits are canned for transportation
- There are two related cultures, rambutan Nephelium lappaceum and longan Dimocarpus longan

Durian, *Durio* spp.

- Several cultivated species, representatives of Malvaceae family
- Large size, unique odor and thorned fruit surface
- "King of the fruits"
- Odor is unusual, it is the reason why durian is banned, e.g., in public transportation. "Smell evokes reactions from deep appreciation to intense disgust, and has been described variously as almonds, rotten onions, turpentine and gym socks"...

Durian

Durian tree

Durian features

- Large tropical trees, fruits may be dangerous because they heavy, thorned and located very high
- Fruit content is rich of carbohydrates and fats
- Originated in Indonesia and became popular in Europe only in XX century

Eating durian

Carambola, starfruit, bilimbi *Averrhoa carambola*

- Tree native to Philippines
- Belongs to Oxalidaceae family
- Tree of tropical wet forests

Starfruit

Carambola features

- Harvested year round
- Fruits are rich of water, vitamin C and oxalic acid (family character)
- Contains antioxidants

Guava, *Psidium* spp.

- Representative of Myrtaceae, the family rich of useful species with medicine and other values
- All parts of plant contain essential oils
- More than 100 species, all are edible, some are cultivated (like *Psidium guajava*)

Guava flowers

Guava fruits

Guava features

- Originated in Central America
- Fruits contain up to 12% of sugars, diverse minerals (e.g., iron), many pectins
- In India, often consumed with salt

Tamarind, *Tamarindus indica*

- The rare fruit legume (Leguminosae)
- One of traditional national Indian fruits
- Edible part of fruit is a pulp, endocarp filling all spaces between seeds

Tamarind

Tamarind candy (India)

Tamarind features

- Plant of multiple uses, legumes used also as starch source (for flour), leaves as vegetables, all parts as medicine
- Normally, do not cultivated in plantations, it is a typical "street tree"
- Well adapted for monsoon climate
- Originated in Africa and was introduced to India in prehistoric times

Acerola, barbados cherry, *Malpighia glabra*

- Caribbean tree from Malpighiaceae family
- Fruits are typically sour, known as a richest source of vitamin C (2% of dry mass)
- Also have antioxidant value

Acerola

38.8 Important subtropical fruits

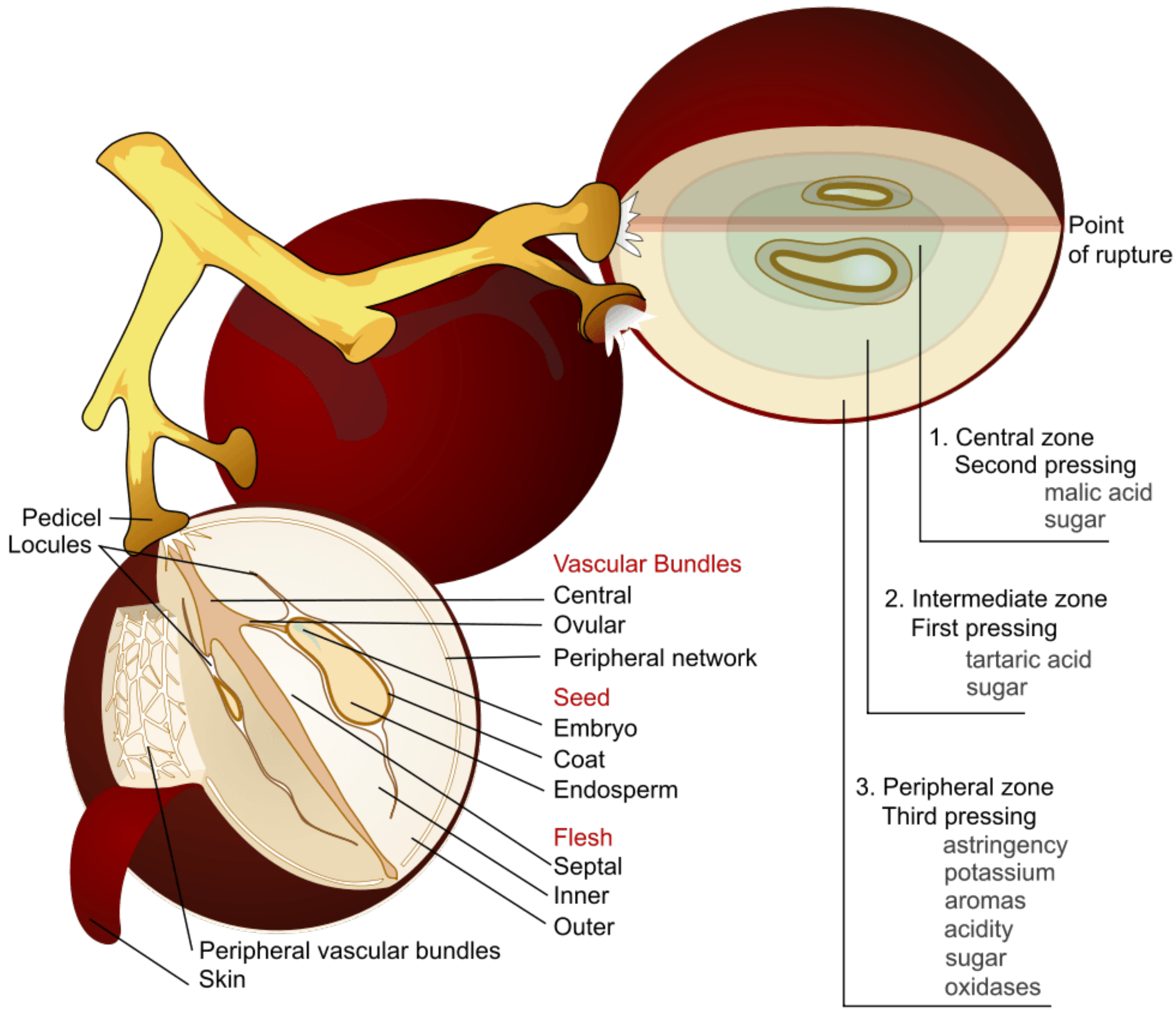
Grape, *Vitis vinifera*

- Belongs to grape family, Vitaceae
- Genus has 70 species, only several are cultivated

Grape biology and agriculture

- Woody vine with tendrils (modified shoots) and palmately lobed leaves
- Agriculture always depend on local climatic conditions
- Forming and cutting are two extremely important techniques

Grape



Grape history

- Central Asian center of origin, cultivated from 4,000 BC
- In Europe, culture flourished in XVII–XVIII centuries
- Used for wine, glucose sugar (raisins) and oil

Persimmon, *Diospiros kaki*

- Belongs to mostly tropical blackwood family, Ebenaceae
- Large genus (200) but from subtropical deciduous species, only one is cultivated

Persimmons

Persimmon features and history

- Originates in China
- Fruits are rich of microelements and carotens
- Used also as dry fruit and in eastern medicine; wood is widely used for furniture

Persimmon tree in Japan

Pomegranate, *Punica granatum*

- Belongs to Lythraceae family, genus has only 2 species
- Semi-evergreen shrub

Pomegranate features and history

- The edible parts of fruit are seed arils (similar to litchi)
- Old Mediterranean culture
- Trees are flowering from 2nd year
- One of the most reach of biologically active compounds fruit: contain ellagitannins, punicalagins, polyphenolic catechins, gallocatechins and anthocyanins. They reduce heart disease risks, oxidation, stimulate digestion and immune system.

Pomegranate flower

Summary

- Multiple tropical fruits are mostly sources of vitamin C
- Many traditional Asian fruit cultures have also a medicinal value

Date palm, *Phoenix dactylifera*

- Belongs to palm family, Palmae; genus with several species which are cultivated mostly as ornamental palms
- Plant of multiple use: everything, from roots to dry stems, are used

Date palm

Date palm biology and agriculture

- Extremely tolerant to heat, may grow with temperatures above 50°C
- Does not tolerate precipitation; water is normally taken only from deeper soil layers
- Propagated with subsidiary shoots (grow faster than seeds)

Date palm history

- One of the oldest cultivated plants
- Dry fruits are the main food source in North Africa; ≈300 kcal per 100 g (highest among all fruits)
- Dates are rich of minerals, especially potassium, sodium and calcium

Fig tree, *Ficus carica*

- Belongs to mulberry family, Moraceae, and to one of the largest flowering plant genus, *Ficus* (≈1,000 species)
- One of the rare deciduous *Ficus*

Fig inflorescence

Fig tree biology and agriculture

- Edible part of fruit is the axis of inflorescence (like in pineapple)
- Have extremely complicated pollination system, including plants with sterile figs (caprifigs), fertile figs and fig wasps

Fig pollination: how complex is it

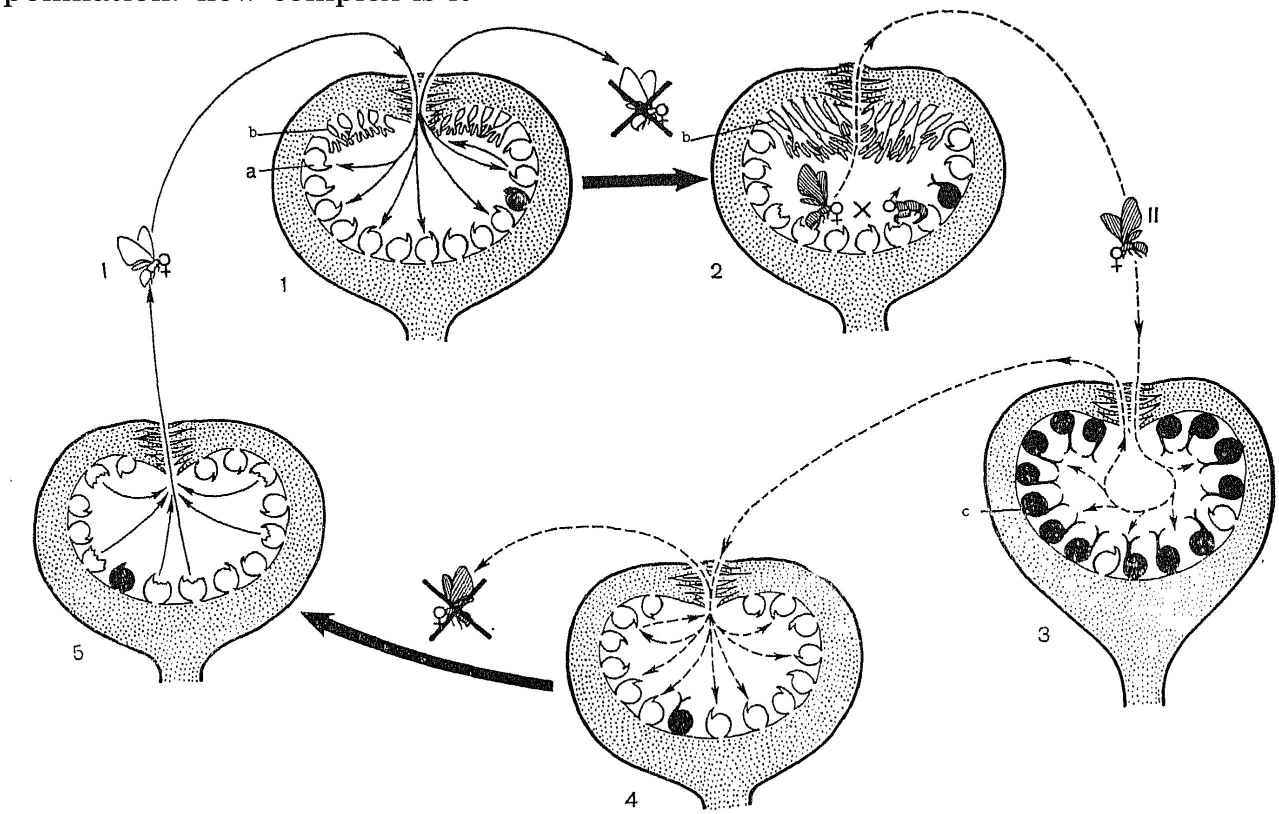


Fig tree history

- Cultivated from Old Testament times in West Asian center
- "carica" is from "Caria", the region in contemporary Turkey

Accursed fig tree (Tissot, illustrations for New Testament)

Mulberry, *Morus* spp.

- Same mulberry family, Moraceae
- Several species are cultivated: black (*Morus nigra*), white (*M. alba*) and red (*M. rubra*)
- Occurs both in Eurasia and North America

Mulberry

Mulberry features and history

- Deciduous trees, with compact raspberry-like inflorescences
- Infructescences are rich of sugars (≈22%), used raw, for wine, syrups etc.
- White mulberry is the feeding plant of silkworm, *Bombyx mori*

Silkworms on mulberry leaves

Cocoons

Kiwifruit, *Actinidia chinensis*

- Belong to Actinidiaceae family, genus contains ≈40 species
- Woody wines, cultivated mostly as ornamentals

Kiwifruit flowers

Kiwifruit biology and agriculture

- Dioecious, fast-growing plant
- Biggest problem is a pollination (needs saturation pollination with reluctant bees)
- Fruits rich of sugars, pectins, organic acid and enzyme actinidin (analog of papain and bromelain)

Kiwifruit history

- In China, was cultivated as ornamental
- After 30 years of intensive selection (started in 1904), New Zealand invented the kiwi fruit

38.9 Small temperate fruits, "berries"

Currants and gooseberries

- Belong to Saxifragaceae family; multiple species of genus *Ribes* are cultivated
- All are shrubs, gooseberries (*Ribes uva-crispa*) have spines whereas currants (mostly *R. rubrum* and *R. nigrum*) not
- Rich of pectins and vitamin C
- Their culture (and also barberry, *Berberis*) suffered in U.S. in 1930s during the fight with rust fungi (which infect wheats).

Gooseberry

Black currant

Blueberry and cranberry

- Belong to heath family, Ericaceae and genus *Vaccinium*
- *Vaccinium macrocarpon* is American cranberry; *V. corymbosum* is the most cultivated species of blueberries
- Have high food and medicinal value, provide vitamins, antioxidants (carotenoids) and organic acids; *V. vitis-idaea* (lingonberry) is probably most valuable

Blueberry

Cranberry

Cranberry harvesting

Lingonberry

38.10 Nuts

Nuts in general

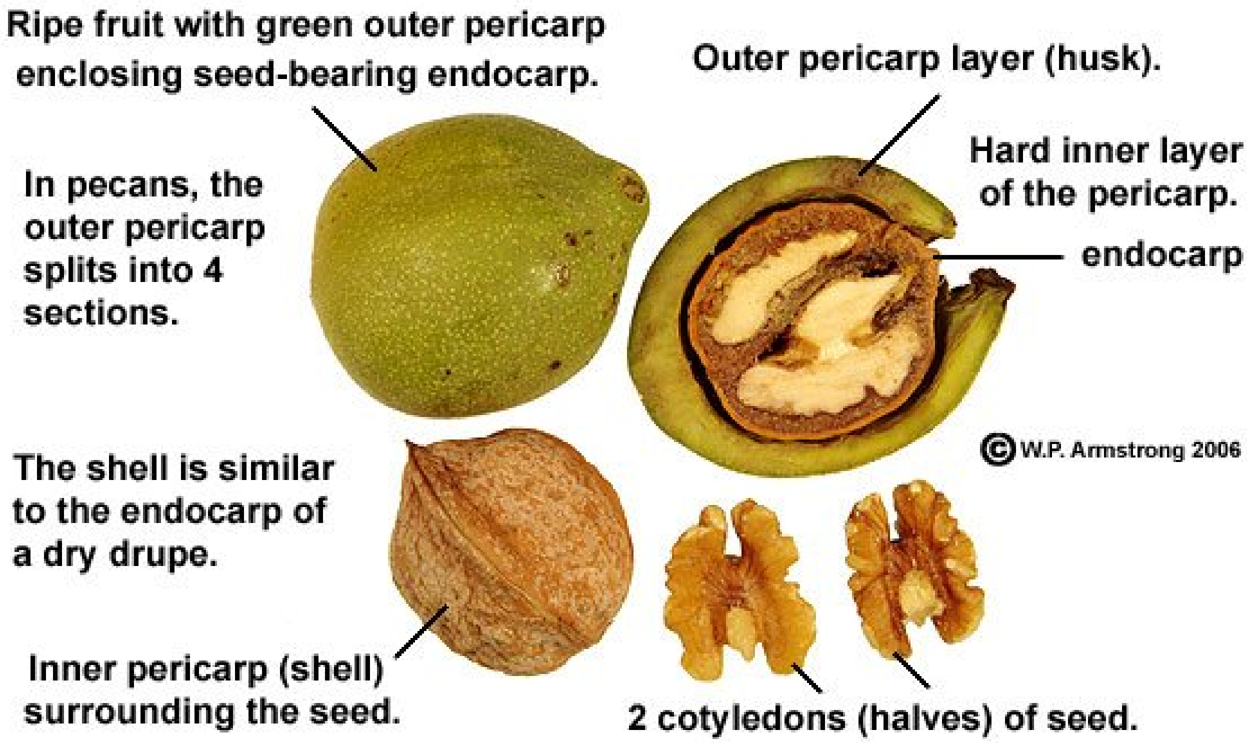
- Contain proteins and oil in seed endosperm and/or cotyledons
- The main way of dispersal is the weak memory of collecting animals
- (Among nuts, almond was partly covered in Rosaceae fruit section, the only difference of almond from other *Prunus* is that pericarp is all dry.)

Walnut, *Juglans regia*

- Genus belongs to walnut family, Juglandaceae, only one species of *Juglans* is cultivated
- Asian origin
- Huge deciduous tree, nuts are rich of tannins and group B vitamins

Walnut flowers

Walnut fruit



Pecan

- From hickory genus (*Carya*), cultivated is *Carya illinoiensis* (pecan)
- American origin
- Similar to walnut, but has less proteins and more sugars

Pecan

Hazelnut, *Corylus avellana* and other species

- Shrub of birch family, Betulaceae; several species are cultivated
- Nut is (among other common compounds) rich of carotenes

Hazel female flower

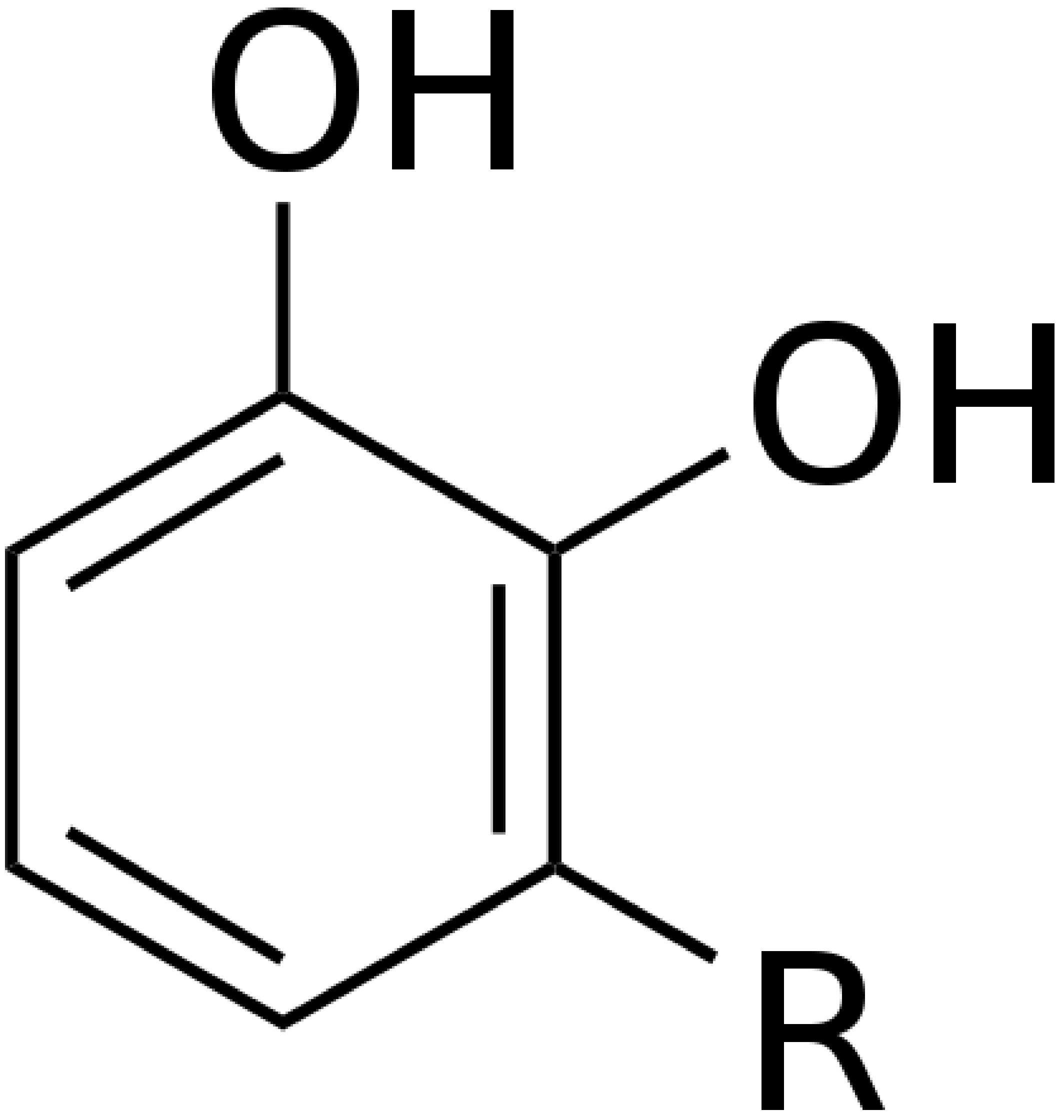
Pistachio, *Pistacia vera* and cashew, *Anacardium occidentale*

- Deciduous trees of Central Asian origin and evergreen tree from East Asia
- Since they are rich of plant oils, nuts promote the lowering of cholesterol level
- Green parts of trees contain poisonous urushiol, like all Anacardiacae family (including poison ivy)
- Cashew has a double use, as cashew apple and cashew nut

Pistachio

Cashew apples and cashew nuts

Urushiol



Brazil nut, *Bertholletia excelsa*

- Large tropical tree of Lecythidaceae family
- Among others, it is the richest dietary source of selenium

Brazil nut flowers

Brazil nut fruit

Macadamia, *Macadamia integrifolia*

- Member of Proteaceae family; Australian plant
- Rich of fats and microelements; toxic to dogs

Macadamia

Chestnut, *Castanea sativa*

- Member of oak family, Fagaceae
- Old European culture, traditional to France, England and Germany
- Rich of tannins and therefore usually fried

Chestnut

38.11 Gourd plants

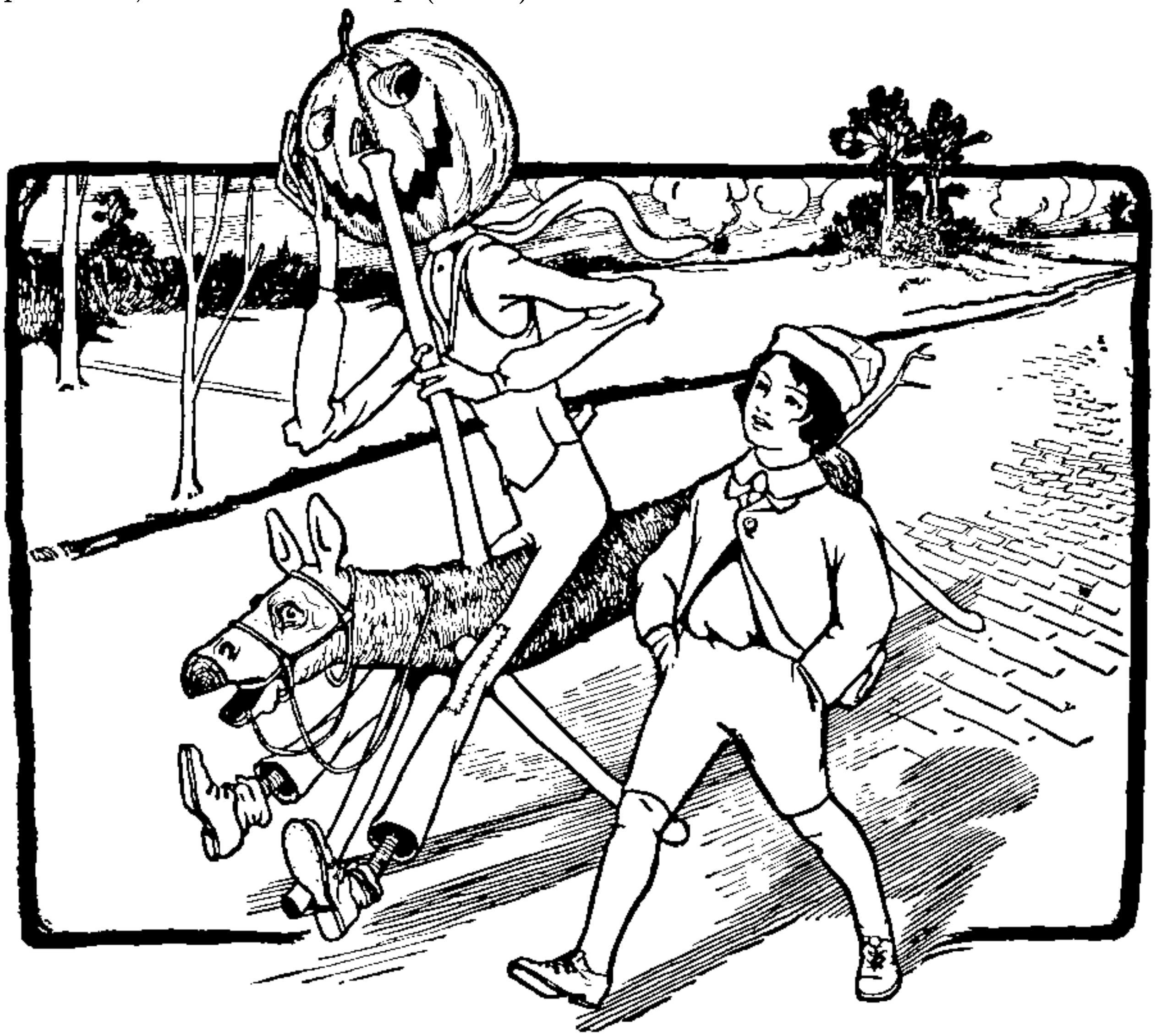
Gourds, Cucurbitaceae family

- $\approx$ 900 species, mostly tropical and subtropical plants
- Prefer dry regions, important component of different deserts
- Hairy herbs or vines with tendrils (modified shoots)
- Flowers unisexual
- Petals and stamens fused
- Pistil with 3 carpels, ovary inferior
- Fruit is a berry

Pumpkins and squashes, *Cucurbita* spp.

- Central American origin
- Plants of multiple uses; it is normal to harvest the underriped

Pumpkinhead, Sawhorse and Tip (Ozma)



Watermelon, *Citrullus lanatus*

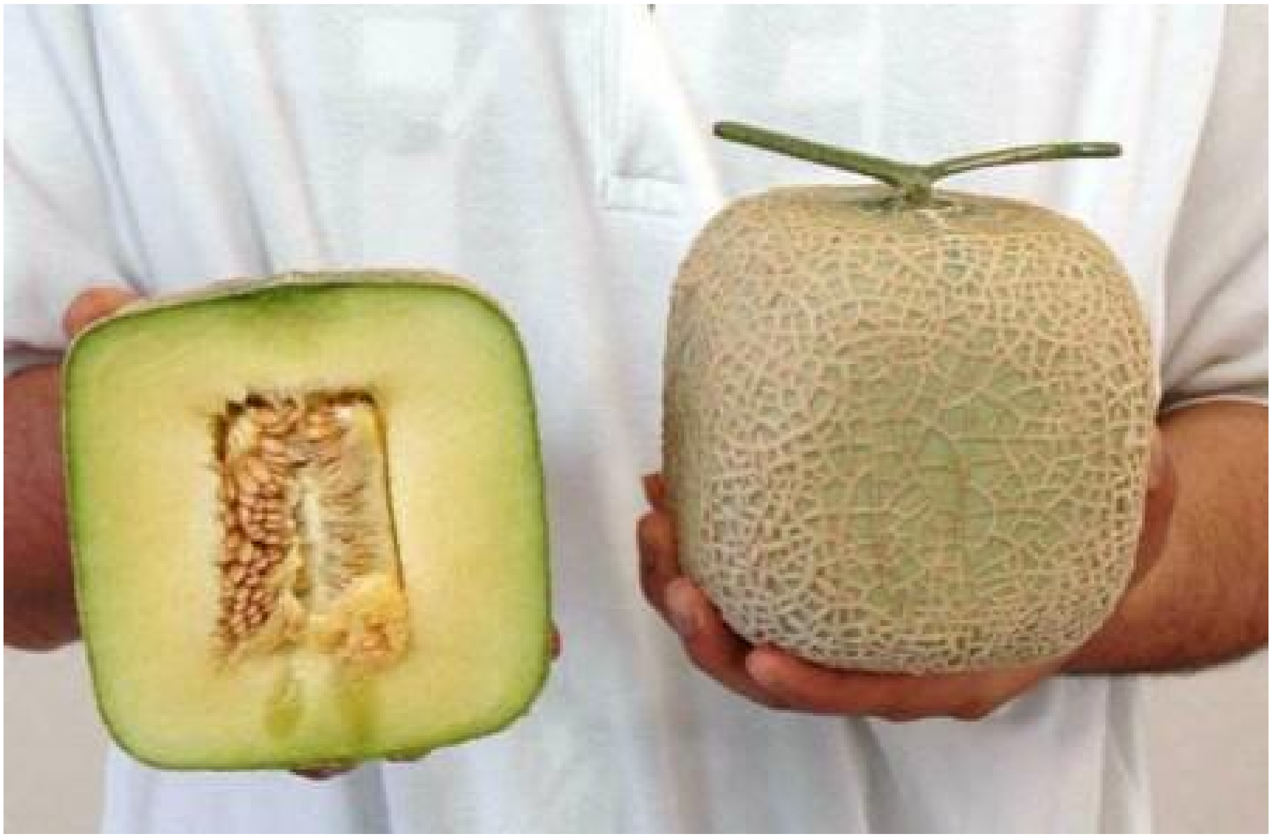
- African origin
- The source of water, multiple medicine uses (e.g., for kidney diseases)

Watermelon flower

Melon, *Cucumis melo*

- Central Asian origin
- Rich of sugars (some cultivars up to 20%), used as sugar source in Central Asia

Japanese square melon



Cucumber, *Cucumis sativus*

- Annual herbaceous vine from India forests, wild relatives not found
- May grow as water culture, widely cultivated in greenhouses, some cultivars have one week for fruit development

Indian Dosakai round cucumber

Chayote, *Sechium edule*

- One of relatively “new” cultures from Mexico
- High yield culture, one plant may give up to 40 kg of fruits

Chayote

Summary

- Nuts are plants accumulating oils and proteins in their seeds, they mostly dispersed by "weak memory" animals
- Gourd plants are intermediates between fruits and vegetables

38.12 Vegetables

Main families of vegetable plants

- Cruciferae, cabbage family, and its main species, *Brassica oleracea*, cabbage
- Umbelliferae, umbel family
- Solanaceae, potato family

Features of vegetables

- All vegetative organs: roots, stems and leaves—may become sources of edible vegetable
- However, fruits of Solanaceae are also considered as vegetables
- Modifications (typically, enlargement) of these organs will increase the value of vegetable
- "Herbs" are intermediates between vegetables and spices

For Further Reading

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Outline

39 Harmful plants

39.1 Prickly plants

Prickly plants

- Bear thorns, spines or prickles
- Cactaceae (like jumping cholla, *Cylindropuntia fulgida*), many Rosaceae (like hawthorn) and some Leguminosae (like *Gleditschia*)
- Sometimes useful for "live hedges"

Jumping cholla spines

Gleditschia thorns

39.2 Stinging plants

Stinging plants

- Covered with "glassy", silica-tipped hairs (like nettles, *Urtica* spp., *Laportea* spp. and others from nettle family, Urticaceae) containing acetylcholine, histamine, serotonin, formic acid or even stronger toxins (like moroidin from stinging trees, *Dendrocnide excelsa*, and *D. moroides*, same family, from Australia)

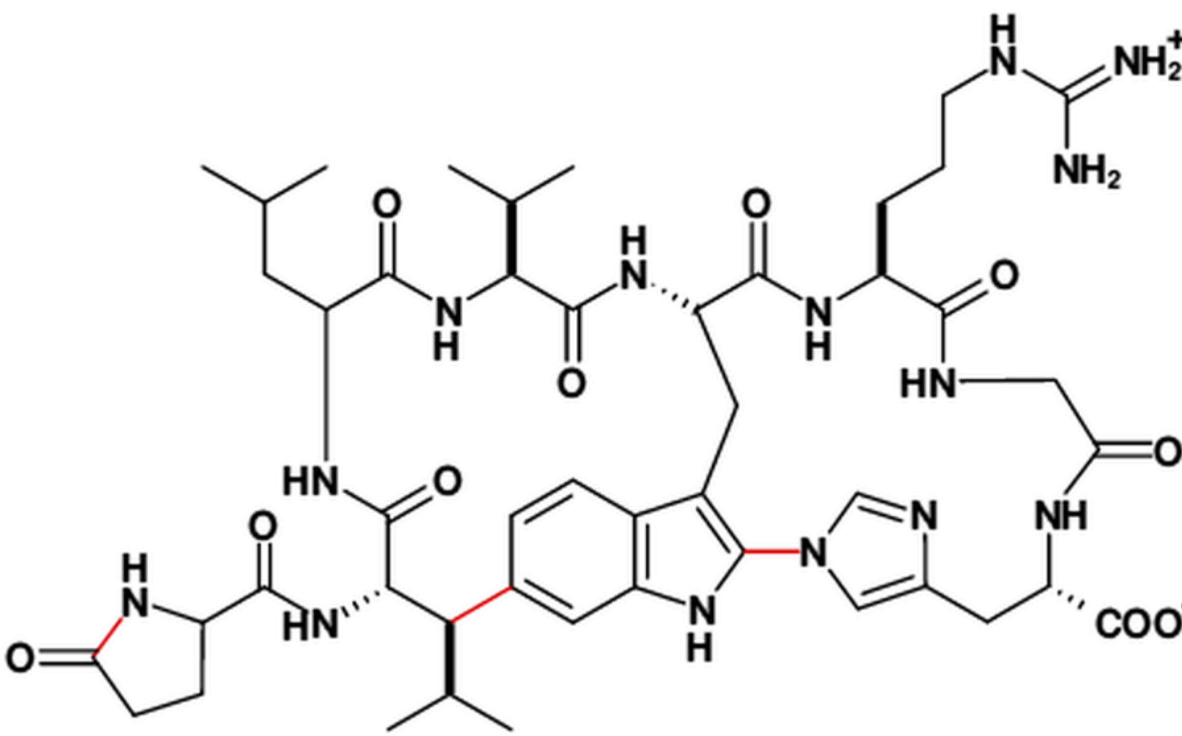
- Plants from other families like Loasaceae (*Eucnide*, desert rock nettle), Euphorbiaceae (*Cnidoscolus*, spurge nettle) and even Leguminosae (*Mucuna*, velvet beans) are similar to nettles.

Nettle stinging hairs

Giant stinging tree

Giant stinging tree leaves

Moroidin



Moroidin

Desert rock nettle

Spurge nettle

Velvet beans

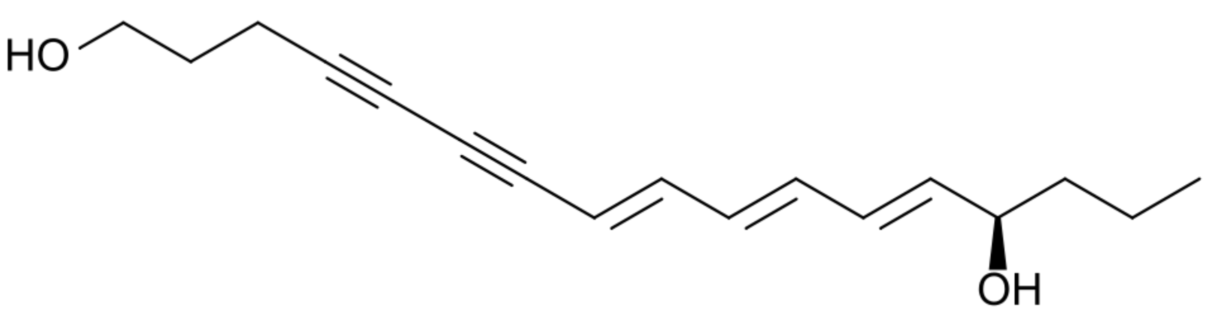
Poisonous plants

- Allergic like poison ivy (*Toxicodendron radicans* from Anacardiaceae, rich of urushiol)
- Phototoxic like giant hogweed (*Heracleum* spp. from Umbelliferae)
- Digestively poisonous like *Strychnos* from Loganiaceae (source of curare), rosary pea *Abrus precatorius* (Leguminosae, contain abrin protein toxin) and castor beans (*Ricinus communis*, Euphorbiaceae) which both deactivate eukaryotic ribosomes, and most poisonous U.S. plant water hemlock (*Cicuta* spp., Umbelliferae, contains terpene cicutoxin which blocks GABA receptors)
- Almost all Solanaceae and Ranunculaceae are poisonous

Rosary pea

Water hemlock

Cicutoxin



Parasitic plants

- Half-parasites (like root half-parasite *Comandra*, bastard toad-flax or stem half-parasite mistletoe) have chlorophyll, mycoparasites (like *Pterospora*) interact with fungi
- Full parasites: root (like *Pholisma*), or internal (only flowers will appear on surface, like *Pilostyles*)
- Full stem parasites dodder (*Cuscuta* spp., Convolvulaceae) and *Cassytha* (Lauraceae) are harmful for many cultivated plants, especially from legume and aster families

Bastard toadflax

Pterospora

Pholisma

Pilostyles

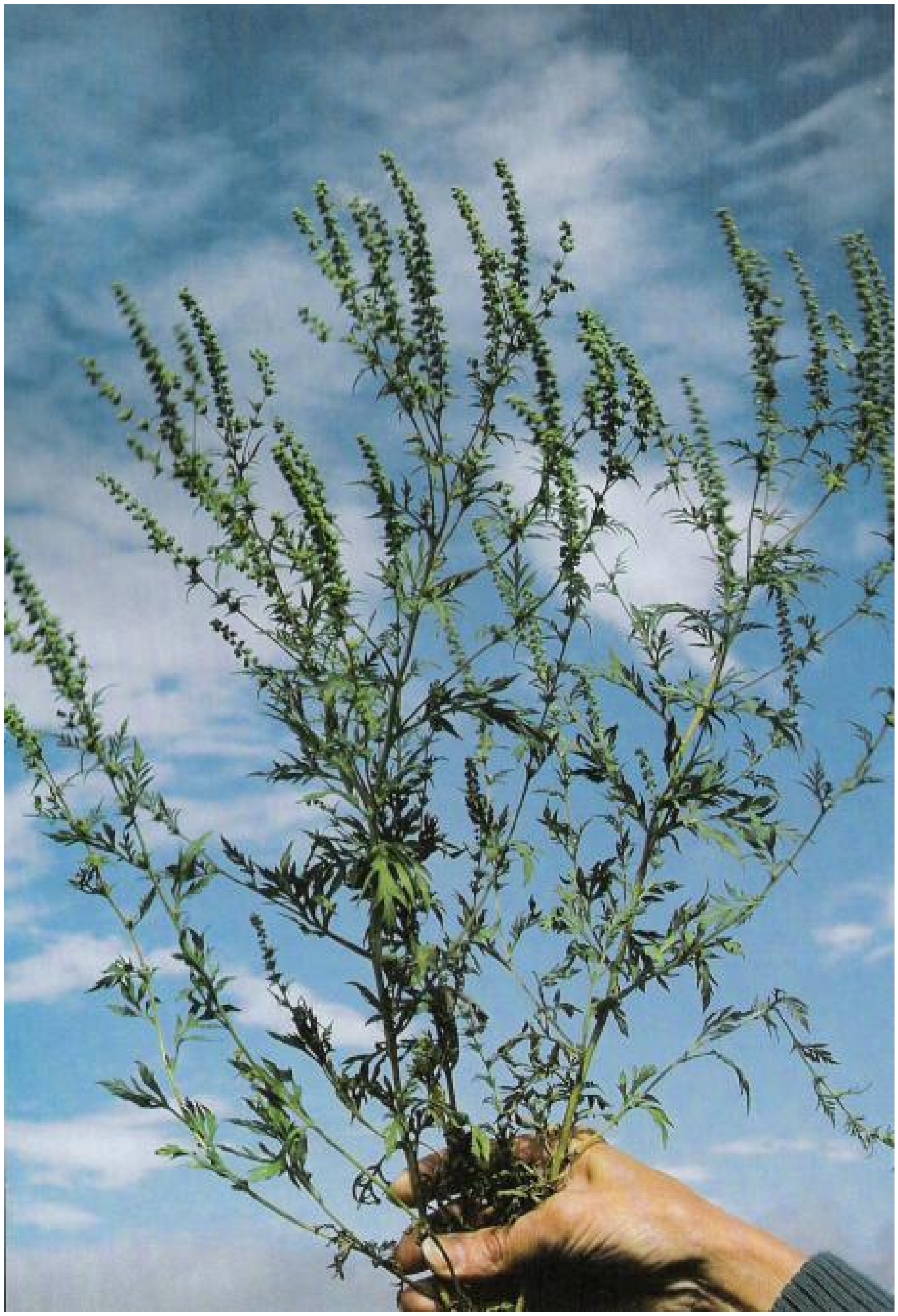
Dodder

Cassytha

Weeds

- Plants which interfere in agro-ecosystems
- In North Dakota, most noxious **native** weeds are common ragweed (*Ambrosia artemisiifolia* from Compositae) and different milkweeds (*Asclepias* spp. from Apocynaceae); first is also highly allergic, seconds are poisonous.

Common ragweed



Milkweed

Invasive plants

- Invasive plants are normally not harmful in their native range, but in exotic range they start to spread uncontrollably
- Nice reciprocal examples are spotted knapweed (*Centaurea stoebe*) and boxelder (*Acer negundo*) in Eurasia and North America
- Leafy spurge (*Euphorbia esula*) is the most problematic invasive plant in North Dakota
- Despite of numerous hypotheses formulated (e.g., presence of symbionts, epigenetic evolution), the reason of invasiveness is still not known

Invasive vs. native knapweed

Invasive weed: leafy spurge, *Euphorbia esula*, Euphorbiaceae, East Europe

40 Technical plants

Forage plants

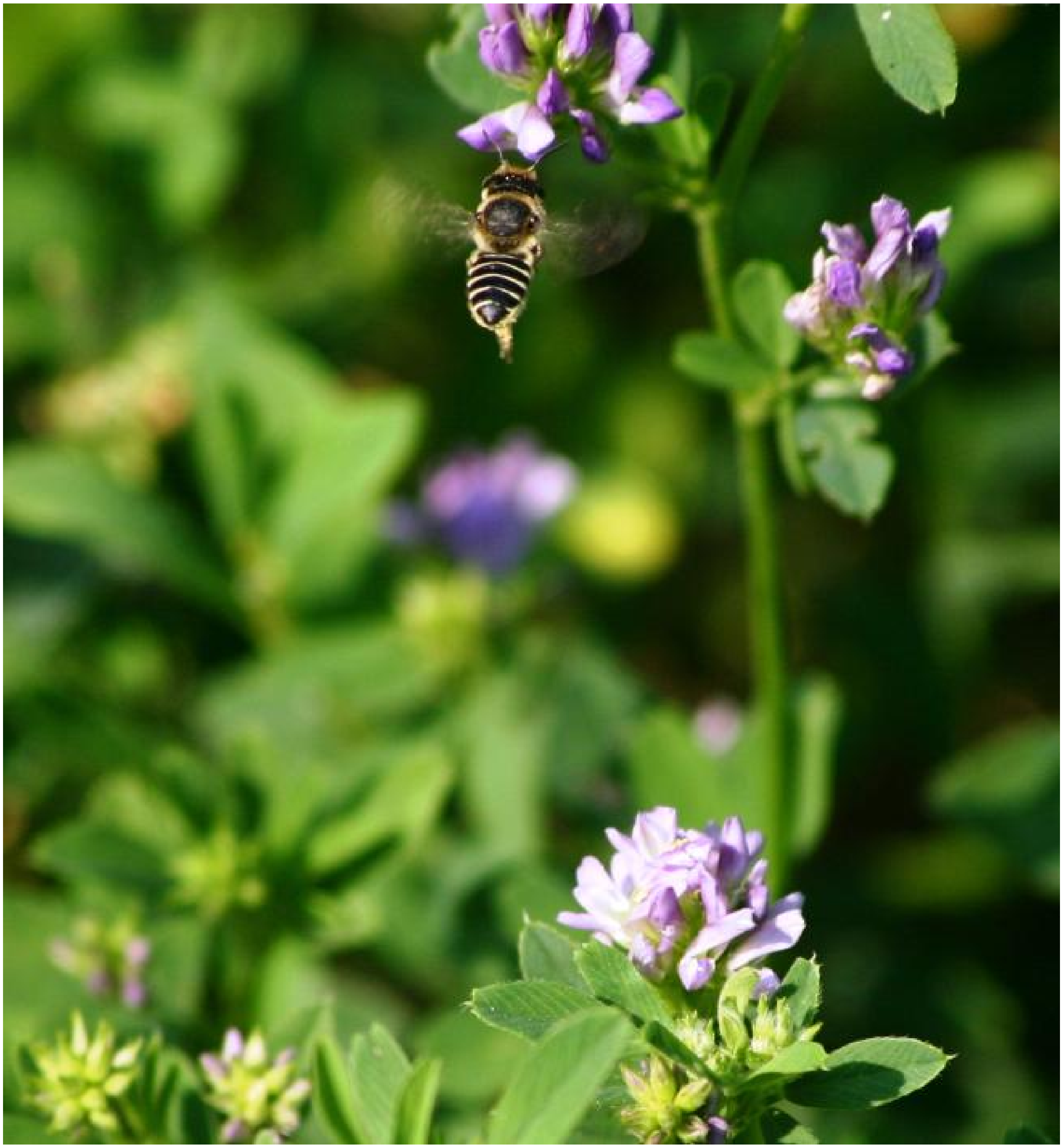
- Need to contain balanced diet: not only carbohydrates, but also proteins, fats and vitamins
- Most important are different Gramineae (like oats, corn and sorghum) and Leguminosae (like clovers, vetches and alfalfa)
- Green parts of grasses are most often used as silage—fermented (with *Lactobacillus plantarum*) cellulose

Silage

Alfalfa, *Medicago sativa*, Leguminosae, Eurasia

- Root nodules contain nitrogen-fixing bacteria, providing plant with nitrogen
- Up to 12 harvests a year
- High in proteins, vitamins C, K, E and some B

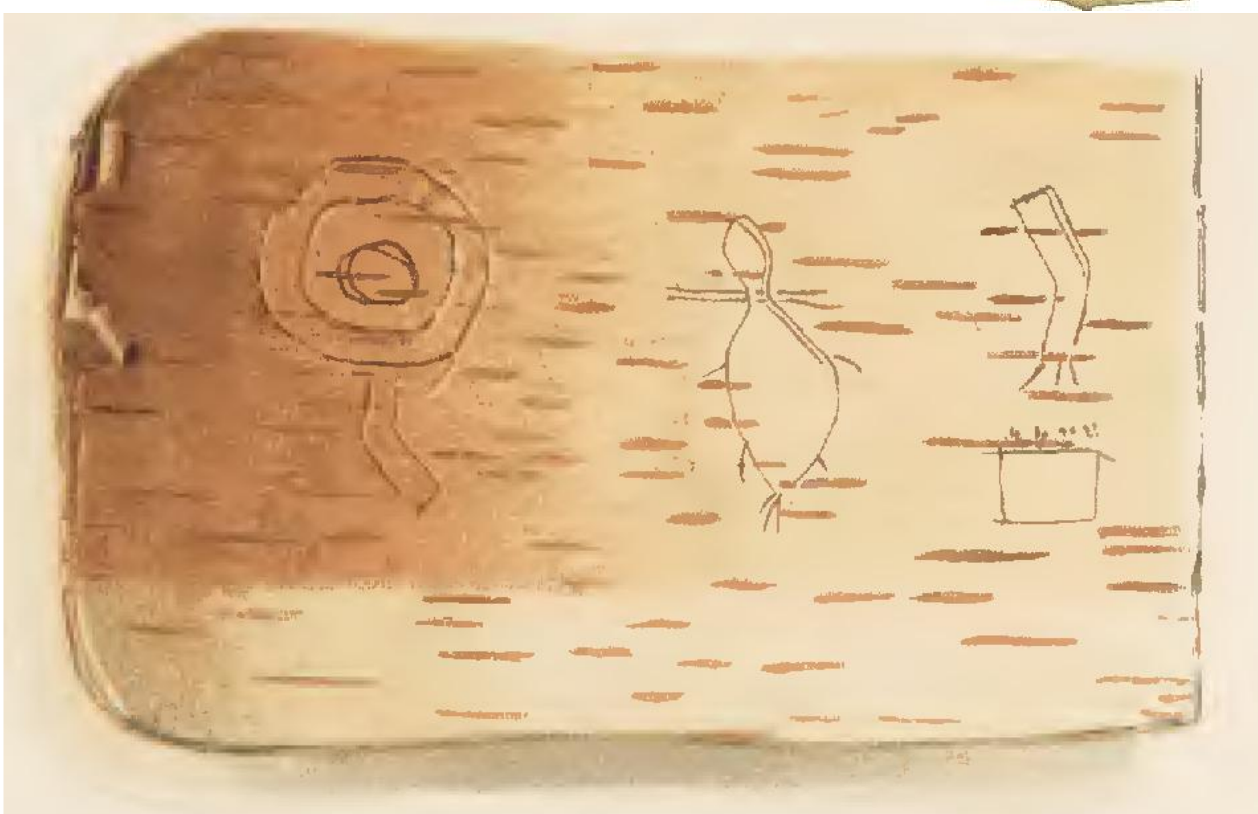
Alfalfa pollination



Lumber, paper and basket plants

- Mostly trees which give hardwood (rosids/asterids) and softwood (conifers)
- For the paper, birch (*Betula* spp.) bark was used by ancient Russians and Ojibwe people ("Wiigwaasabak"), papyrus sedge (*Cyperus papyrus*, Cyperaceae) was used in ancient Egypt, and pulpwood is used now
- For baskets and similar things (like bast shoes), gourd (*Lagenaria* spp.) fruits, birch and linden (*Tilia* spp.) bark and willow (*Salix* spp.) twigs were used most frequently in our latitudes

Russian and Ojibwe bark documents



Bast shoes

Baskets

Hybrid poplar, *Populus deltoides* hybrids, Salicaceae, North America

- Sometimes referred as *Populus* ×*euroamericana*
- One of the fastest growing trees
- Accept wide range of soils, but require moist habitats, with high water level in soil
- Used for making pulpwood

Hybrid poplar plantation

Cork oak, *Quercus suber*, Fagaceae, Mediterranean

- Evergreen oak with extremely thick cork
- Used mostly for stoppers in wine bottles and in chemical labs
- Main producer is Portugal

Cork oak

Bamboos, Gramineae, East Asia (mostly)

- Subfamily of grasses, Bambusoideae
- Woody but temporary stems, plants often monocarpic
- Resistant to fungi and termites

Bamboo house

Fiber plants

- Normally, bast (phloem) is used for fibers
- Most important stem fibers are flax (*Linim usitatissimum*), jute (*Corchorus* spp., Malvaceae, South Asia) and hemp (*Cannabis sativa*); fruit fibers are cotton, coir (outer part of coconut, *Cocos nucifera*) and kapok (*Ceiba pentandra*, Malvaceae, Central America); leaf fibers are abaka (*Musa textilis*, Musaceae, Philippines), sisal (*Agave sisalana*, Asparagaceae, Mexico), snake plant (*Sanseviera* spp., Asparagaceae, Africa) and New Zealand flax (*Phormium tenax*, Xnanthorrhoeaceae)
- Native Americans used "Indian hemp" (*Apocynum cannabinum*) stems

Kapok

Indian "hemp"

Cotton, *Gossypium* spp., Malvaceae, West Asia

- Several species which were domesticated independently in Old and New Worlds, now the most cultivated species is American *Gossypium hirsutum*
- Requires high temperatures, humidity and (for best result) manual harvesting
- Biggest producers are China, India and U.S.

Vegetable lamb of Tartary

Cotton

Dye plants

- Most of these cultures are declined after invention of artifical dyes in 1920s
- Examples are: "bloodwood" *Haematoxylum campechianum* (Leguminosae, Central America, red haematoxylin); achiote *Bixa orellana* (Bixaceae, South America, yellow annatto), true indigo *Indigofera tinctoria* (Leguminosae, blue indigotin), safflower and others.

Achiote fruits

True indigo

Cochineal, *Dactylopius coccus*/Homoptera + *Opuntia* spp./Cactaceae, North America

- Almost unique combinational culture of scale insect and opuntia (similar to mulberry/silkworm): cultivated ecosystem
- For several centuries, have been Mexican most valued export
- Insect produces carminic acid
- Another similar "combination" is kermes scale insect (*Kermes* spp., Homoptera) and Kermes oak (*Quercus coccifera*) in Mediterranean which used to produce crimson dye.

Cochineal

Latex plants

- Latex is a stable dispersion (emulsion) of polymer (mostly terpenes) microparticles
- Occur in many plants, but frequently used only several species, e.g., guayule *Parthenium argentatum* (Compositae, Mexico), Panama rubber tree *Castilla elastica* (Moraceae, Central America), little elastic and bio-inert Gutta-percha *Palaquium* spp. (Sapotaceae, South Asia), chewing gum tree *Manilkara chicle* (Sapotaceae, Central America)

Rubber tree, *Hevea brasiliensis*, Euphorbiaceae

- Large tropical tree originated in Amazonian but cultivated mainly in Southeastern Asia
- Natural rubber is extremely elastic but fragile at low temperatures
- In 1839, Charles Goodyear invented vulcanization (hyper-polymerization with sulfur)

Para rubber tree

Incense plants (ceremonial odors)

- Used in many religions, most often in Eastern Christian churches, Hindu and Buddhism
- Multiple plants with essential oils, plus some specific species like myrrh *Commiphora myrrha* (Burseraceae, West Asia), styrax *Sryrax benzoin* (Styracaceae, West Asia) and sandalwood *Santalum* spp. (Santalaceae, Old World tropics)

Incense stick in Buddhist temple

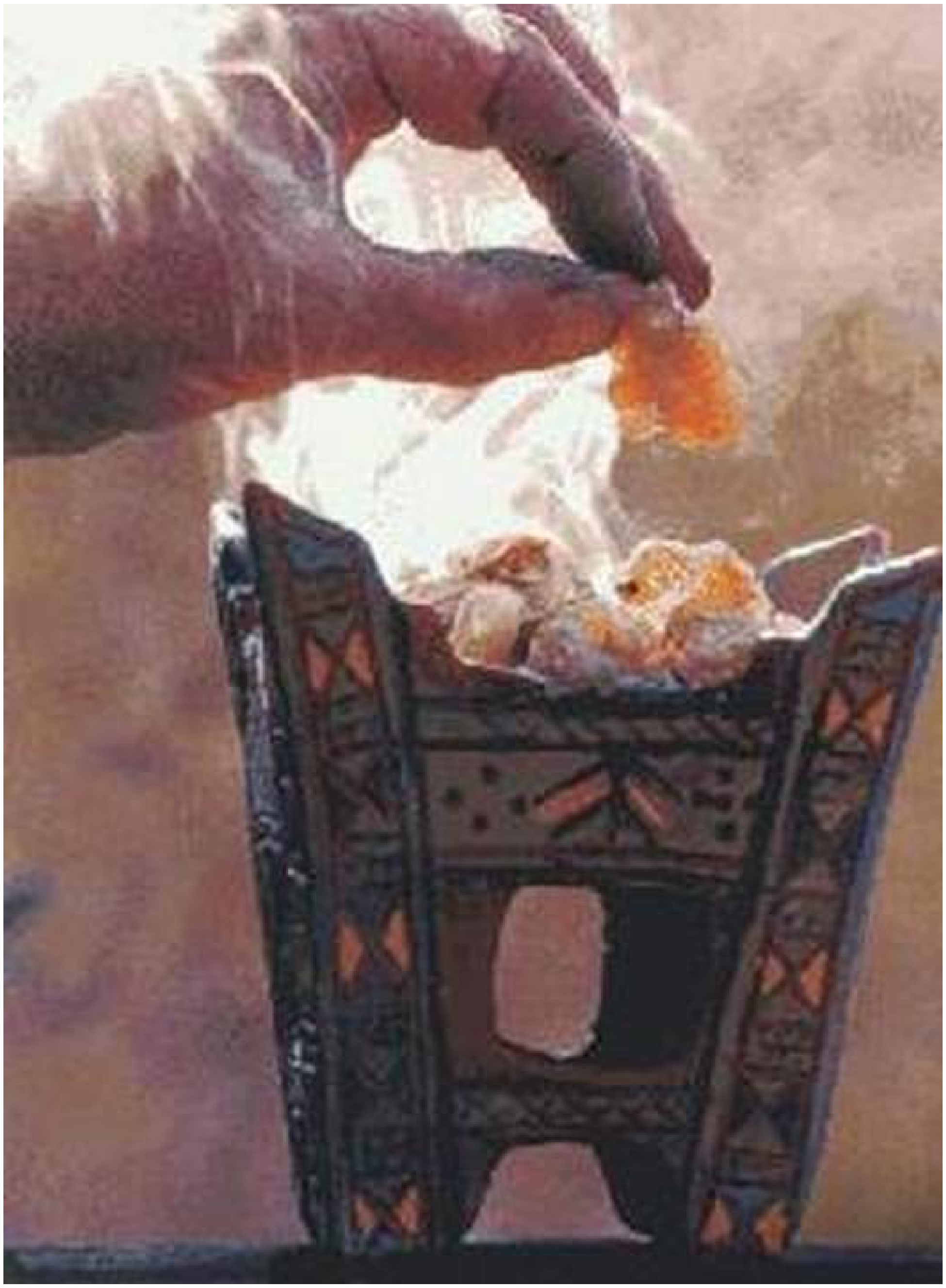
Sandalwood cultivation

Frankincense, *Boswellia sacra*, Burseraceae, Africa

- Aromatic resin from *Boswellia* trees
- Burning of frankincense came from ancient Egypt to Hebrew church and then to Christian churches
- Contains a complicated set of terpenes which have also medicinal effects

Frankincense tree

Frankincense in church



41 Ornamental plants

Indoor plants

- Should be adapted for dry and relatively dark conditions

Some groups of indoor plants

- Cacti and other succulents
- Orchidaceae: tropical orchids; *Phalaenopsis* is one of the most frequently cultivated
- Bromeliaceae: South American bromeliads; *Cryptanthus*, *Neoregelia* and *Guzmania* are frequently cultivated

- *Begonia* from Begoniaceae, all tropics, is extremely shade-tolerant (and also ferns)
- Many ornamentals (indoor or outdoor) are variegated plants: induced variegation or naturally pigmented leaves

Begonia

***Neoregelia*, naturally variegated**

Rubber ficus (*Ficus elastica*, Moraceae, Old Word tropics), variegated mutant

Bonsai

- Specific way of cultivation resulted in dwarf plants
- Variety of temperate tree species used, cultivation is in-house but outdoor (in patio)
- Specific techniques are: leaf trimming, stem pruning and wiring, use stony substrate and small pots

Bonsai pine

Cut plants

- Cultivated throughout the year in greenhouses and/or open grounds, then cut
- Forcing of flowering is needed for most cases (hormones, temperature, day length, selection)

Most frequent cut plants

- Rose: *Rosa* spp., Rosaceae, China
- Carnation: *Dianthus caryophyllus*, Caryophyllaceae, Mediterranean
- Lily: *Lilim* spp., North Hemisphere
- Chrysanthemum: *Chrysanthemum* ×*koreanum*, Compositae, East Asia
- Gerbera hybrids: *Gerbera*, Compositae, South Africa

Carnation

Gerbera

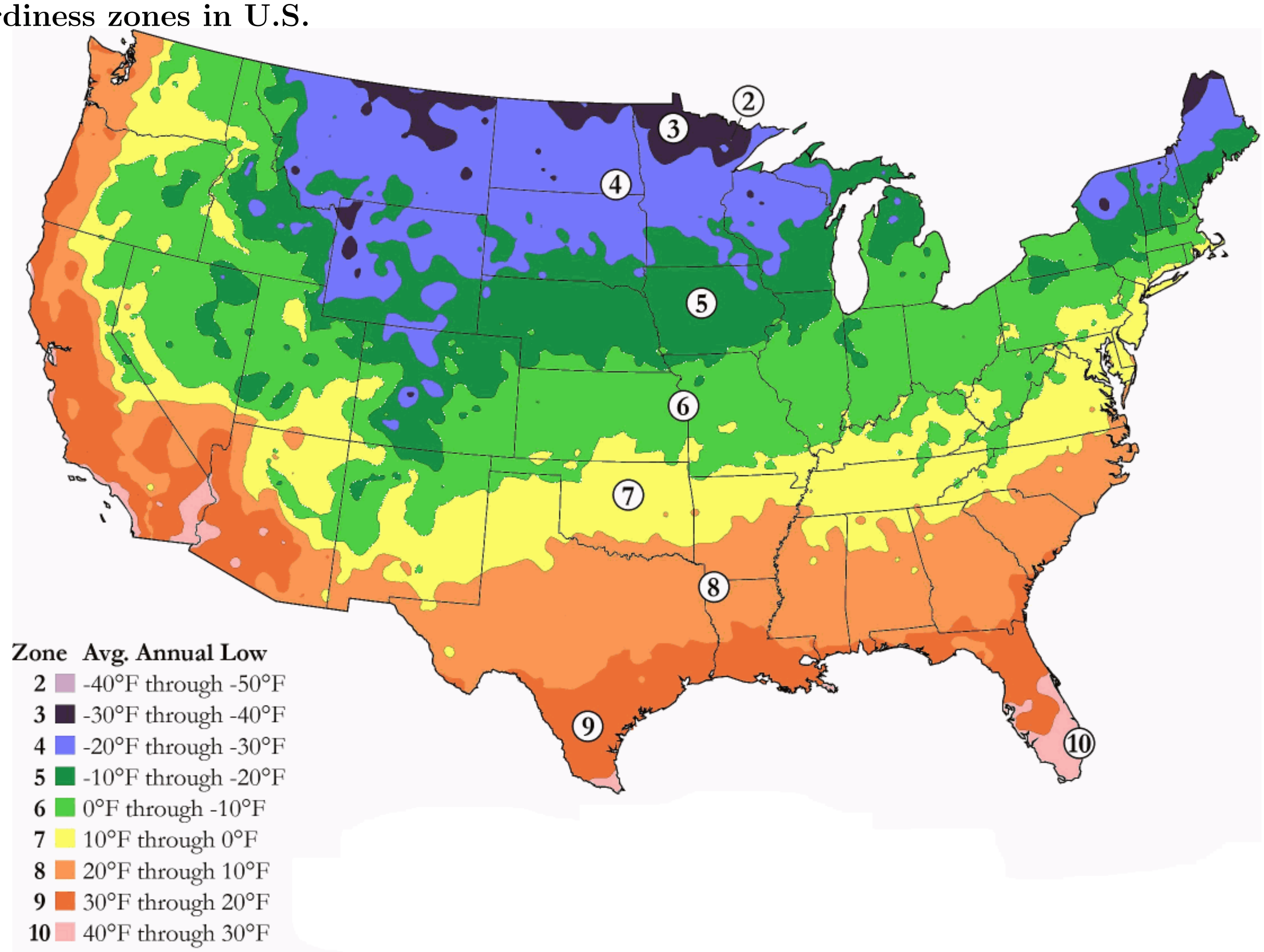
Outdoor annuals and perennials

- Plants from diverse families
- Annuals should (like petunia, *Petunia hybrida*, Solanaceae, South America) be fast-growing
- Biennials like pansy (*Viola x wittrockiana*, Violaceae, Europe) produce vegetative part in the first year
- Perennials normally have underground rhizomes (like peony, *Paeonia* spp., Paeoniaceae, East Asia) or bulbs (like daffonlids, *Narcissus* spp., Mediterranean), often wintering indoor (like geraniums, *Pelargonia* spp., Geraniaceae, South Africa)
- Traditionally, flowering shrubs like roses, lilacs (*Syringa* spp., Oleaceae) are also referred here

Hardiness zones

- Determined from average lowest temperature
- North Dakota belongs to zones 3 and 4

Hardiness zones in U.S.



Petunia

Pansy

Peony

Bulb plants

- Liliaceae: lily *Lilium*, tulip *Tulipa*, fritillary *Fritillaria*
- Amaryllidaceae: daffondil *Narcissus*, snowdrop *Galanthus*
- Asparagaceae: grape hyacinth *Muscari*, hyacinth *Hyacinthus*, squill *Scilla*, common bluebell *Hyacinthoides*

Common bluebell

Landscape woody plants

- Trees, shrubs, rarely vines
- Evergreen and deciduous

Conifers

- Pinaceae: *Picea* (especially blue spruce, *Picea pungens*, North America), *Pinus*, *Larix*
- Cupressaceae: *Cupressus*, *Juniperus*

Blue (Colorado) spruce

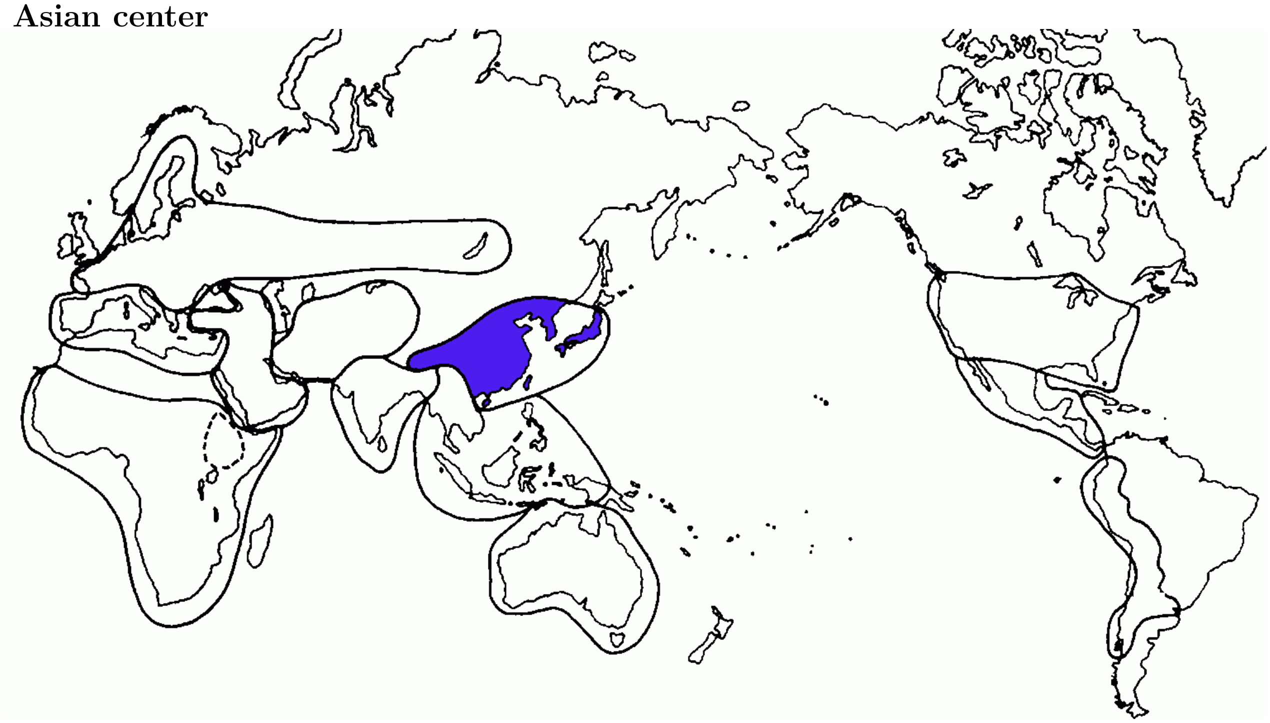
Special groups

- Plants for alpine (rocky) gardens like stonecrops, *Sedum* spp., Crassulaceae
- Aquatic ornamentals: ponds (like waterlily, *Nymphaea* spp.) and fishtanks (like *Pistia*, *Elodea* etc.)
- Lawn plants: *Lolium perenne*, ryegrass and species of bluegrass (*Poa*) and bentgrass (*Agrostis*)

Water lily

42 The most important cultivated plants and their centers of origins

East Asian center



East Asian center: main food

- Rice
- Soybeans

East Asian center: fruits and vegetables

- Peach
- Orange
- Radish

East Asian center: sugar and oil

- Tung

East Asian center: spices and drinks

- Tea
- Camphor tree

East Asian center: medicinal

- Ginseng
- Ginkgo

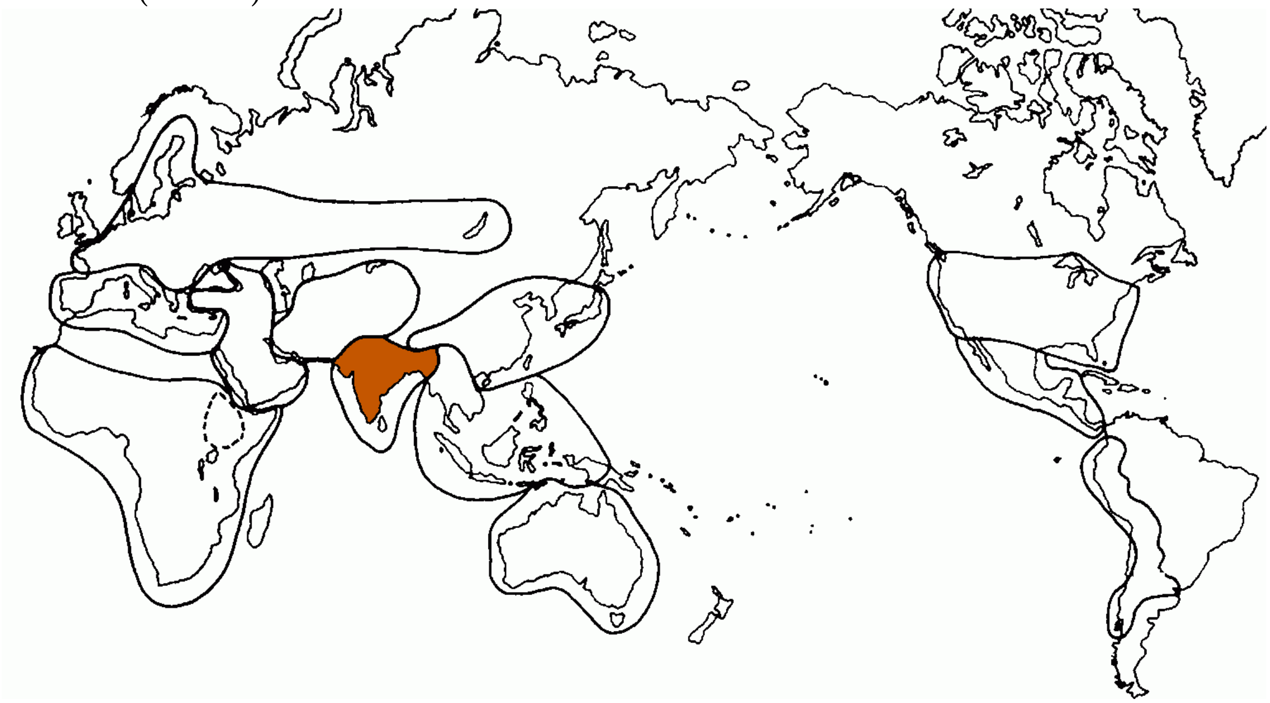
East Asian center: technical

- Bamboos
- Gutta percha

East Asian center: ornamental

- Chrysanthemum
- Ornamental maples

South Asian (Indian) center



South Asian (Indian) center: main food

- Buckwheat
- Chickpea

South Asian (Indian) center: fruits and vegetables

- Mango
- Cucumber

South Asian (Indian) center: sugars and oils

- Sugarcane
- Sesame

South Asian (Indian) center: spices and drinks

- Black pepper
- Cinnamon

South Asian (Indian) center: technical

- Jute
- Cotton (partly)

South Asian (Indian) center: medicinal

- Turmeric
- Gotu kola

South Asian (Indian) center: ornamental

- Rhododendron
- Ficus

West Asian center

West Asian center: main food

- Wheat (partly)
- Lentils
- Barley
- Oats

West Asian center: sugars and oils

- Sugar beet
- Olive

West Asian center: fruits and vegetables

- Grapes
- Pomegranate
- Walnut
- Cabbage
- Pear

West Asian center: spices and drinks

- Coriander
- Cumin
- Dill
- Bay leaf

West Asian center: technical

- Alfalfa
- Flax
- Clover

West Asian center: medicinal

- Chamomile
- Senna
- Deadly nightshade
- Autumn crocus

West Asian center: ornamental

- Rose
- Tulip
- Carnation
- Lilac
- Primrose

African (Ethiopian) center

African (Ethiopian) center: main food

- Sorghum

African (Ethiopian) center: fruits and vegetables

- Watermelon
- Date palm

African (Ethiopian) center: sugars and oils

- Castor
- Oil palm

African (Ethiopian) center: spices and drinks

- Coffee

African (Ethiopian) center: technical

- Gourd

African (Ethiopian) center: medicinal

- Aloe
- Madagascar periwinkle

African (Ethiopian) center: ornamental

- Geranium
- Gerbera

Central American (Mexican) center

Central American (Mexican) center: main food

- Corn
- Beans

Central American (Mexican) center: fruits and vegetables

- Avocado
- Squash

Central American (Mexican) center: sugars and oils

- Sunflower

Central American (Mexican) center: spices and drinks

- Red pepper

Central American (Mexican) center: technical

- Cochineal

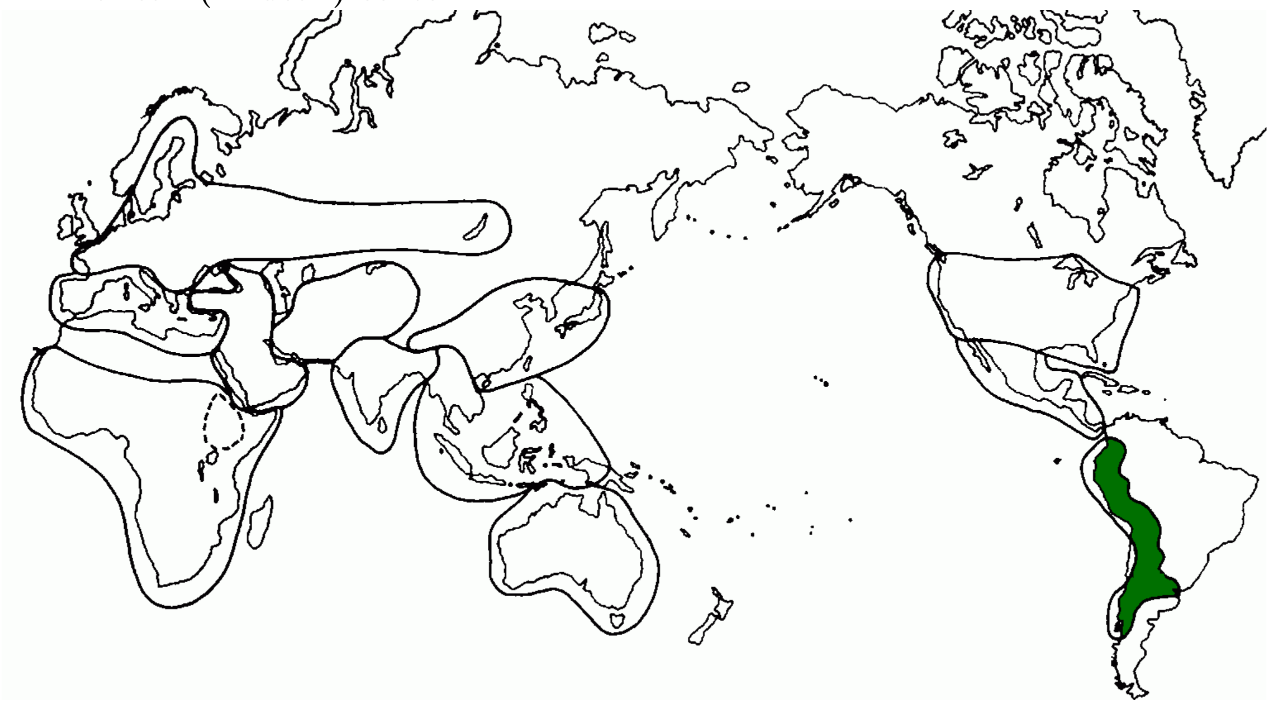
Central American (Mexican) center: medicinal

- Quassia

Central American (Mexican) center: ornamental

- Marigold
- Cacti

South American (Andean) center



South American (Andean) center: main food

- Potato
- Sweet potato

South American (Andean) center: fruits and vegetables

- Pineapple
- Tomato

South American (Andean) center: sugars and oils

- Peanut

South American (Andean) center: spices and drinks

- Cocoa
- Vanilla

South American (Andean) center: technical

- Para rubber tree

South American (Andean) center: medicinal

- Quina
- Ipecac

South American (Andean) center: ornamental

- Canna
- Bromeliads

Really short anonymous voluntary survey

1. What do you **like** most in ethnobotany course?
2. What do you **dislike** most in ethnobotany course?
3. **Which lab** do you remember most of all?
4. Please grade (1—bad, 5—excellent):

   1 Lectures
   2 Labs
   3 Exams
   4 Presentations

5. How to improve Ethnobotany (labs, textbook, course content *etc.*)?

Summary

- Anti-cancer plant compounds often suppress cell division
- Many supportive plants are still waiting for the scientific evidence of their effects
- Anti-inflammatory, antibacterial and astringent compounds are most important for treating cold and skin diseases
- Plant quinones and essential oils tend to be antimicrobial
- Main groups of harmful plants: prickly, stinging, poisonous, parasitic, weed/invasive
- Main groups of technical plants: forage, wood, fiber, dye, latex, incense
- Main groups of ornamental plants: indoor, cut, outdoor annuals and perennials, landscape woody

For Further Reading

References

[1] A. Shipunov. *Ethnobotany* [Electronic resource]. 2011—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_310`

[2] Heinrich et al. 2012 (or 2004). *Fundamentals of Pharmacognosy and Phytotherapy*. Churchill Livingstone, Edinburgh. Mode of access: `http://ashipunov.info/shipunov/school/biol_310/heinrich2004_fund_pharm_part.pdf`