Uporaba zaporedij DNA v raziskovanju evolucije rastlin

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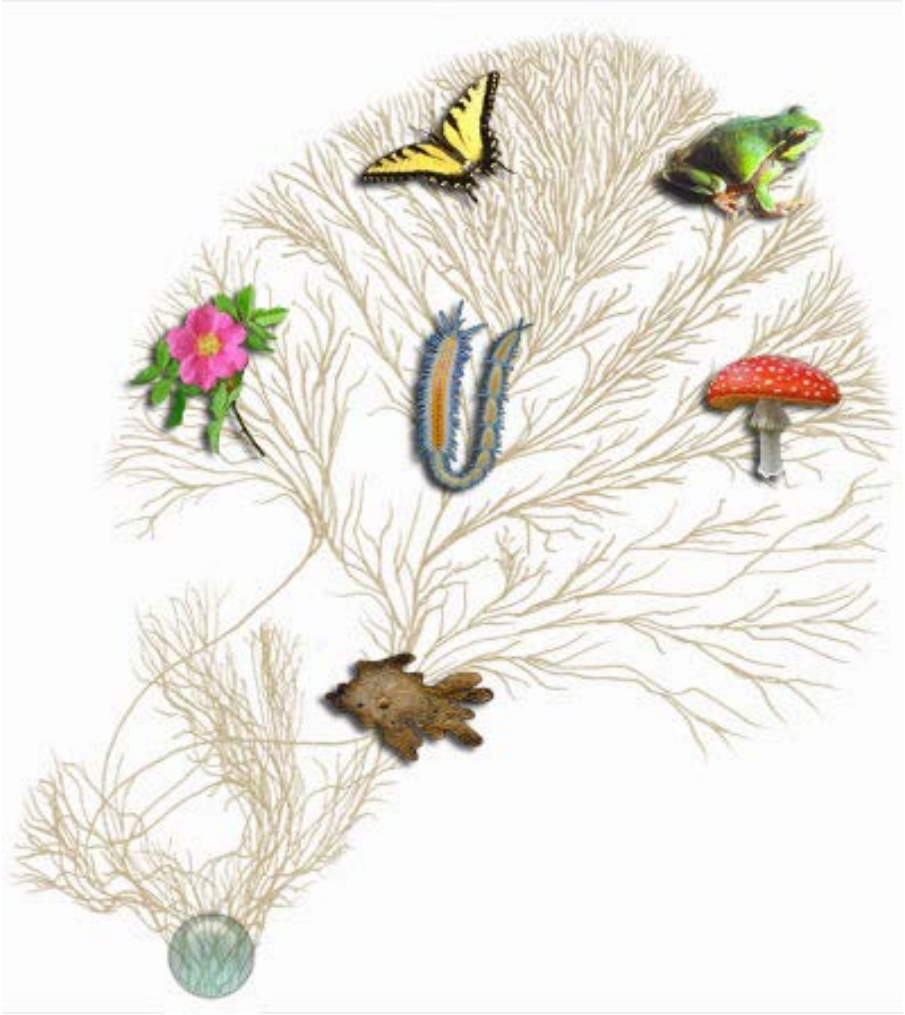
Preučevanje raznolikosti življenja



Koliko vrst je na Zemlji?

Znanstveniki ocenjujejo, da je na Zemlji 30 milijonov različnih vrst rastlin, živali, gliv in mikroorganizmov. Vsaka od teh vrst igra pomembno vlogo v globalnem ekosistemu.

Taksonomi so do danes odkrili in poimenovali le majhen delež teh vrst – 1,7 milijona, od tega 380.000 rastlin.

NATURAL HISTORY MUSEUM

Projekt "Tree of life": http://tolweb.org/tree/

Raznolikost življenja se je spreminjala skozi čas

nastanek Zemlje

nastanek oceanov in kontinentov

prvi organizmi
(preprosti prokarionti)

fotosintetski organizmi

fotosintetski organizmi,
ki sproščajo O_2 -
cianobakterije

evkarionti

aerobno celično dihanje
postane razširjen pojav

fotosintetski evkarionti

večcelične rastline

večcelične živali

vretenčarji

glive

kopenske rastline

vaskularne rastline

kopenske živali

semenke

plazilci

dinozavri

sesalci

ptiči

kritosemenke

primati

sodobni človek

4000

3000

2000

1000

0

Čas
(milijoni let)

Can We Name Earth's Species Before They Go Extinct?

Mark J. Costello,[1*] Robert M. May,[2] Nigel E. Stork[3]

Some people despair that most species will go extinct before they are discovered. However, such worries result from overestimates of how many species may exist, beliefs that the expertise to describe species is decreasing, and alarmist estimates of extinction rates. We argue that the number of species on Earth today is 5 ± 3 million, of which 1.5 million are named. New databases show that there are more taxonomists describing species than ever before, and their number is increasing faster than the rate of species description. Conservation efforts and species survival in secondary habitats are at least delaying extinctions. Extinction rates are, however, poorly quantified, ranging from 0.01 to 1% (at most 5%) per decade. We propose practical actions to improve taxonomic productivity and associated understanding and conservation of biodiversity.

Costello et al. (2013) Science

www.pinterest.com

Tik pred izumrtjem je:

- 1 od 8 ptic
- 1 od 4 sesalcev
- 1 od 4 golosemenk
- 1 od 3 dvoživk
- 6 od 7 morskih želv

(International Union for Conservation of Nature; IUCN)

REVIEW

Cardinale et al. (2012) Nature

doi:10.1038/nature11148

Biodiversity loss and its impact on humanity

Bradley J. Cardinale[1], J. Emmett Duffy[2], Andrew Gonzalez[3], David U. Hooper[4], Charles Perrings[5], Patrick Venail[1], Anita Narwani[1], Georgina M. Mace[6], David Tilman[7], David A. Wardle[8], Ann P. Kinzig[5], Gretchen C. Daily[9], Michel Loreau[10], James B. Grace[11], Anne Larigauderie[12], Diane S. Srivastava[13] & Shahid Naeem[14]

The most unique feature of Earth is the existence of life, and the most extraordinary feature of life is its diversity. Approximately 9 million types of plants, animals, protists and fungi inhabit the Earth. So, too, do 7 billion people. Two decades ago, at the first Earth Summit, the vast majority of the world's nations declared that human actions were dismantling the Earth's ecosystems, eliminating genes, species and biological traits at an alarming rate. This observation led to the question of how such loss of biological diversity will alter the functioning of ecosystems and their ability to provide society with the goods and services needed to prosper.

Why is biodiversity in crisis?

www.iucn.org

The escalating extinction crisis shows that the diversity of nature cannot support the current pressure that humanity is placing on the planet.

primorske novice — Naslovnica — Novi

Izginjanje vrst ogroža človeka

sobota, 30. oktober 2010, 11:40

Aktuelle Rote Liste: Fast 21.000 Tier- und Pflanzenarten vom Aussterben bedroht

7. Juli 2013, 12:14 derStandard.at

DIE WELT

19.03.10 | Biodiversität

Pro Jahr sterben rund 30.000 Arten aus

United Nations Decade on Biodiversity

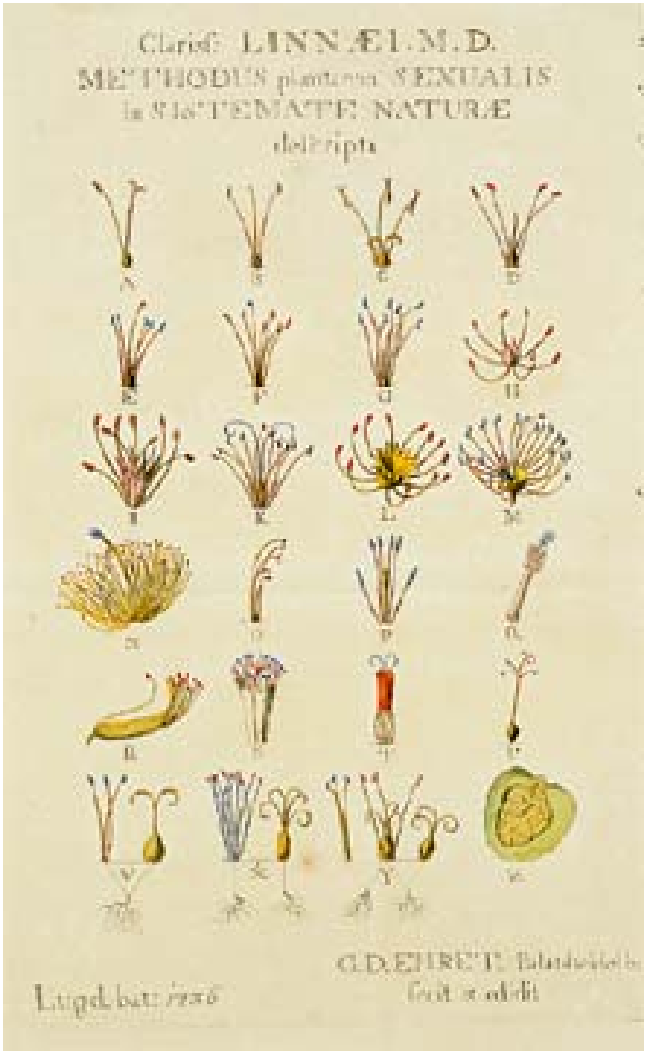
Living in harmony with nature

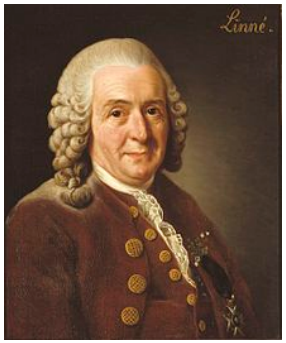
Desetletje biotske raznovrstnosti, ki so ga razglasili Združeni narodi, prispeva k izvajanju Konvencije o biotski raznovrstnosti, ki to raznovrstnost opredeljuje zelo široko: od molekularne preko vrstne ravni, vse do ekosistemov.

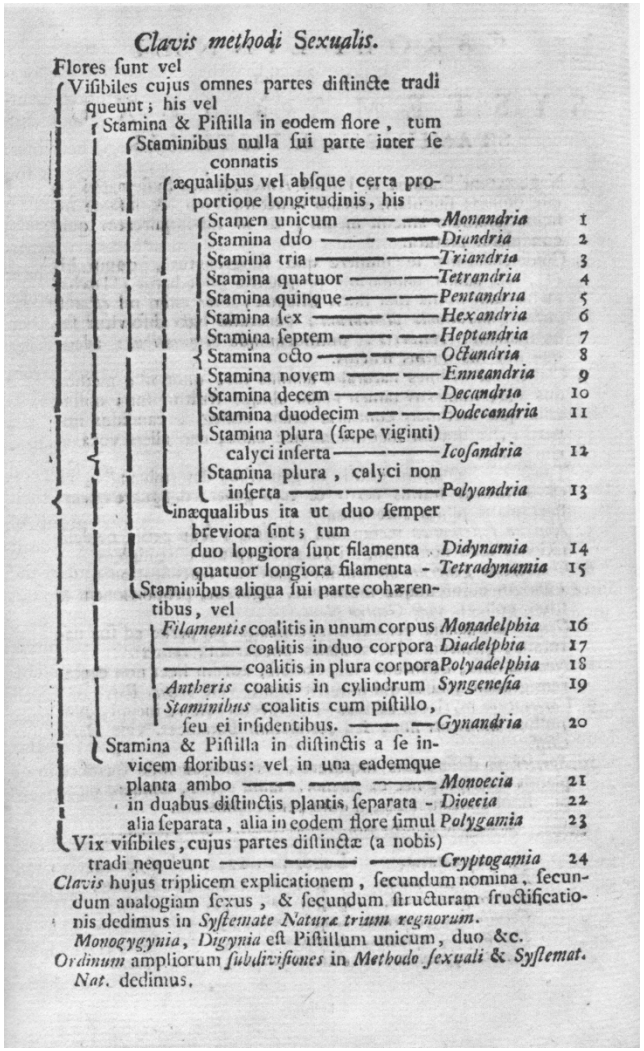
Glavni cilj Konvencije o biotski raznovrstnosti je ohranitev biotske raznovrstnosti na državni in krajevni ravni ter trajnostna raba njenih sestavin, zlasti poštena in pravična delitev koristi od rabe genskih virov, kot tudi vključevanje načel varstva narave v vse oblike delovanja na državni in lokalni ravni.

Convention on Biological Diversity

Preučevanje raznolikosti rastlin







Clavis methodi Sexualis.

Flores sunt vel
- Visibiles cujus omnes partes distincte tradi queunt; his vel
  - Stamina & Pistilla in eodem flore, tum
    - Staminibus nulla sui parte inter se connatis
      - æqualibus vel absque certa proportione longitudinis, his
        - Stamen unicum — *Monandria* 1
        - Stamina duo — *Diandria* 2
        - Stamina tria — *Triandria* 3
        - Stamina quatuor — *Tetrandria* 4
        - Stamina quinque — *Pentandria* 5
        - Stamina sex — *Hexandria* 6
        - Stamina septem — *Heptandria* 7
        - Stamina octo — *Octandria* 8
        - Stamina novem — *Enneandria* 9
        - Stamina decem — *Decandria* 10
        - Stamina duodecim — *Dodecandria* 11
        - Stamina plura (sæpe viginti) calyci inserta — *Icosandria* 12
        - Stamina plura, calyci non inserta — *Polyandria* 13
      - inæqualibus ita ut duo semper breviora sint; tum
        - duo longiora sunt filamenta — *Didynamia* 14
        - quatuor longiora filamenta — *Tetradynamia* 15
    - Staminibus aliqua sui parte cohærentibus, vel
      - *Filamentis* coalitis in unum corpus *Monadelphia* 16
      - coalitis in duo corpora *Diadelphia* 17
      - coalitis in plura corpora *Polyadelphia* 18
      - *Antheris* coalitis in cylindrum *Syngenesia* 19
      - *Staminibus* coalitis cum pistillo, seu ei insidentibus. — *Gynandria* 20
  - Stamina & Pistilla in distinctis a se invicem floribus: vel in una eademque planta ambo — *Monoecia* 21
    - in duabus distinctis plantis separata — *Dioecia* 22
    - alia separata, alia in eodem flore simul *Polygamia* 23
- Vix visibiles, cujus partes distinctæ (a nobis) tradi nequeunt — *Cryptogamia* 24

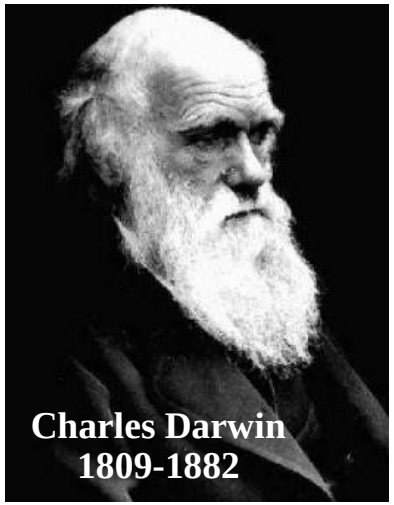
Clavis hujus triplicem explicationem, secundum nomina, secundum analogiam sexus, & secundum structuram fructificationis dedimus in *Systemate Naturæ trium regnorum*.

Monogygynia, *Digynia* est Pistillum unicum, duo &c.

Ordinum ampliorum *subdivisiones* in *Methodo sexuali* & *Systemat. Nat.* dedimus.

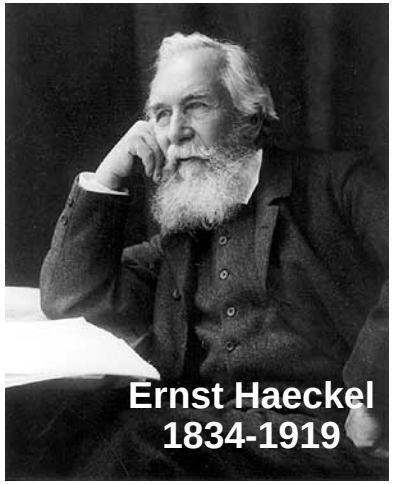
Carolus Linnaeus (1707–1778) – Systema naturae (1758): Linné je razvrščal (klasificiral) rastline glede na število prašnikov (Classes, e.g., Monandria) in pestičev (Ordines, e.g., Monogynia).

Filogenetski pogled



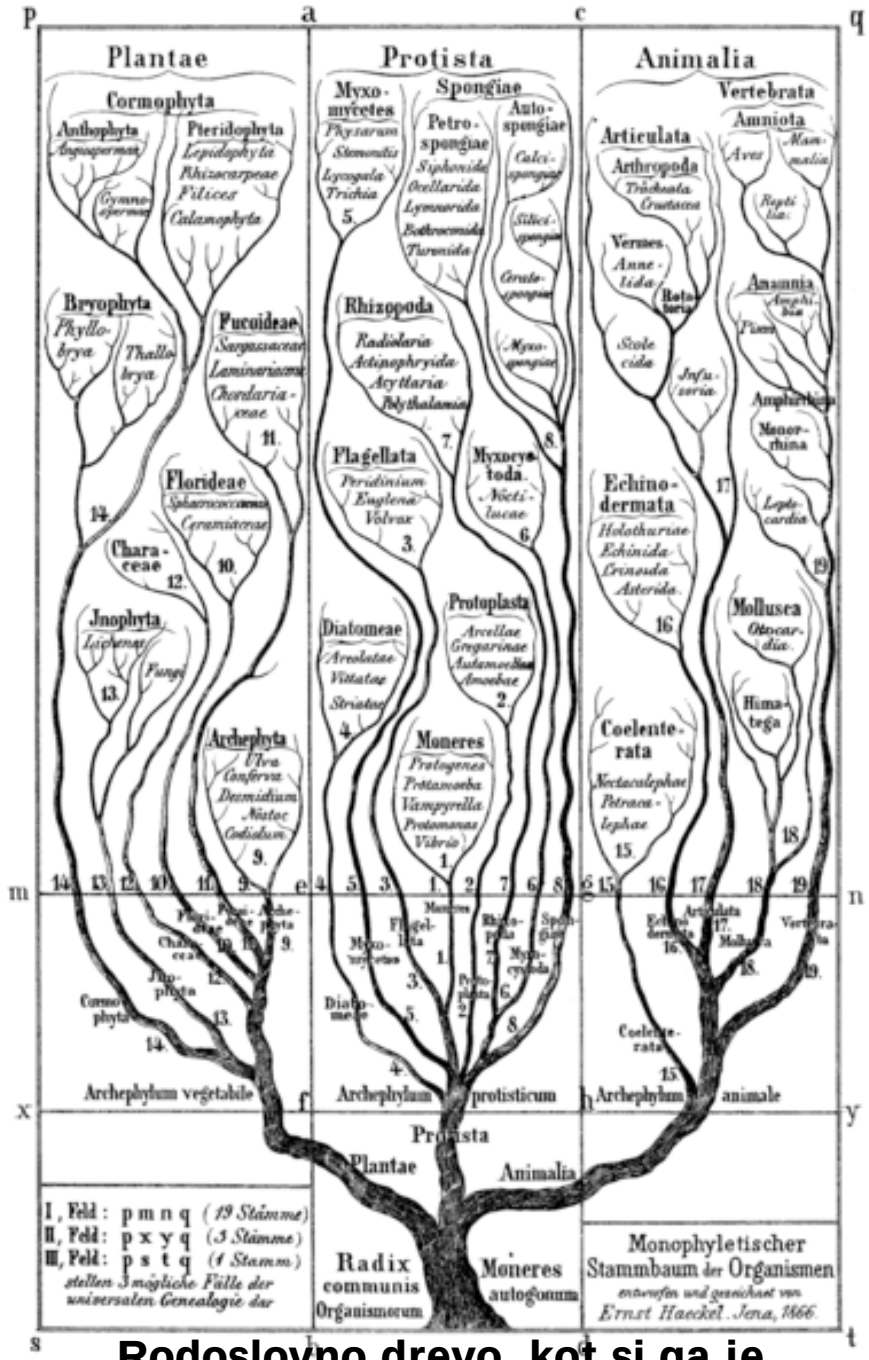
Darwinovo "Drevo življenja"

"Medsebojne odnose med vsemi živimi bitji lahko predstavimo kot veliko **drevo** … Zelene in brsteče veje predstavljajo obstoječe vrste, tiste starejše pa dolgo sosledje izumrlih vrst…"



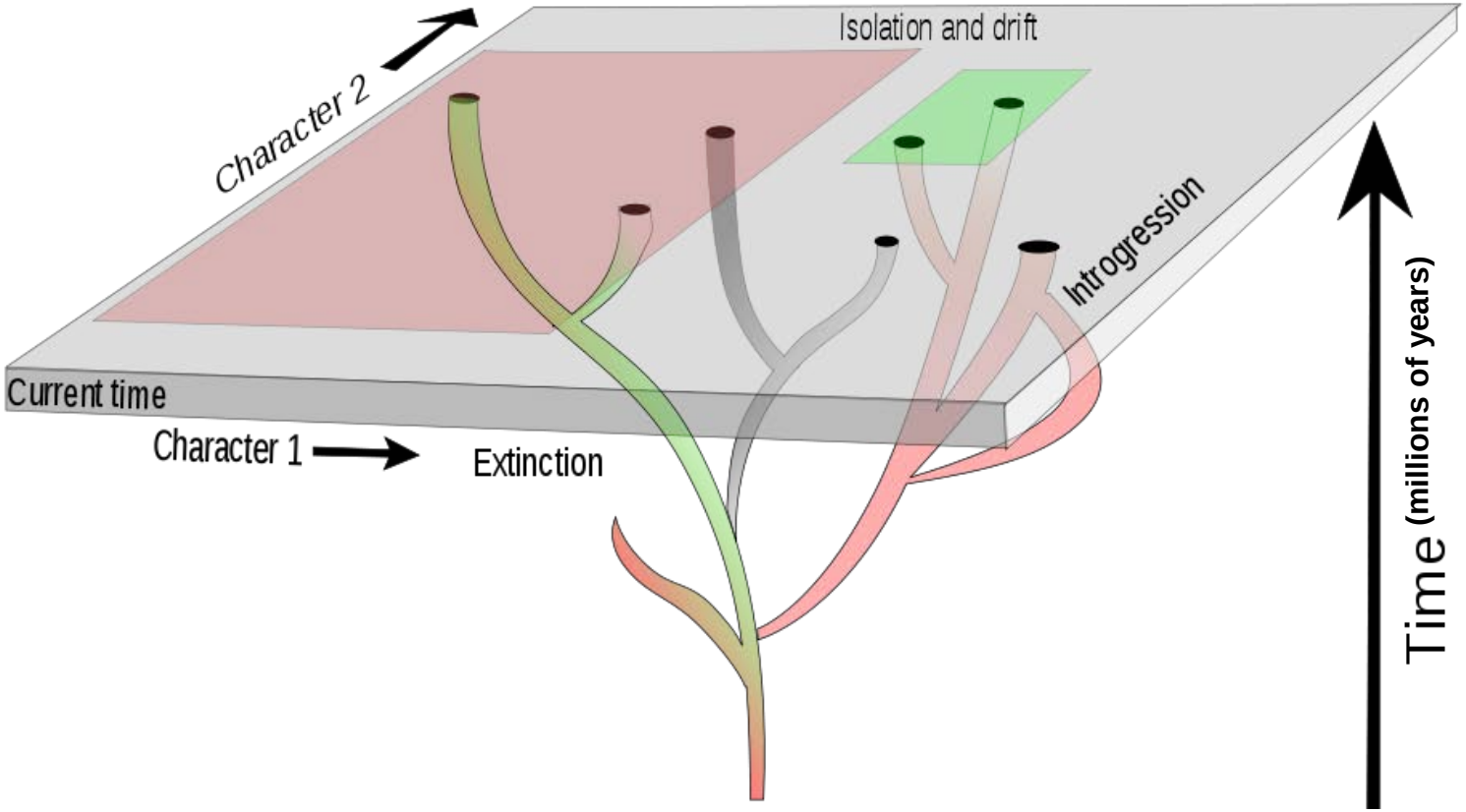
Haeckelovo "Drevo življenja"

uvede pojem „**filogenija**" (evolucijska zgodovina vrst in njihovih medsebojnih sorodstvenih odnosov)



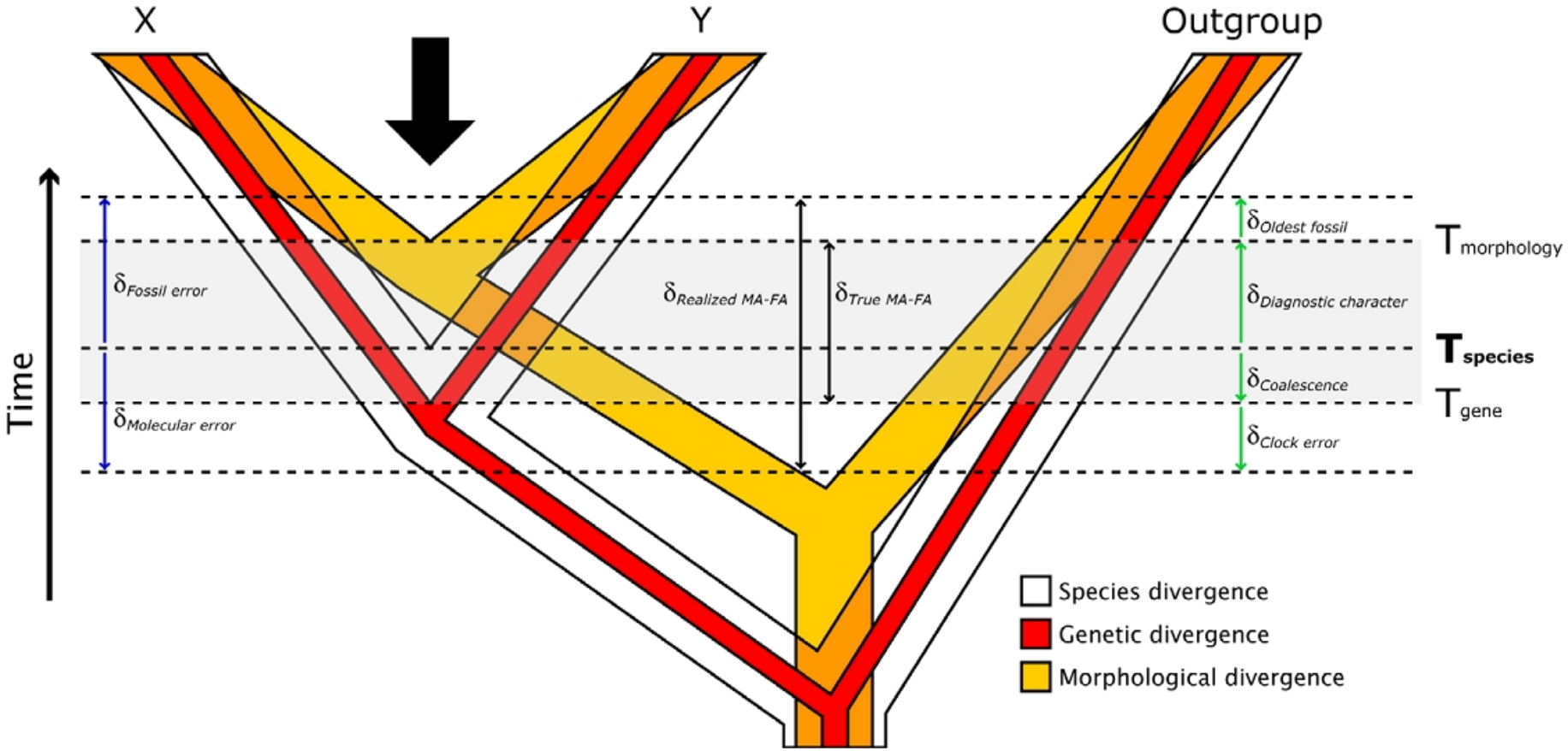
Rodoslovno drevo, kot si ga je predstavljal Haeckel (1866)

Raznolikosti življenja je raznolikost bolj ali manj diskretnih skupin organizmov



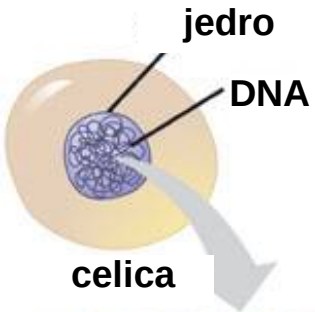
Speciacija je rezultat naravnega izbora, ki deluje na različice, ki so rezultat mutacij in rekombinacij in nevtralnega genetskega dritfa. S stopnjo razhajanja linij se postopno povečujejo tudi genetske razlike med njimi.

Genetska in morfološka razhajanja niso sočasna



Species Divergence. Brown et al., 2008

Dedni zapis je v molekulah DNA - genom



dvojna vijačnica DNA

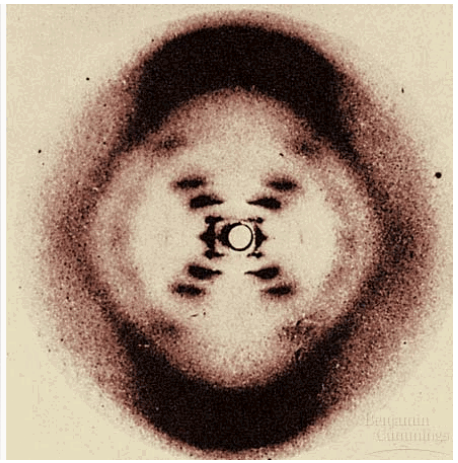
Nobelova nagrada za medicino 1962

“za odkritja o molekulski zgradbi nukleinskih kislin in njenega pomena za prenos informacije v živem materialu”

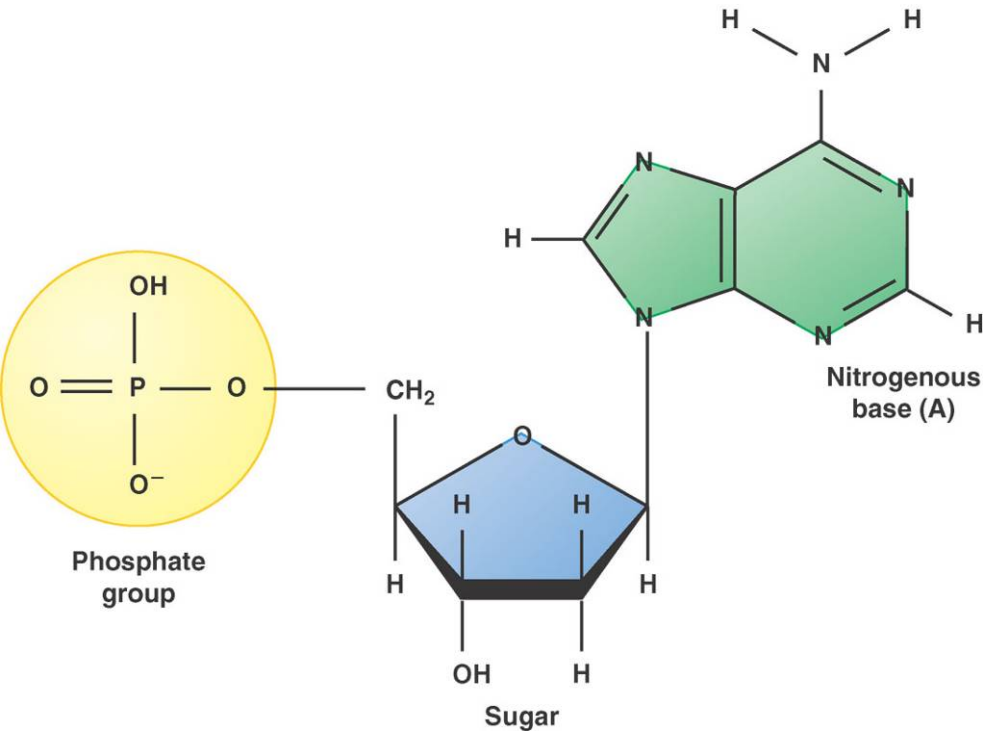
Francis Crick
(1916-2004)

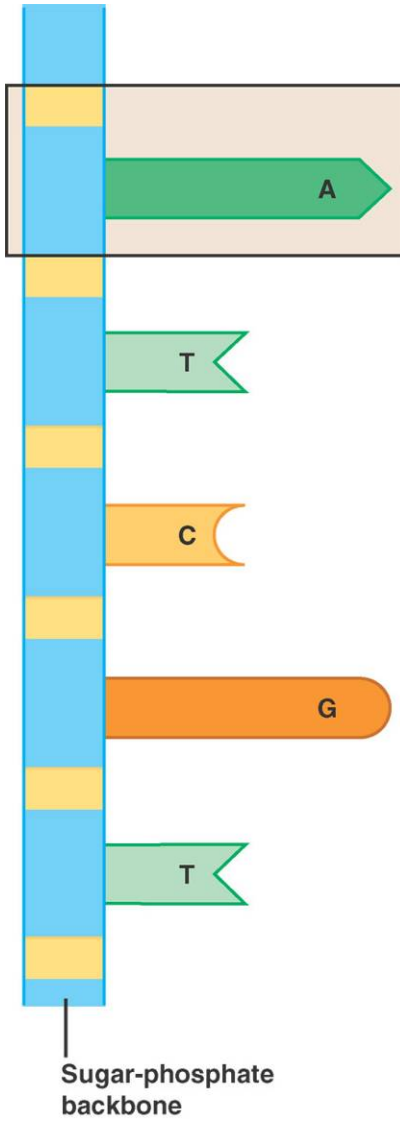
James D. Watson
(1928)

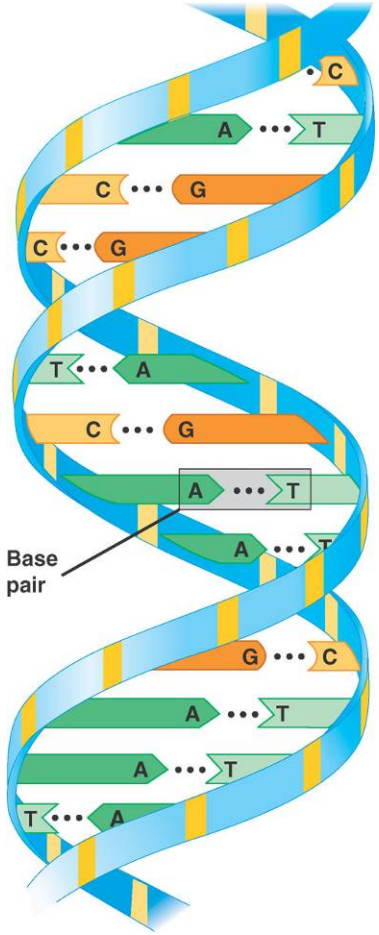
Maurice Wilkins
(1916-2004)



Rosalind Franklin (1920-1958)





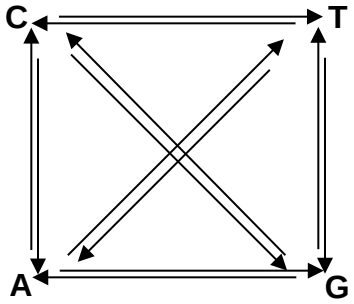


Informacija za sintezo proteinov je zapisana v zaporedju nukleotidov v DNA

Zaporedje DNA spreminjajo mutacije

točkovne mutacije

- zamenjave posameznih nukleotidov



mutacije večjega obsega

- delecije, duplikacije, insercije, transpozicije,inverzije

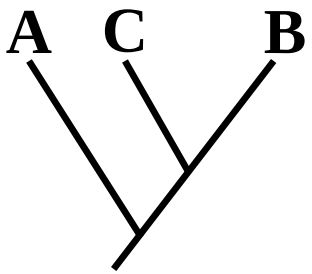
mutacije v regijah, ki vsebujejo zapis za sintezo beljakovin, so za organizme večinoma negativne/smrtne

Zaradi mutacij v evoluciji nastajajo nove vrste - zaporedja DNA med organizmi se razlikujejo

A CCCCGAGGACTTTTT

B CCCCCAGGACATTTT

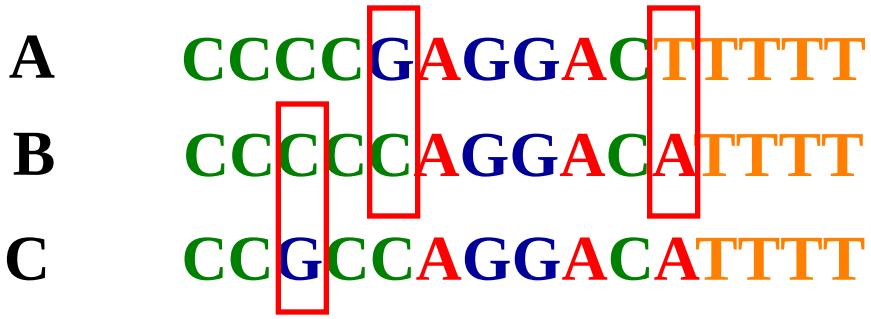
C CCGCCAGGACATTTT



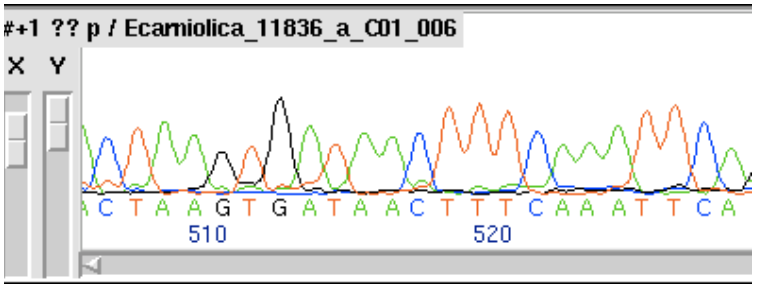
filogenetsko drevo - hipoteza evolucijske zgodovine

na razlikah v zaporedjih DNA temeljijo filogenetske analize

Kako dobimo zaporedja DNA?



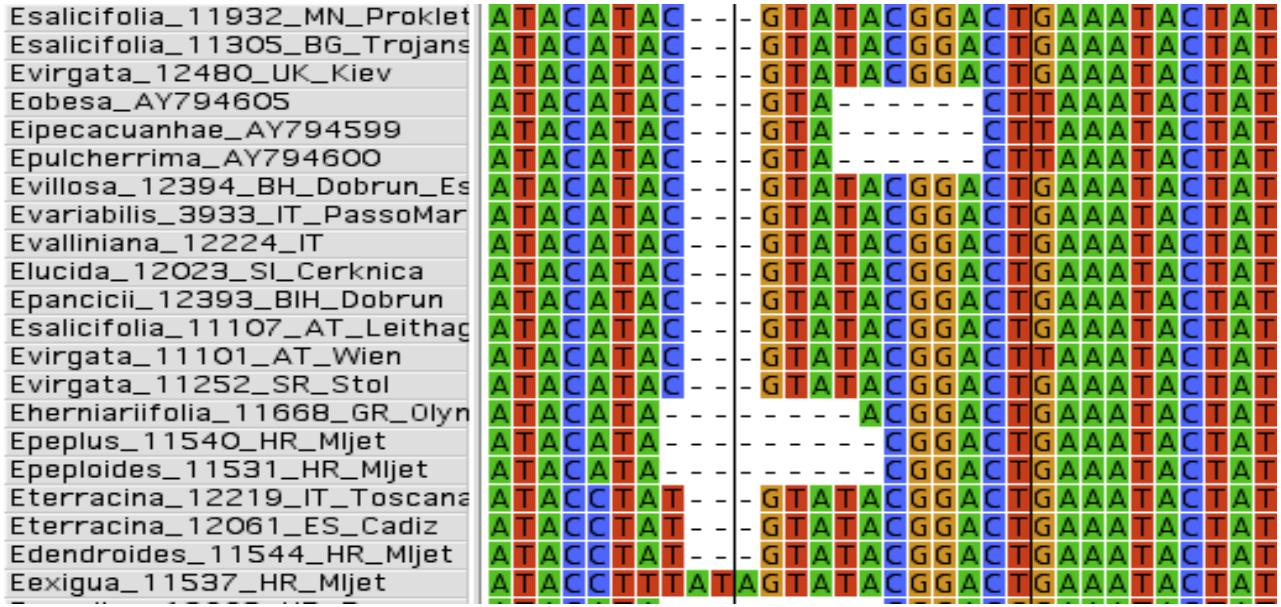
- **izolacija (ekstrakcija) DNA iz rastlinskega tkiva**
- **pomnoževanje izbranih odsekov DNA (PCR)**
- **sekveniranje izbranih odsekov DNA**



Kromatogram

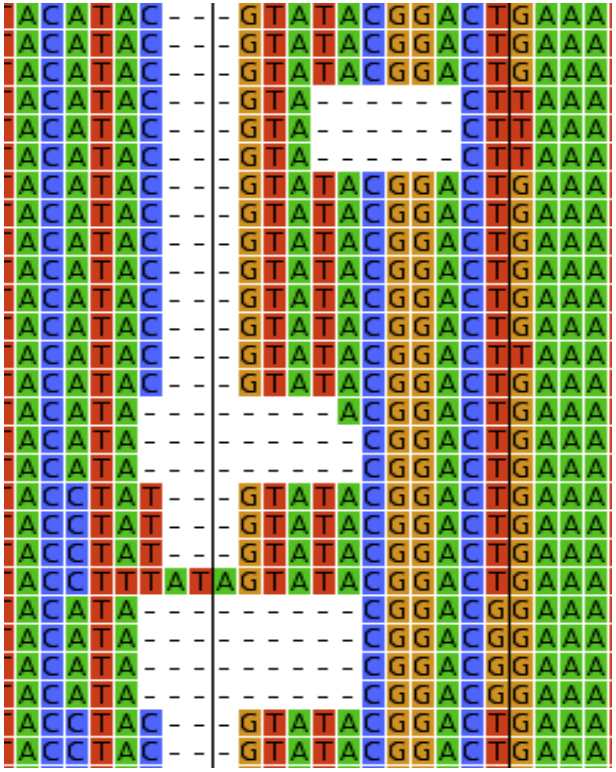
Poravnava večih zaporedij

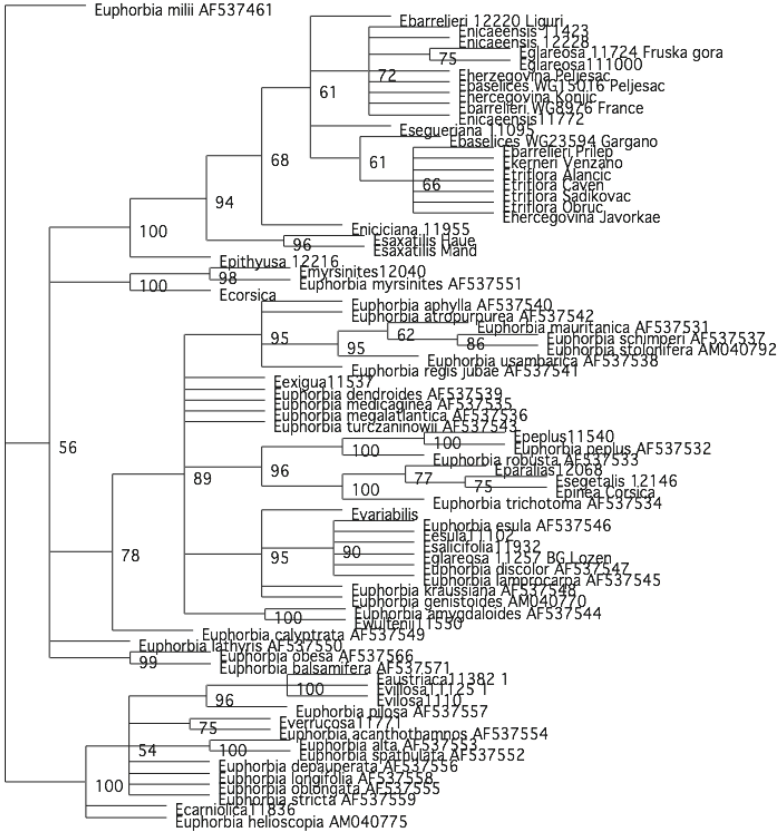
- ATACATACGTATACGGACTGAAATACTATCT
- ATACATACGTACTTAAATACTATCT
- ATACATACGGACTGAAATACTATCT
- ATACCTTTATAGTATACGGACTGAAATACTATCT
- ATACATACGGACGGAAATACTATCTC



Bistvena je homologija!

Od poravnave do filogenetskega drevesa



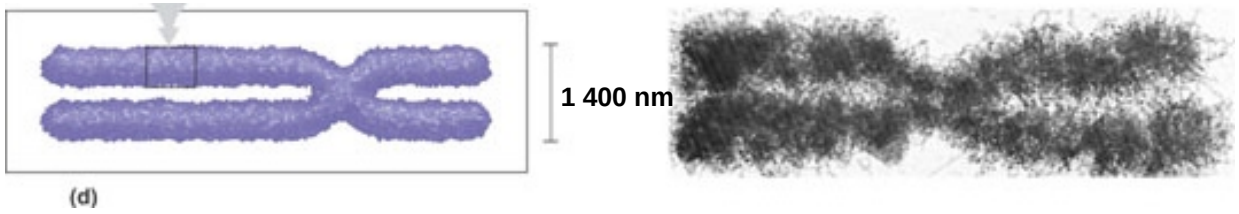


- več različnih tipov analiz
- številni zapleteni algoritmi
- analize trajajo od nekaj ur do nekaj dni ali tednov

Struktura rastlinskega genoma

- **20-40 % v obliki edinstvenih, neponovljivih odsekov DNA**
  - odseki, ki vsebujejo zapis za sintezo beljakovin (geni)
- **60-80 % v obliki ponovljenih odsekov**
  - odseki, ki se v genomu le nekajkrat (do nekaj 1000 krat) ponovijo: npr. nekateri histonski in rRNA geni (ITS)
  - odseki, ki se v genomu velikokrat (10^5-10^7 krat) ponovijo (t.i. »highly repeated sequences«)

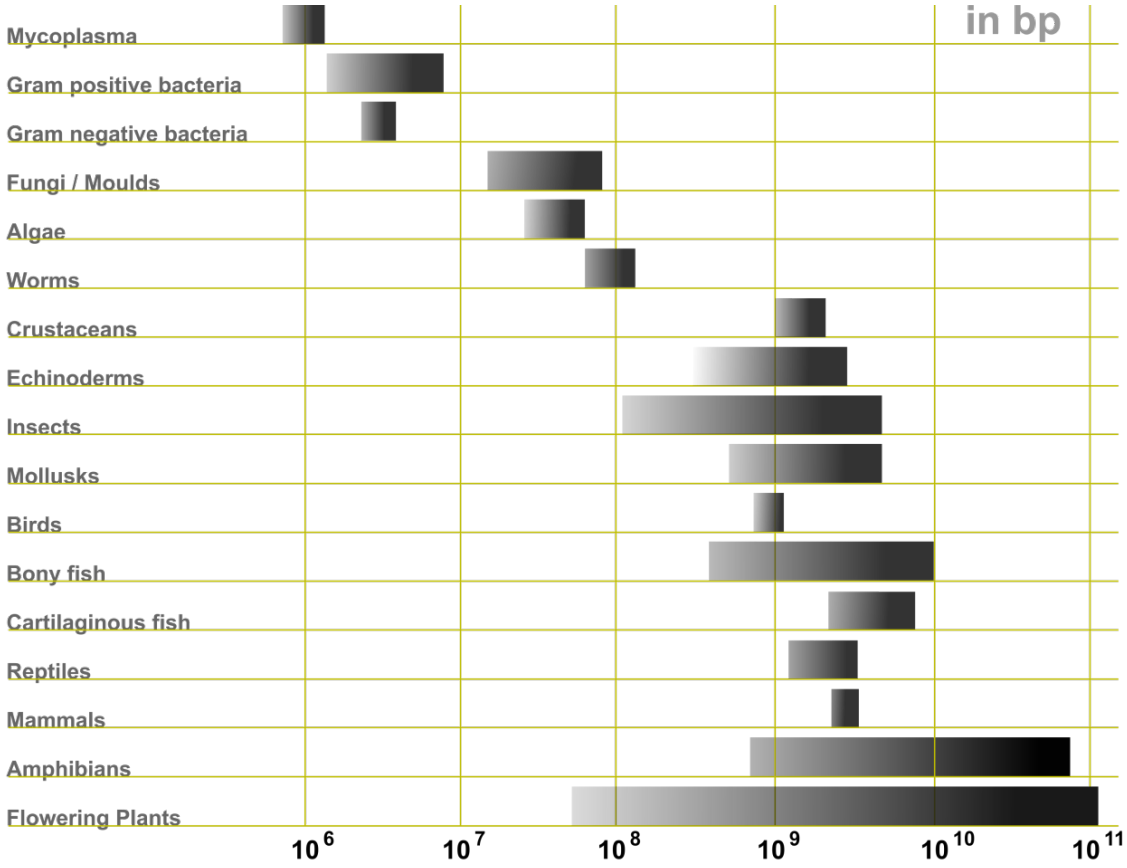
DNA v jedru je močno zvita in organizirana v kromosome



Kolikšna je skupna dolžina DNA v jedru?

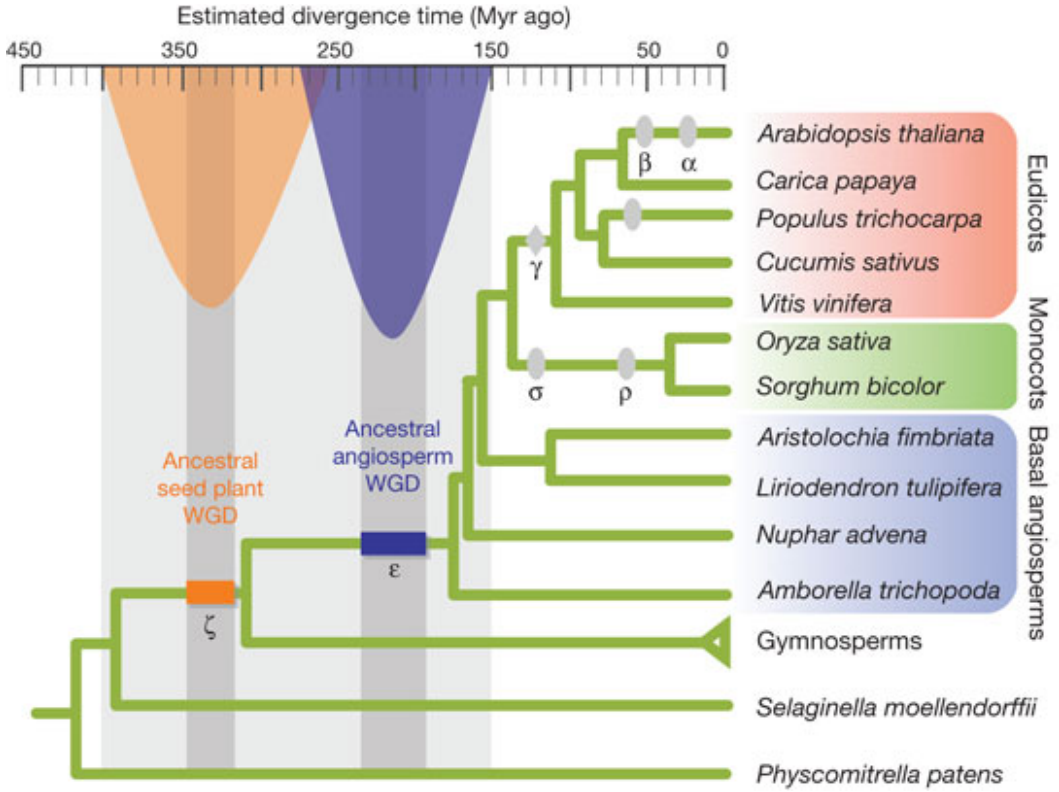
1 pg DNA = 0.3 m (1 pikogram = 10^{-12} g ~ 10^{9} bp)

človek:	2 m (7 pg)	soja:	1.5 m (2.7 pg)
čebula:	10 m (33 pg)	redkev:	0.4 m (1.4 pg)
grah:	2.5 m (9 pg)	repnjakovec:	0.09 m = 9 cm (0.3 pg)



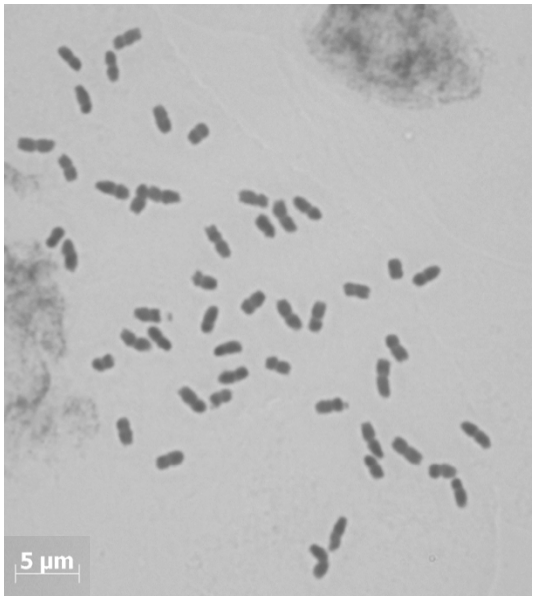
http://en.wikipedia.org/wiki/Genome_size

V evoluciji rastlin je večkrat prišlo do podvojitev genoma



Nature 473: 97–100

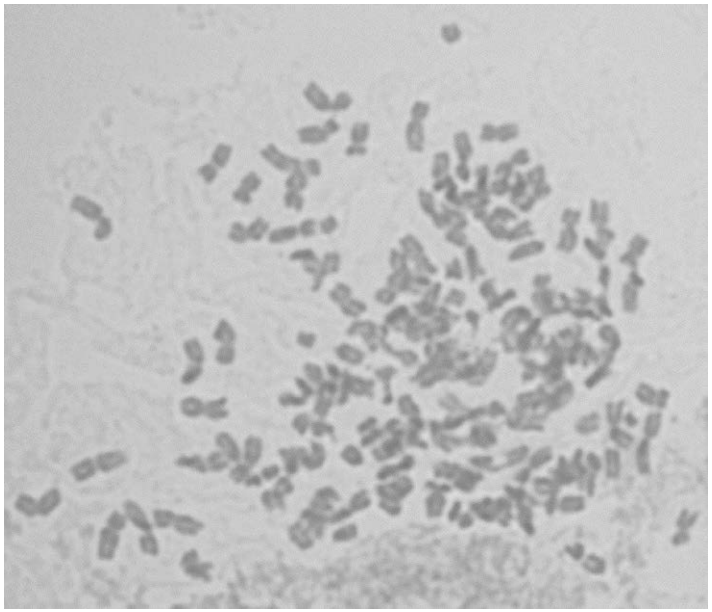
Poliploidizacija pri južnoameriških lepnicah (*Silene*)



***Silene antarctica* *2n*=48; *x*=12**
tetraploid

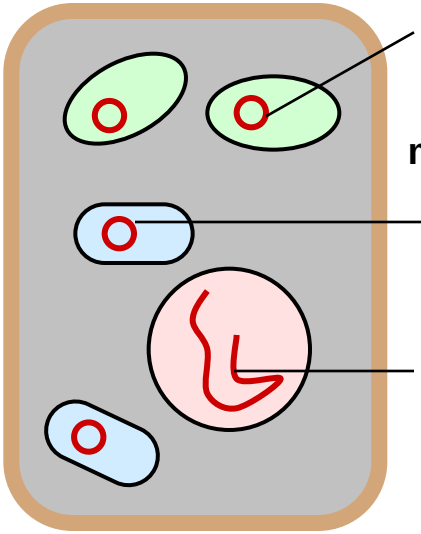
v Evropi je večina lepnic diploidov (*2n*=24)

Poliploidizacija pri južnoameriških lepnicah (*Silene*)

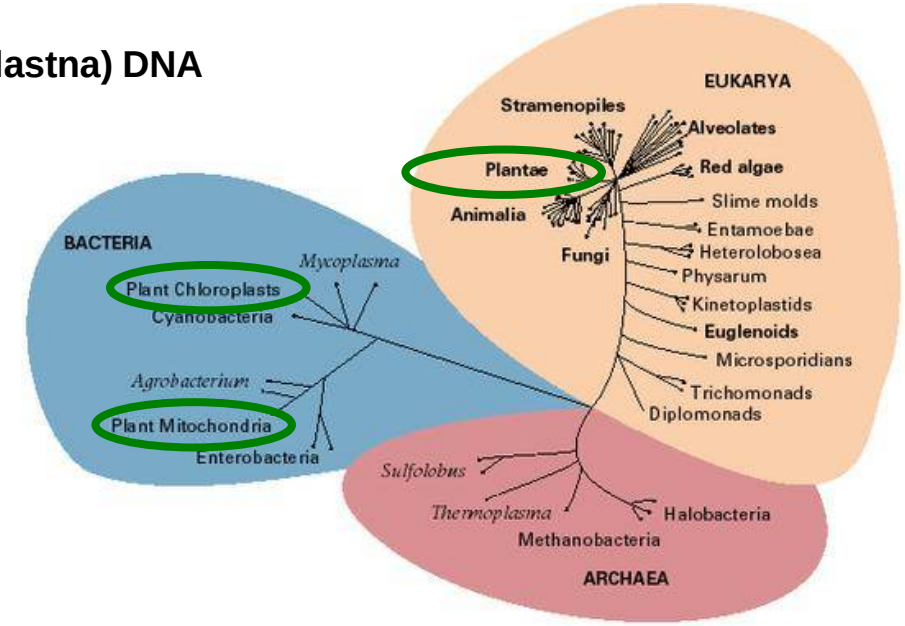


***Silene chilensis* *2n*=120;**
***x*=12**
dekaploid

Trije genomi v rastlinski celici



rastlinska celica

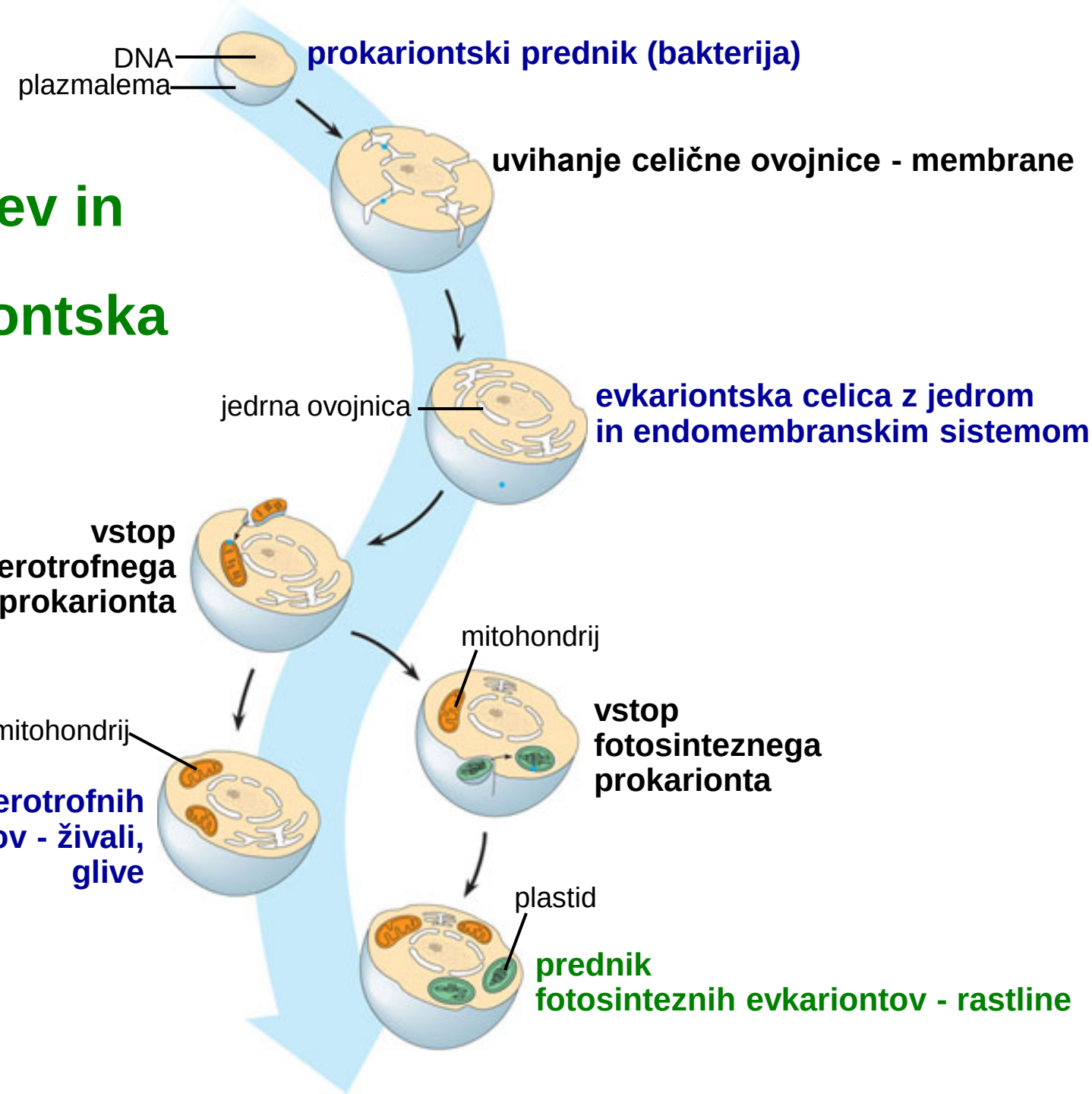


Plastid in mitohondrij imata:

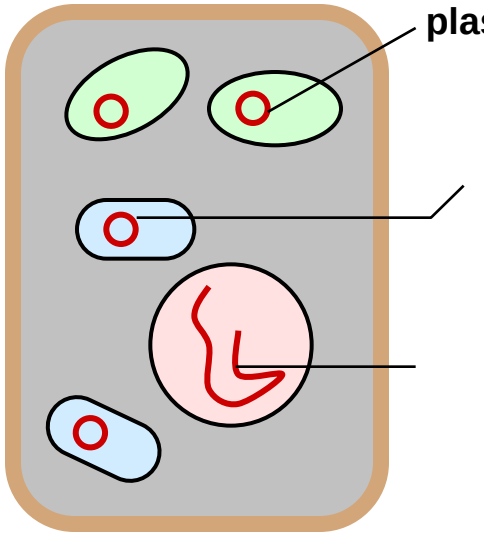
lastno DNA (izvira iz bakterijskega prednika)

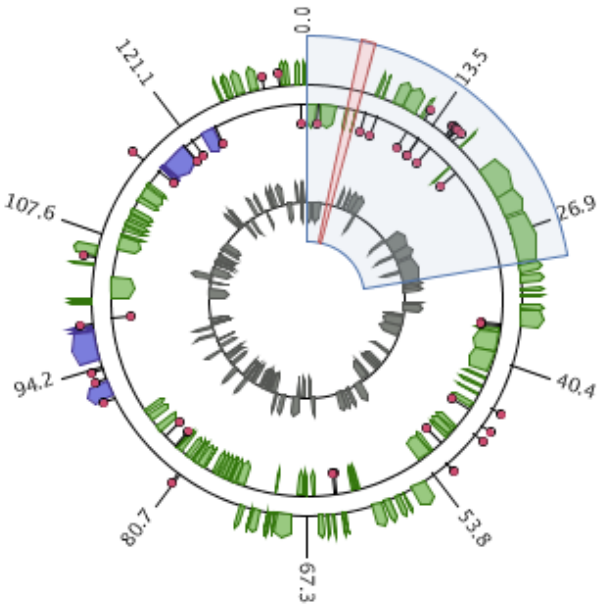
se samostojno (avtomnomno) podvajata

Izvor jedra, mitohondrijev in plastidov (endosimbiontska teorija)



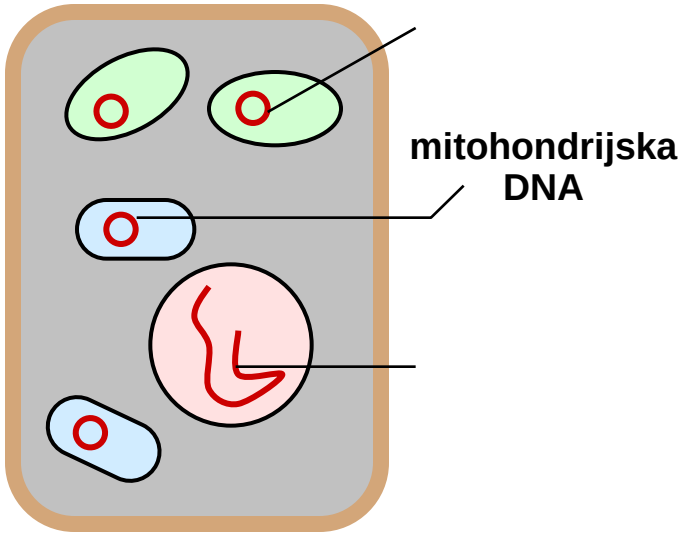
Plastidni genom

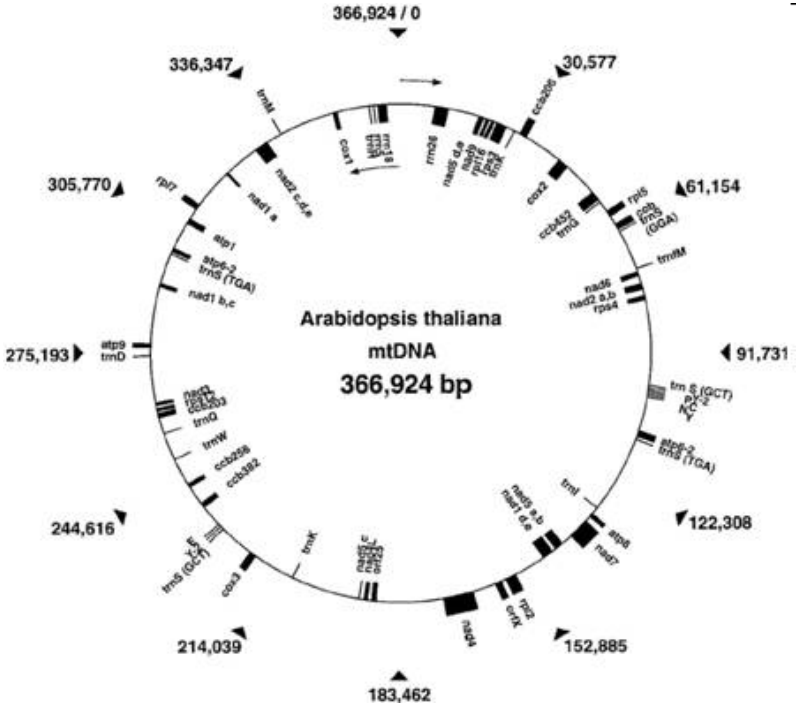




- krožna vijačnica DNA (70-220 kbp)
- se deduje le po maternalni liniji (obstajajo izjeme!)
- z mutacijami se zmerno hitro spreminja
- se veliko uporablja

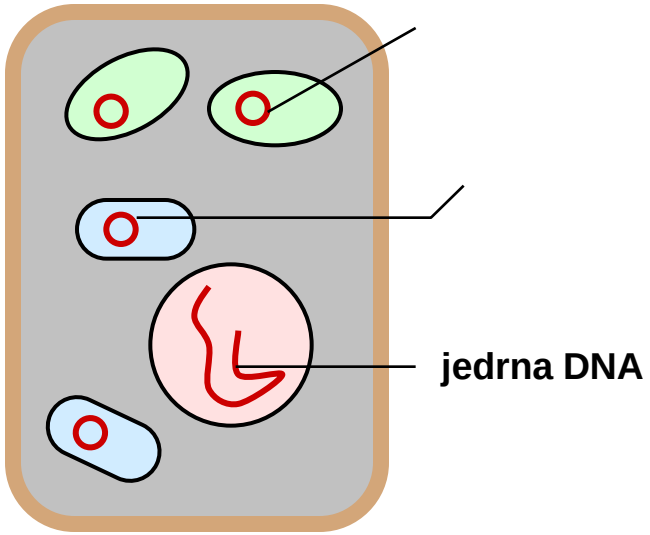
Mitohondrijski genom

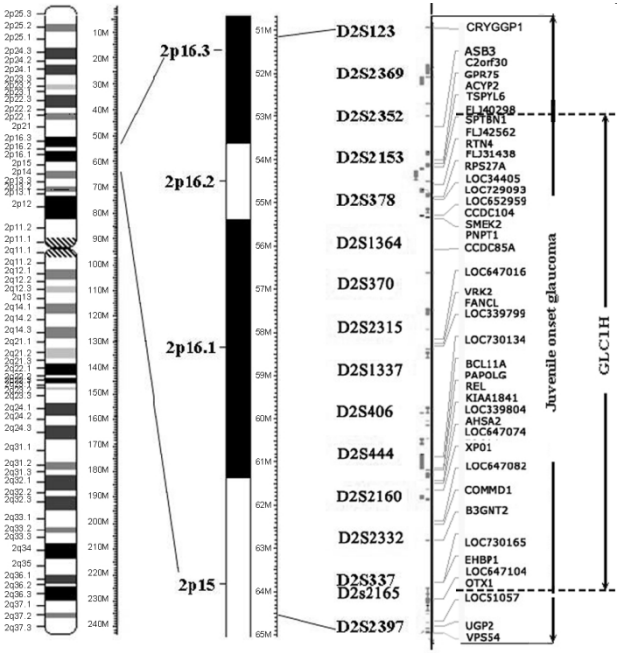




- krožna vijačnica DNA (200-2400 kbp; 50-60 genov)
- se deduje le po maternalni liniji (obstajajo izjeme!)
- pogoste strukturne spremembe in preureditve
- se redko uporablja (pri živalih zelo pogosto!)

Jedrni genom



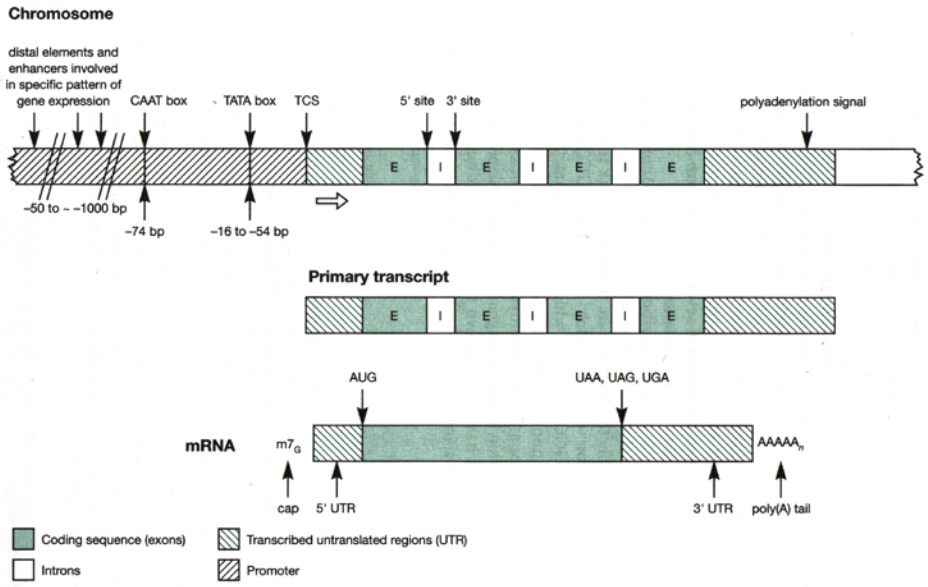


- predstavlja večji del genoma
- se deduje po obeh linijah
- različna hitrost spreminjanja z mutacijami v različnih delih
- se pogosto uporablja (zlasti ITS)

Geni: eksoni in introni

• **eksoni**: odseki DNA, ki vsebujejo dejanski zapis za proteine; se počasi spreminjajo (oz. so njihove spremembe smrtne)

• **introni**: vmesni odseki med eksoni, se hitro spreminjajo

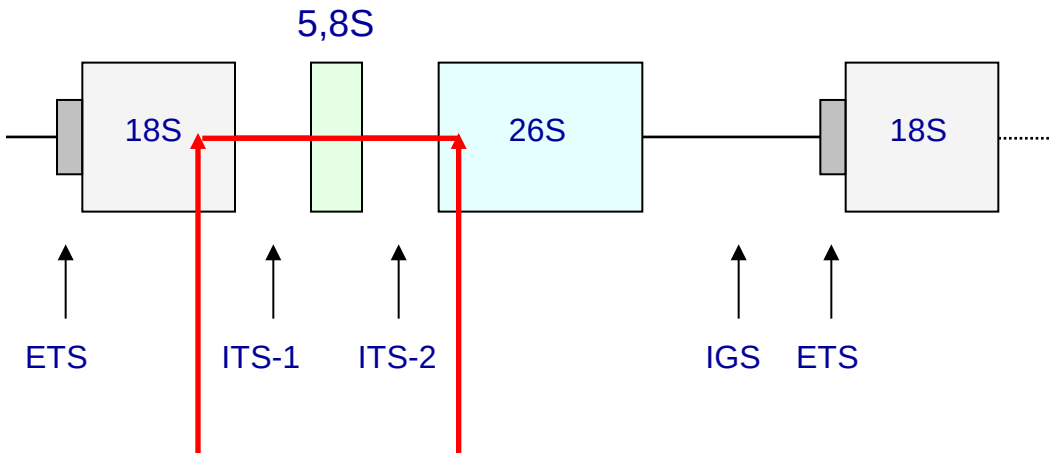


• **eksoni**: njihova zaporedja uporabna na višjih taksonomskih ravneh (primerjave med rodovi, družinami, redovi,....)

• **introni**: filogenetske analize na vrstni in rodovni ravni

ITS (Internal Transcribed Spacer)

- notranji prepisni vmesnik prisoten v nekaj 1000 kopijah v genomu
- **“S” regija** vsebuje zapis za ribosomalno RNA (pomembna v sintezi proteinov!); se zelo počasi spreminja
- **ETS** in **ITS** se zelo hitro spreminja



Se zelo pogosto uporablja v filogenetskih študijah rastlin

Asyneuma comosiforme

soteska “Shija” pri vasi Bicaj (SV Albanija)

Asyneuma comosiforme Hayek & Janch. in Hayek, Österr. Bot. Z. 70: 20–21, 1921). Type: “Nordost-Albanien: Felsen am unteren Ende der Šija-Schlucht bei Bicaj, ca. 400 m, leg. H. Zerny, 15. Juni 1918”

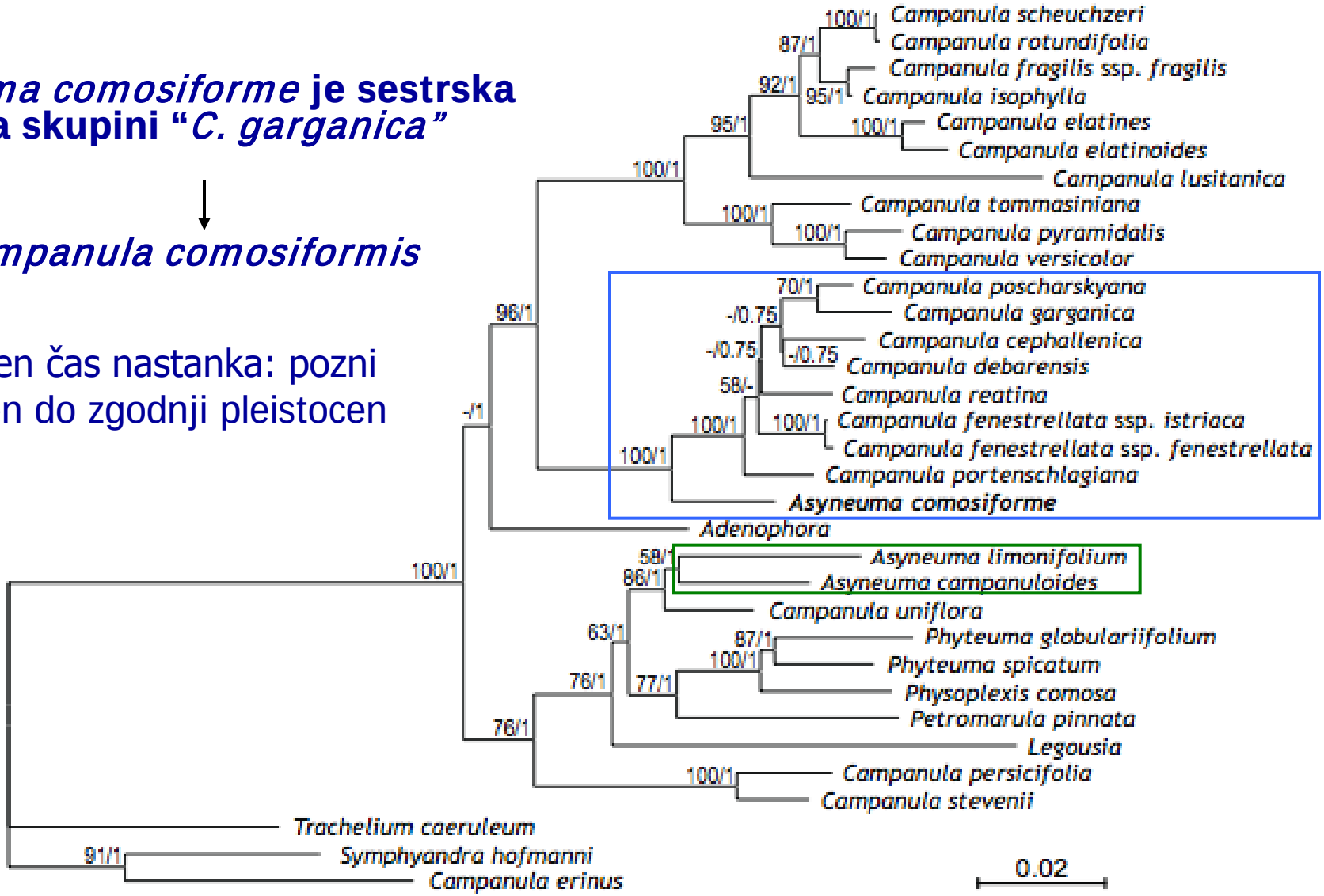
Campanula comosiformis

***Asyneuma comosiforme* je sestrska vrsta skupini "*C. garganica*"**

↓

Campanula comosiformis

ocenjen čas nastanka: pozni miocen do zgodnji pleistocen



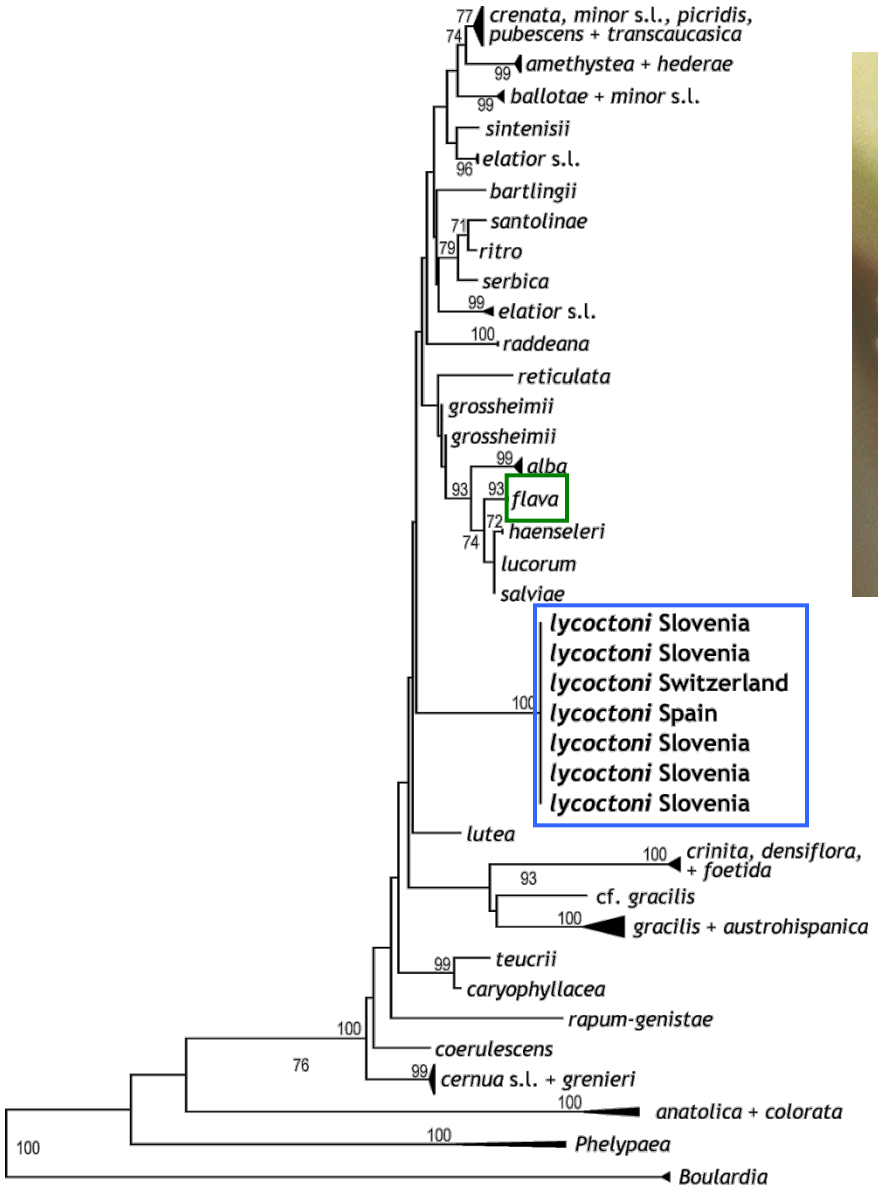
Frajman & Schneeweiss, 2009

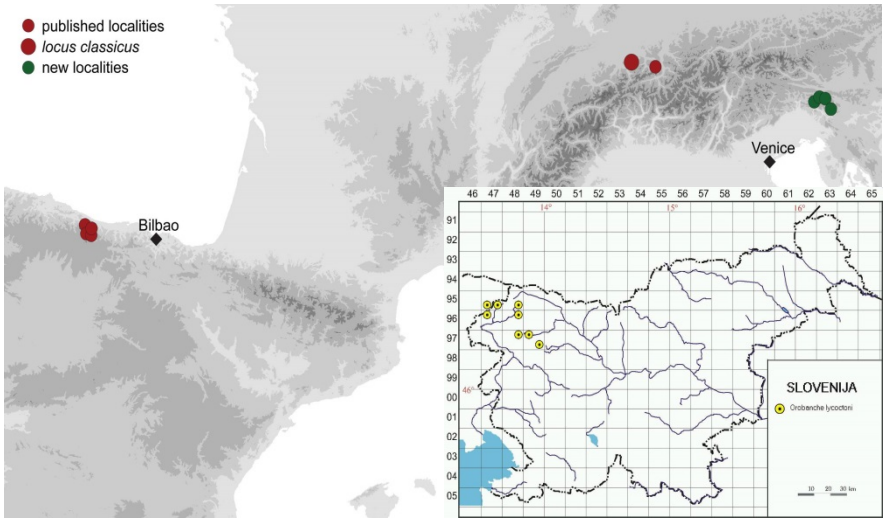
skupna analiza plastidne *trnL-trnF* in ITS

Orobanche - pojalnik

Ali gre za *Orobanche flava* ali *O. lycoctoni*?

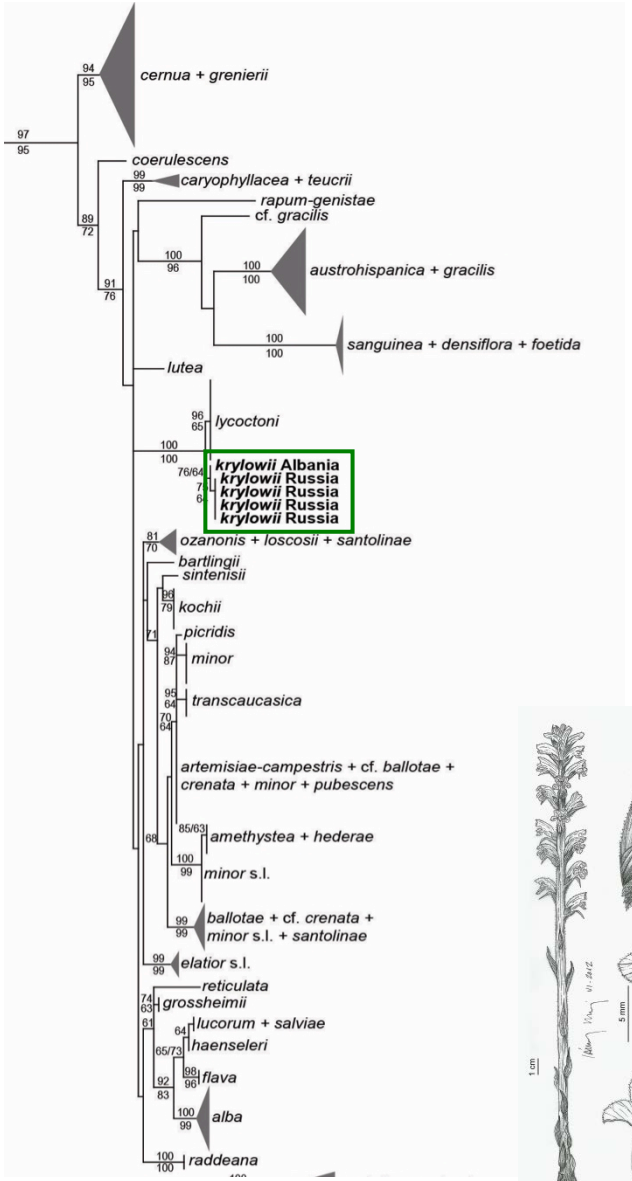
Orobanche lycoctoni



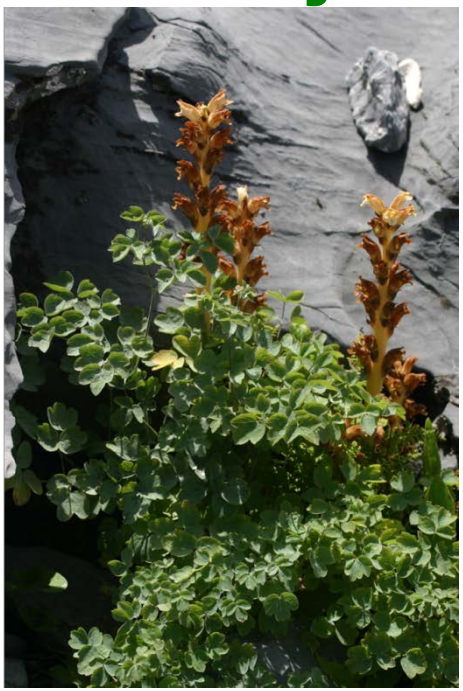


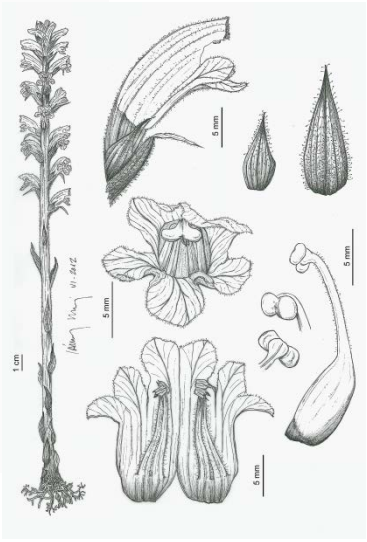
Schneeweiss, Frajman & Dakskobler, 2009

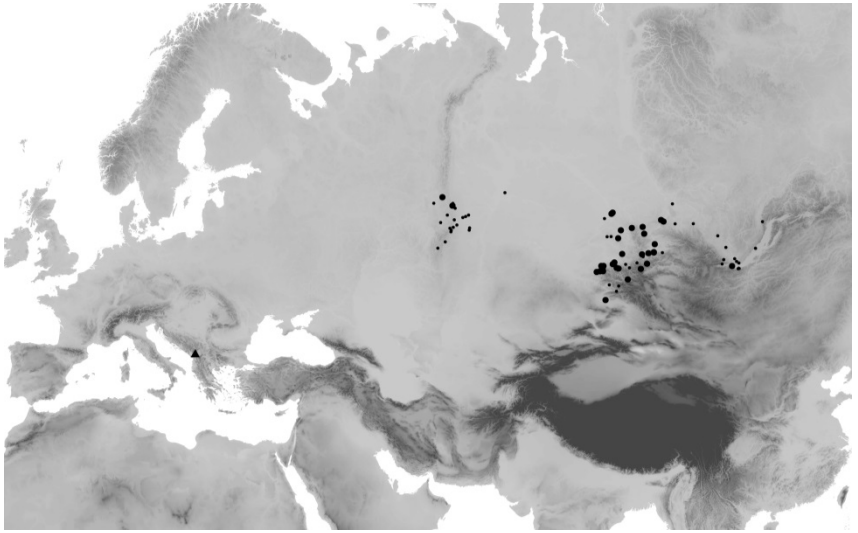
Orobanche krylowi v Albaniji



Frajman & al., 2009







Kadar ni željene variabilnosti...

poskusimo uporabiti bolj občutljive metode, npr. AFLP

Amplified Fragment Length Polymorphism

Nucleic Acids Research, 1995, Vol. 23, No. 21 4407–4414

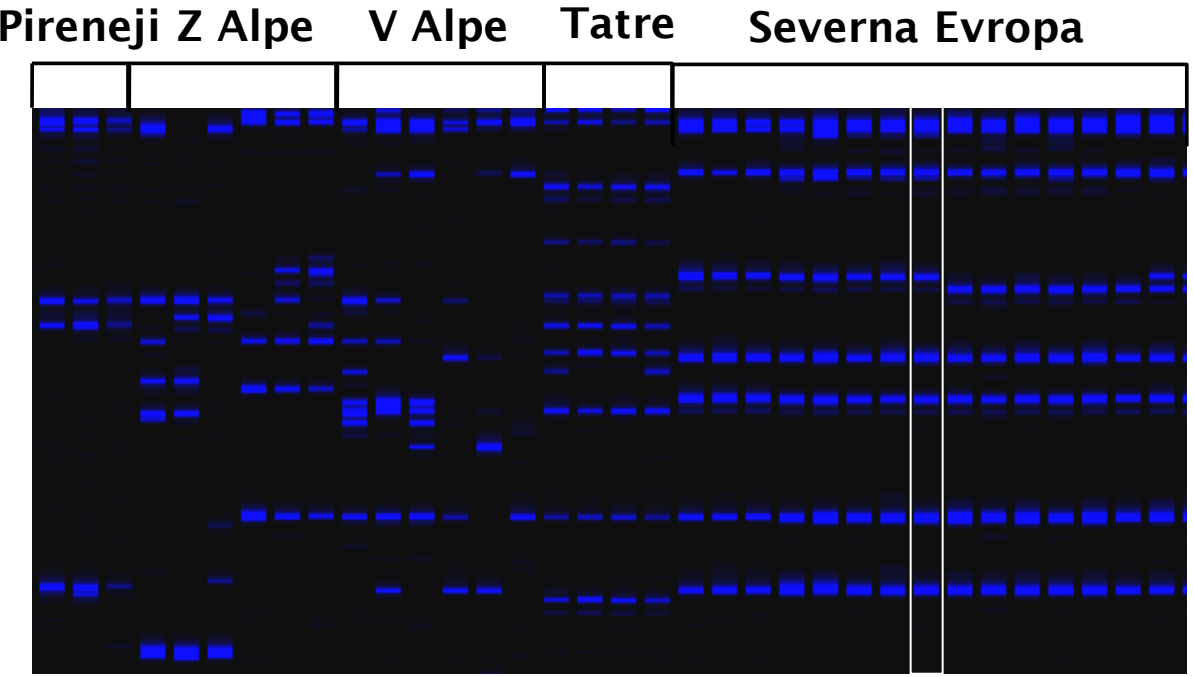
AFLP: a new technique for DNA fingerprinting

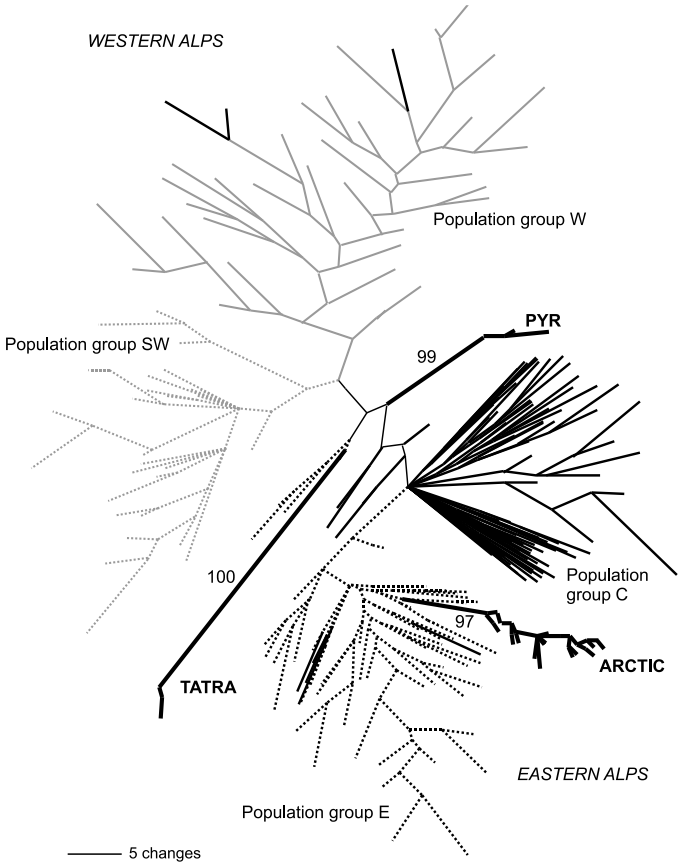
Pieter Vos*, Rene Hogers, Marjo Bleeker, Martin Reijans, Theo van de Lee, Miranda Hornes, Adrie Frijters, Jerina Pot, Johan Peleman, Martin Kuiper and Marc Zabeau

Keygene N.V., PO Box 216, Wageningen, The Netherlands

odnosi med populacijami iste vrste ali med ozko sorodnimi vrstami

Ranunculus glacialis: AFLP





po ledenih dobah je vrsta arktične predele kolonizirala iz vzhodnih Alp

nizka genetska variabilnost na severu, visoka v Alpah

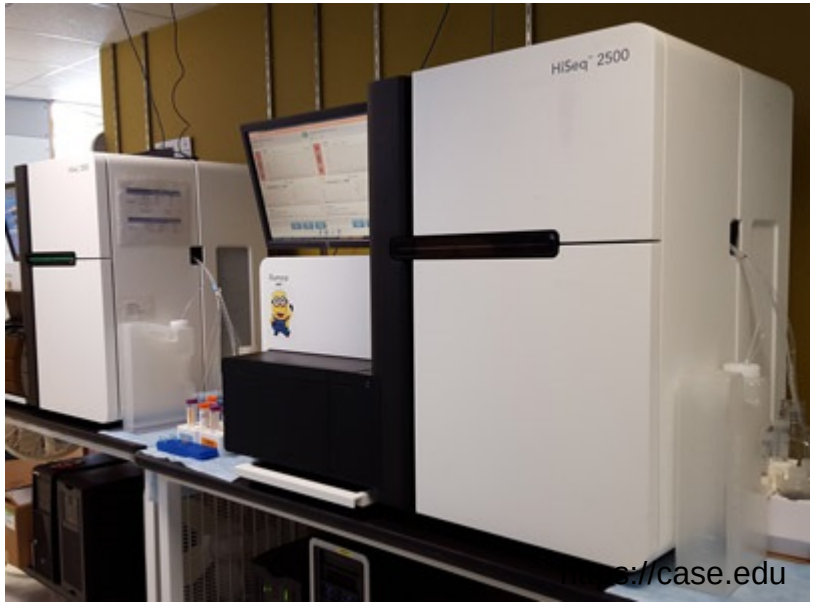
Schönswetter & al.

Sekvenciranje naslednje generacije

- sekvenciranje celotnih genomov
- sekvenciranje velikega števila zaporedij DNA
- veliko večja resolucija filogenetskih dreves (več informacij)

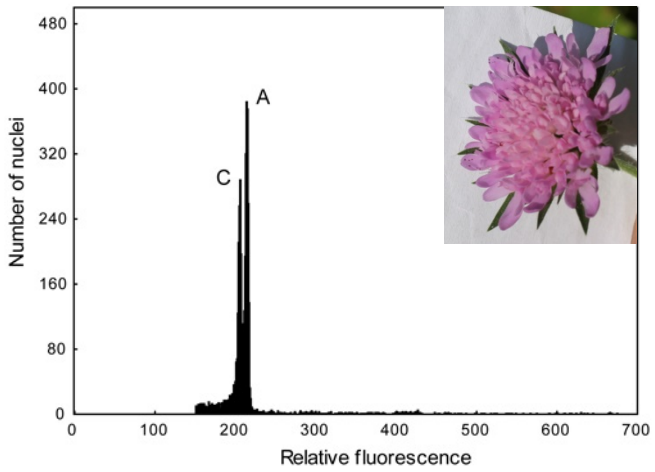
Pogosto se uporablja:

- RAD sekvenciranje (populacijske študije)
- „gene capture“ (raziskovanje odnosov znotraj neke določene skupine organizmov)



http://case.edu

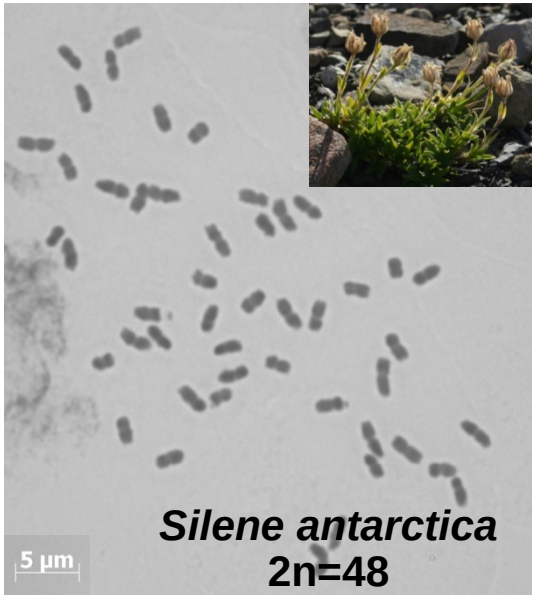
Ne samo molekularne metode!



Velikost genoma

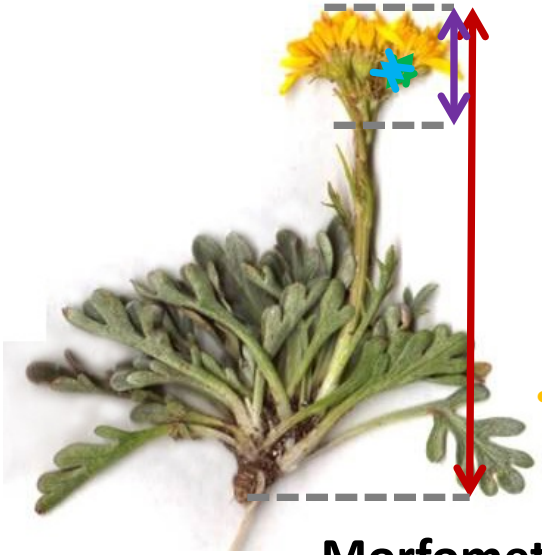
Buphthalmum salicifolium
Galium austriacum
Seseli austriacum
Sesleria varia
Thymus praecox

Ekološke razlike



Silene antarctica
2n=48

Kromosomska števila

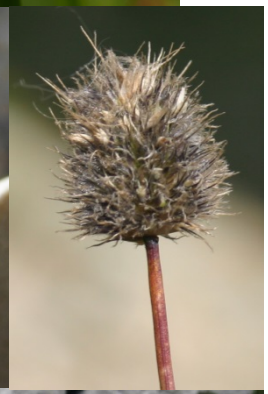


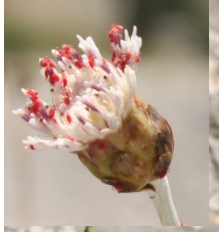
- **Višina rastline**
- **Višina socvetja**
- **Število koškov**
- **Širina ovojka**
- **Dolžina ovojka**
- **Št. jezičastih cvetov**
- **Št. cevastih cvetov**

Morfometrija

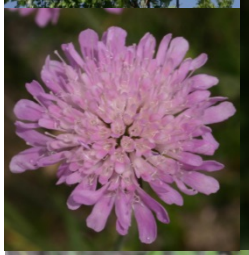






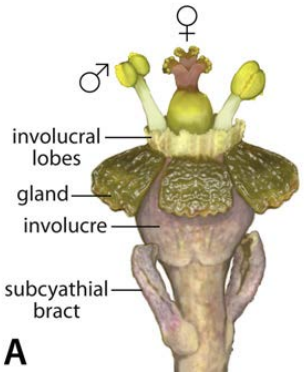



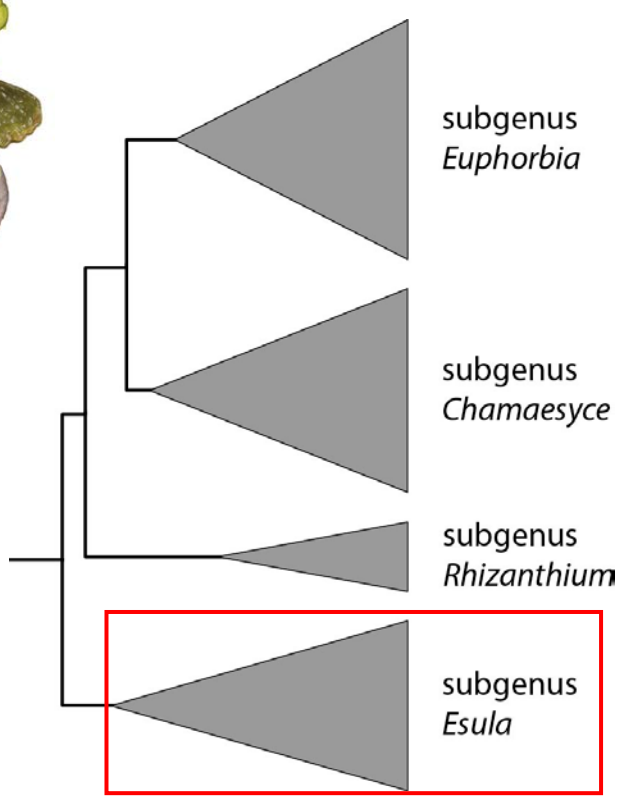


Amborellales
Nymphaeales
Austrobaileyales
Magnoliales
Laurales
Piperales
Canellales
Chloranthales
Arecales
Poales
Commelinales
Zingiberales
Asparagales
Liliales
Dioscoreales
Pandanales
Petrosaviales
Alismatales
Acorales
Ceratophyllales
Ranunculales
Proteales
Trochodendrales
Buxales
Gunnerales
Fabales
Rosales
Fagales
Cucurbitales
Oxalidales
Malpighiales
Celastrales
Zygophyllales
Geraniales
Myrtales
Crossosomatales
Picramniales
Malvales
Brassicales
Huerteales
Sapindales
Vitales
Saxifragales
†Dilleniales
Berberidopsidales
Santalales
Caryophyllales
Cornales
Ericales
Aquifoliales
Asterales
Escalloniales
Bruniales
Apiales
Dipsacales
Paracryphiales
Solanales
Lamiales
†Vahliales
Gentianales
†Boraginales
Garryales
†Metteniusales
†Icacinales
Angiosperms
Monocots
Eudicots
Superrosids
Rosids
Superasterids
Asterids
Magnoliids
Commelinids
Fabids
Malvids
Campanulids
Lamiids

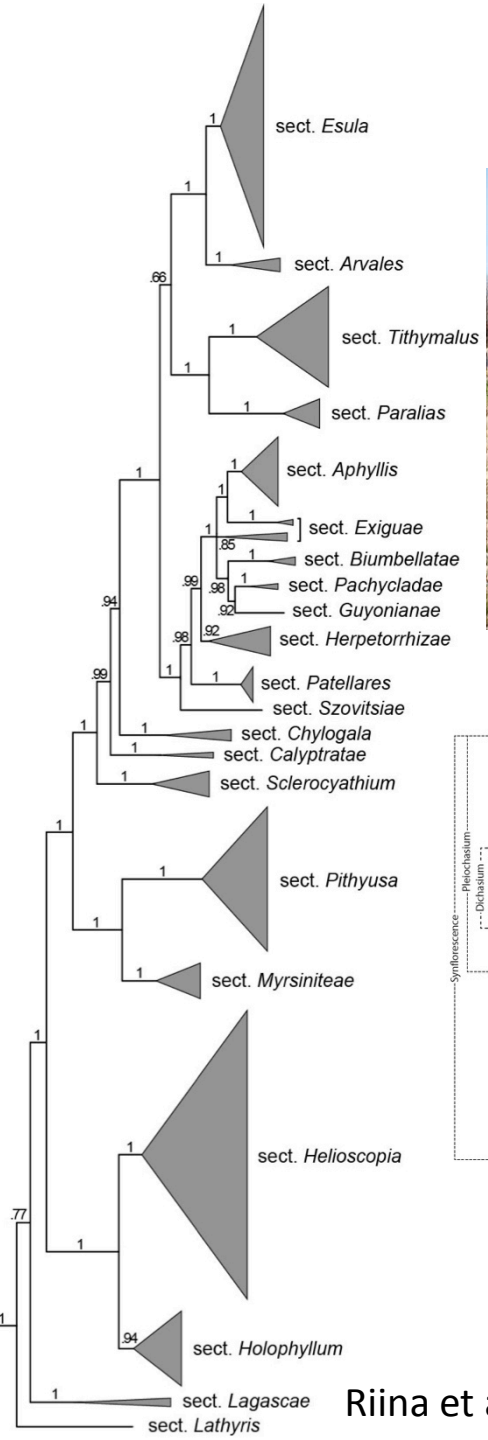
Mlečki (*Euphorbia*) so eden največjih rodov semenk



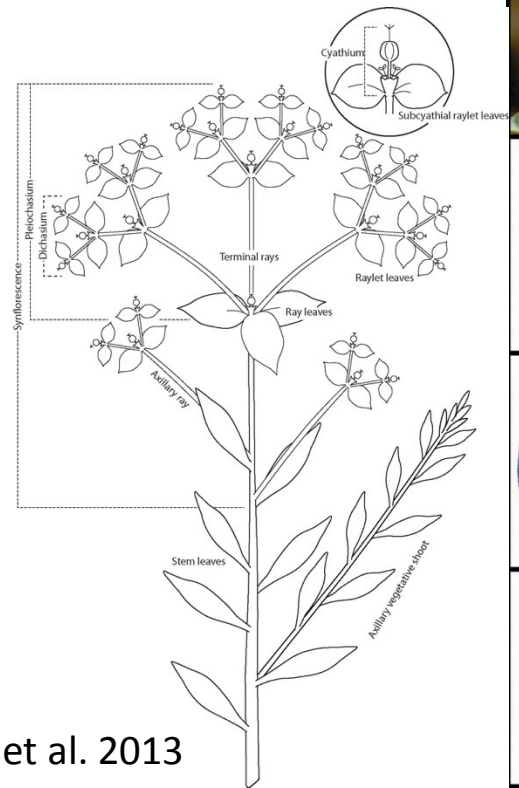


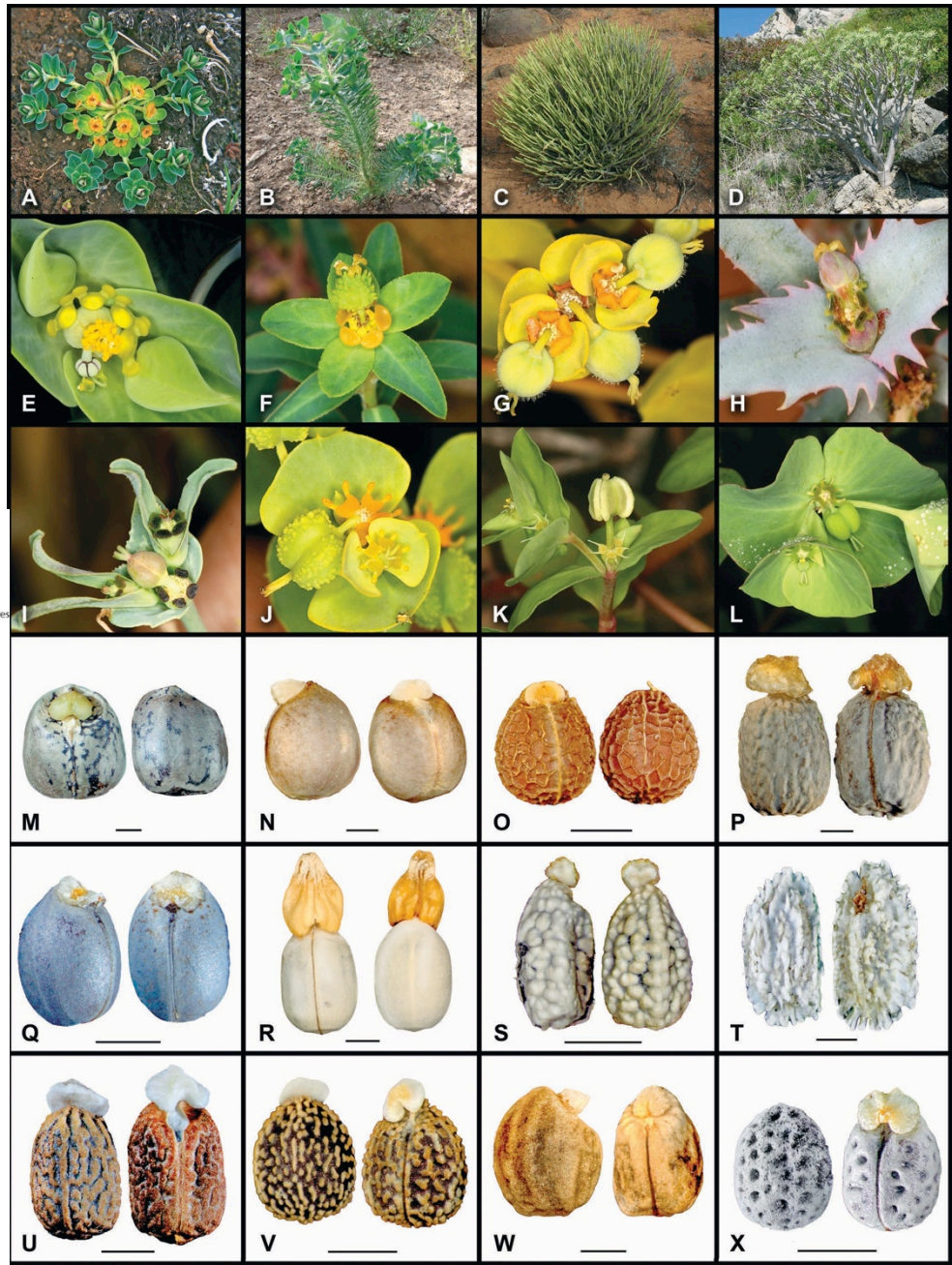
Horn et al. 2012

Euphorbia subgenus *Esula*



Riina et al. 2013

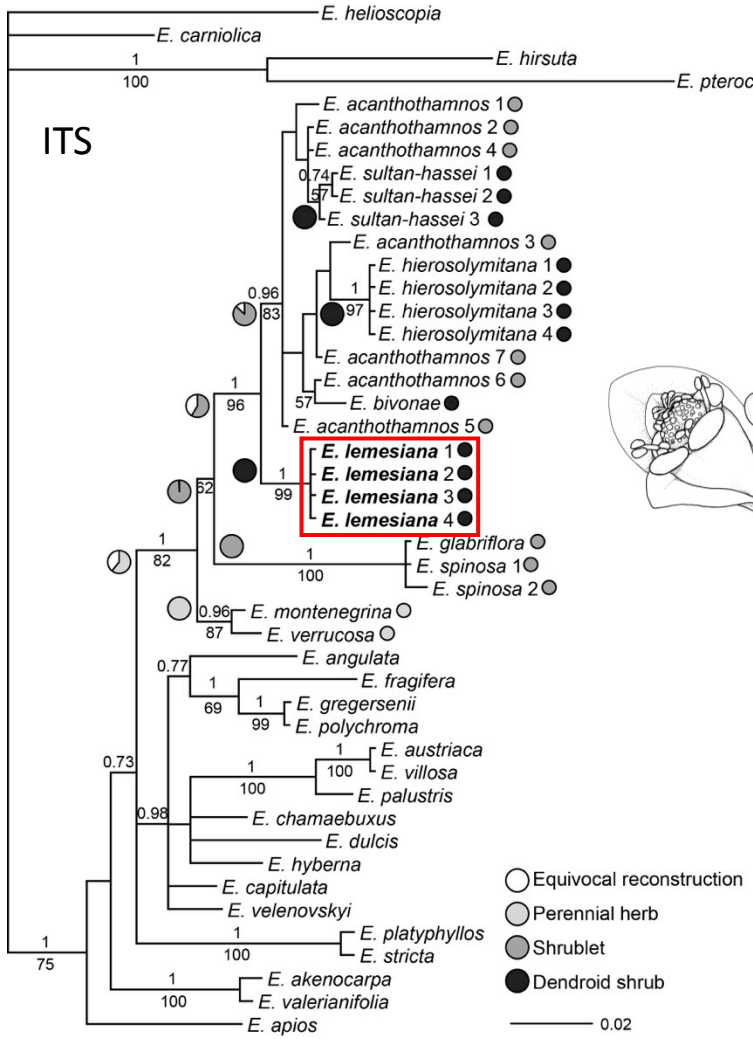


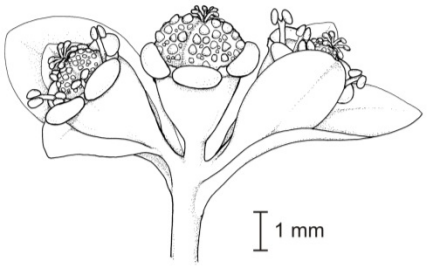


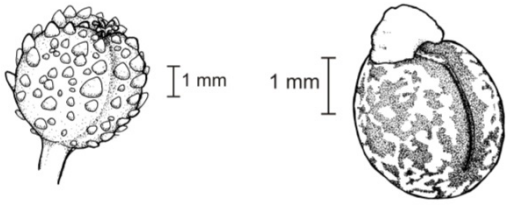
Multiple origins of dendroid shrubs in the eastern Mediterranean *Euphorbia hierosolymitana* group (Euphorbiaceae) with description of a new species, *Euphorbia lemesiana*, from Cyprus

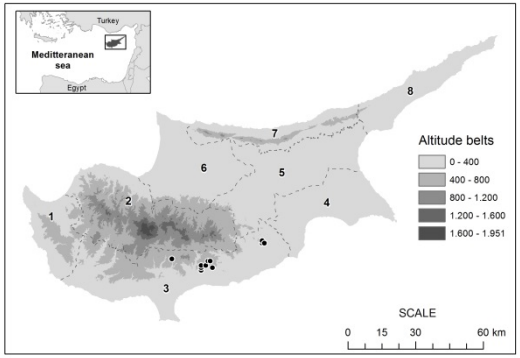
RALF HAND[1], GEORGIOS N. HADJIKYRIAKOU[2], CHARALAMBOS S. CHRISTODOULOU[3] and BOŽO FRAJMAN[4]*

Botanical Journal of the Linnean Society, 2015, **179**, 295–307.









Euphorbia lemesiana Hadjik., Hand, Christodoulou & Frajman


Euphorbia hierosolymitana


Euphorbia sultan-hassei


www.wikiwand.com
Euphorbia acanthothamnos


Euphorbia bivonae
www.naturamediterraneo.com


Euphorbia melitensis

Genetska struktura disjunktno razširjenje Dinarske smiljke (*Cerastium dinaricum*)

Molecular Phylogenetics and Evolution 78 (2014) 365–374

Contents lists available at ScienceDirect

Molecular Phylogenetics and Evolution

journal homepage: www.elsevier.com/locate/ympev

Escaping to the summits: Phylogeography and predicted range dynamics of *Cerastium dinaricum*, an endangered high mountain plant endemic to the western Balkan Peninsula

Denis Kutnjak [a,b], Michael Kuttner [c], Marjan Niketić [d], Stefan Dullinger [c], Peter Schönswetter [a], Božo Frajman [a,*]

[a] Institute of Botany, University of Innsbruck, Sternwartestraße 15, 6020 Innsbruck, Austria
[b] Department of Biotechnology and Systems Biology, National Institute of Biology, Večna pot 111, Ljubljana, Slovenia
[c] Department of Botany and Biodiversity Research, University of Vienna, Rennweg 14, A-1030 Vienna, Austria
[d] Natural History Museum, Njegoševa 51, 11000 Belgrade, Serbia

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Global warming
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Phylogeny
Rare endemic plant

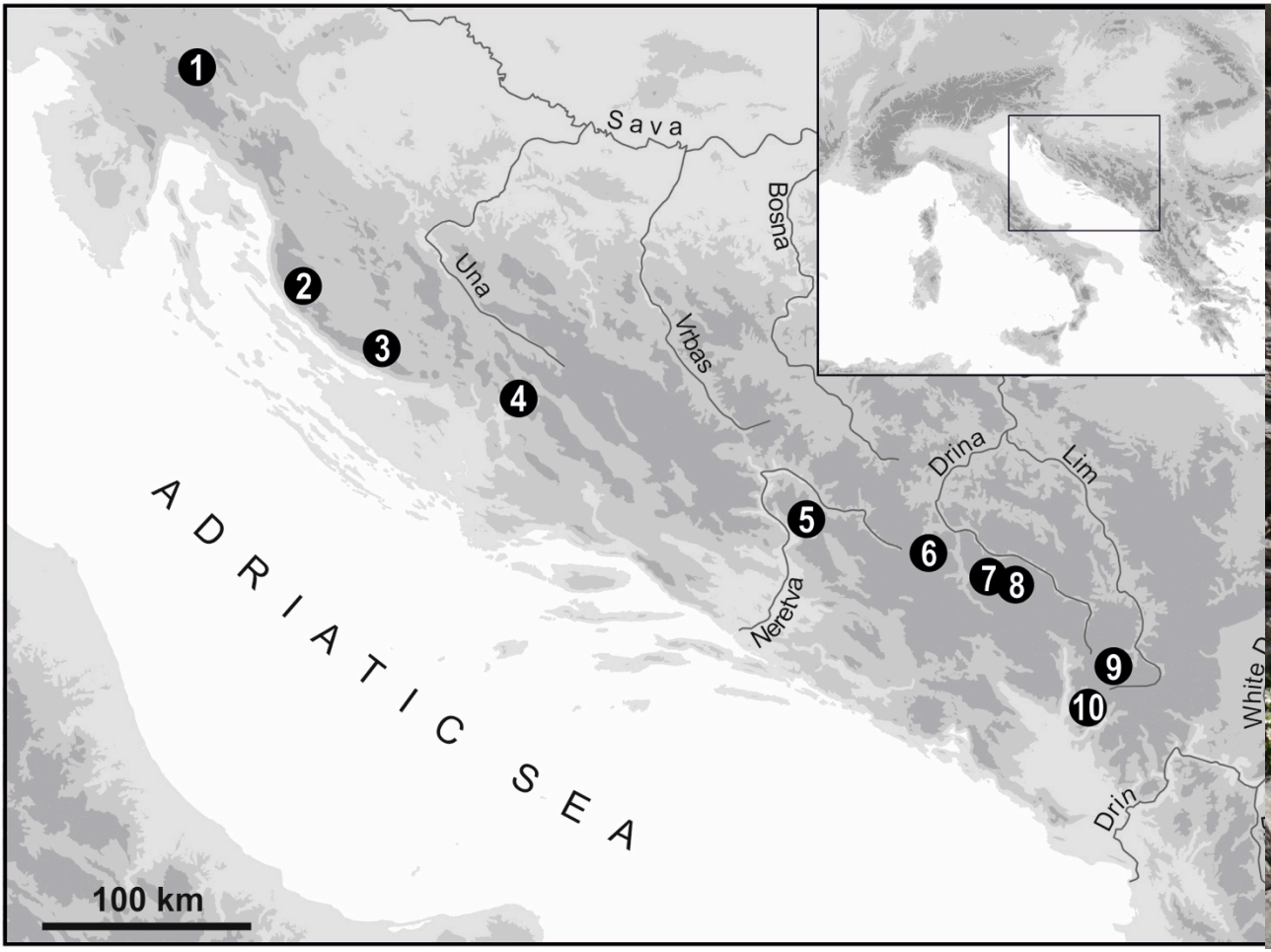
ABSTRACT

The Balkans are a major European biodiversity hotspot, however, almost nothing is known about processes of intraspecific diversification of the region's high-altitude biota and their reaction to the predicted global warming. To fill this gap, genome size measurements, AFLP fingerprints, plastid and nuclear sequences were employed to explore the phylogeography of *Cerastium dinaricum*. Range size changes under future climatic conditions were predicted by niche-based modeling. Likely the most cold-adapted plant endemic to the Dinaric Mountains in the western Balkan Peninsula, the species has conservation priority in the European Union as its highly fragmented distribution range includes only few small populations. A deep phylogeographic split paralleled by divergent genome size separates the populations into two vicariant groups. Substructure is pronounced within the southeastern group, corresponding to the area's higher geographic complexity. *Cerastium dinaricum* likely responded to past climatic oscillations with altitudinal range shifts, which, coupled with high topographic complexity of the region and warmer climate in the Holocene, sculptured its present fragmented distribution. Field observations revealed that the species is rarer than previously assumed and, as shown by modeling, severely endangered by global warming as viable habitat was predicted to be reduced by more than 70% by the year 2080.

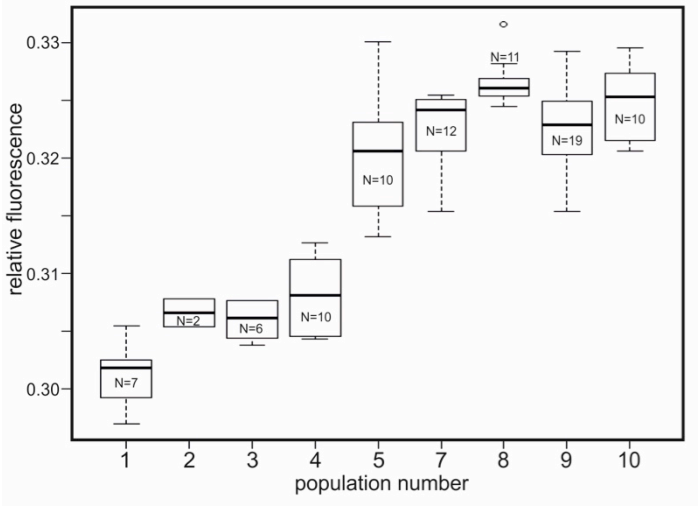
Dinarska smiljka

- enedemit zahodnega Balkana
- hladnoljubna vrsta melišč in skal
- v Sloveniji le na Snežniku
- Natura 2000 vrsta

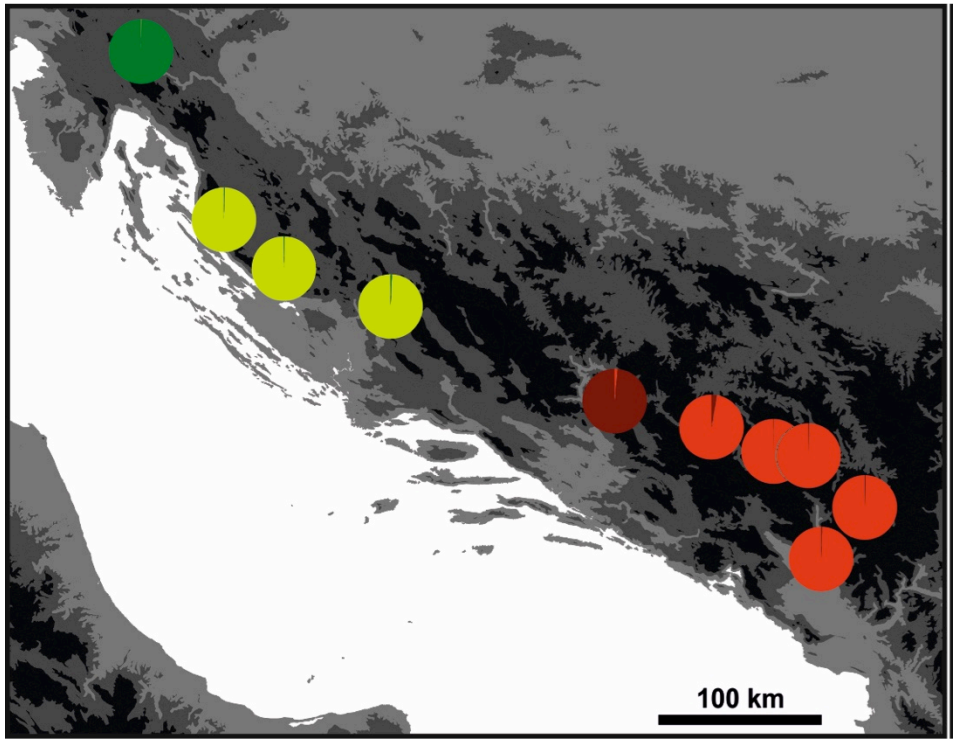
Disjunktna razširjenost

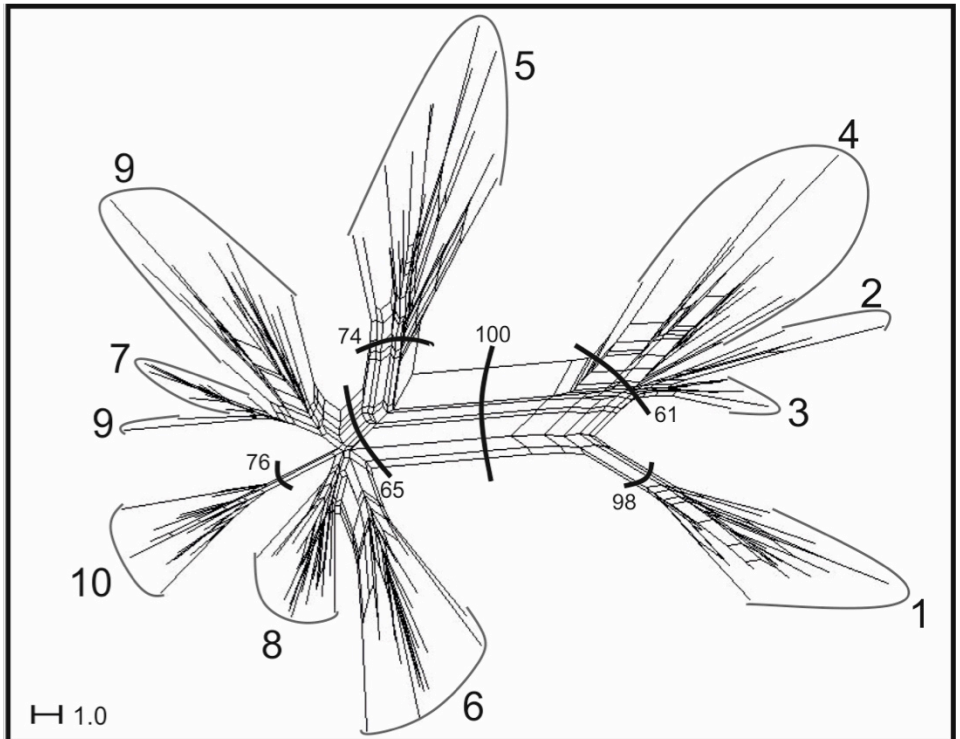


Velikost genoma in genetska struktura

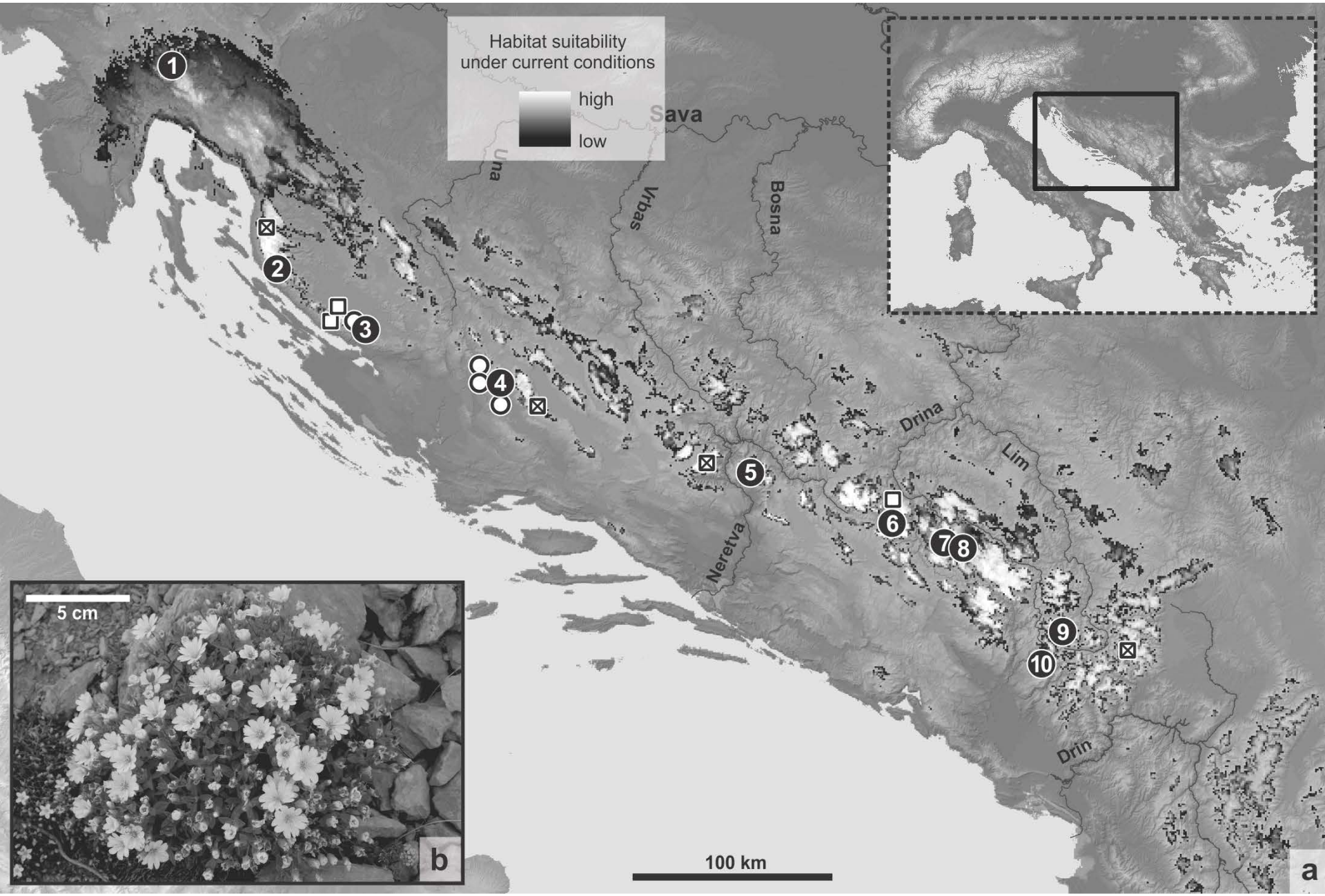


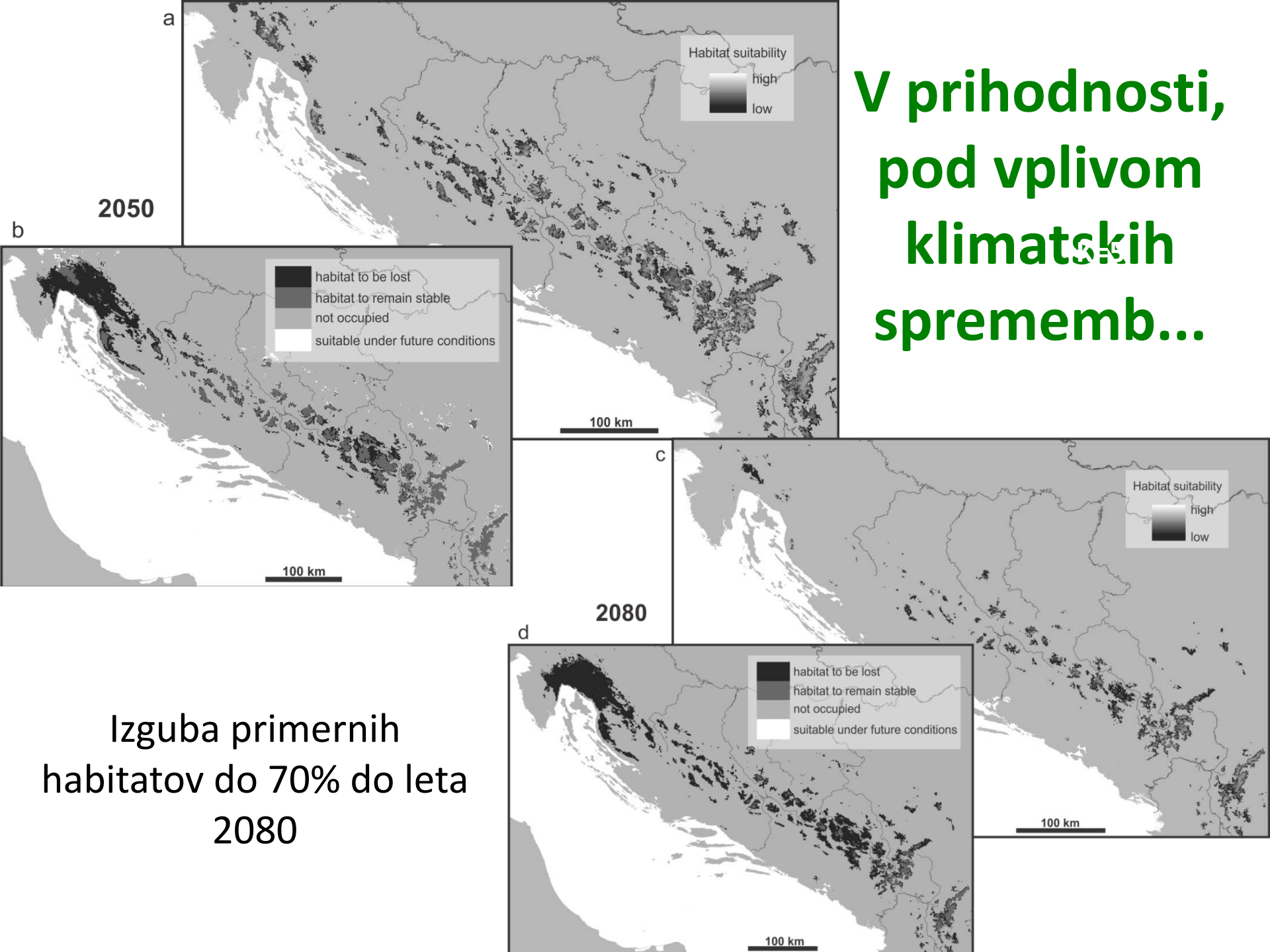
Močna genetska bariera sovpada z reko Neretvo





Modelirana ustreznost habitatov danes...





V prihodnosti, pod vplivom klimatskih sprememb...

Izguba primernih habitatov do 70% do leta 2080

Koliko vrst je v sorodstvu obirskega grobelnika (*Alyssum ovirense*)?

Alyssum ovirense

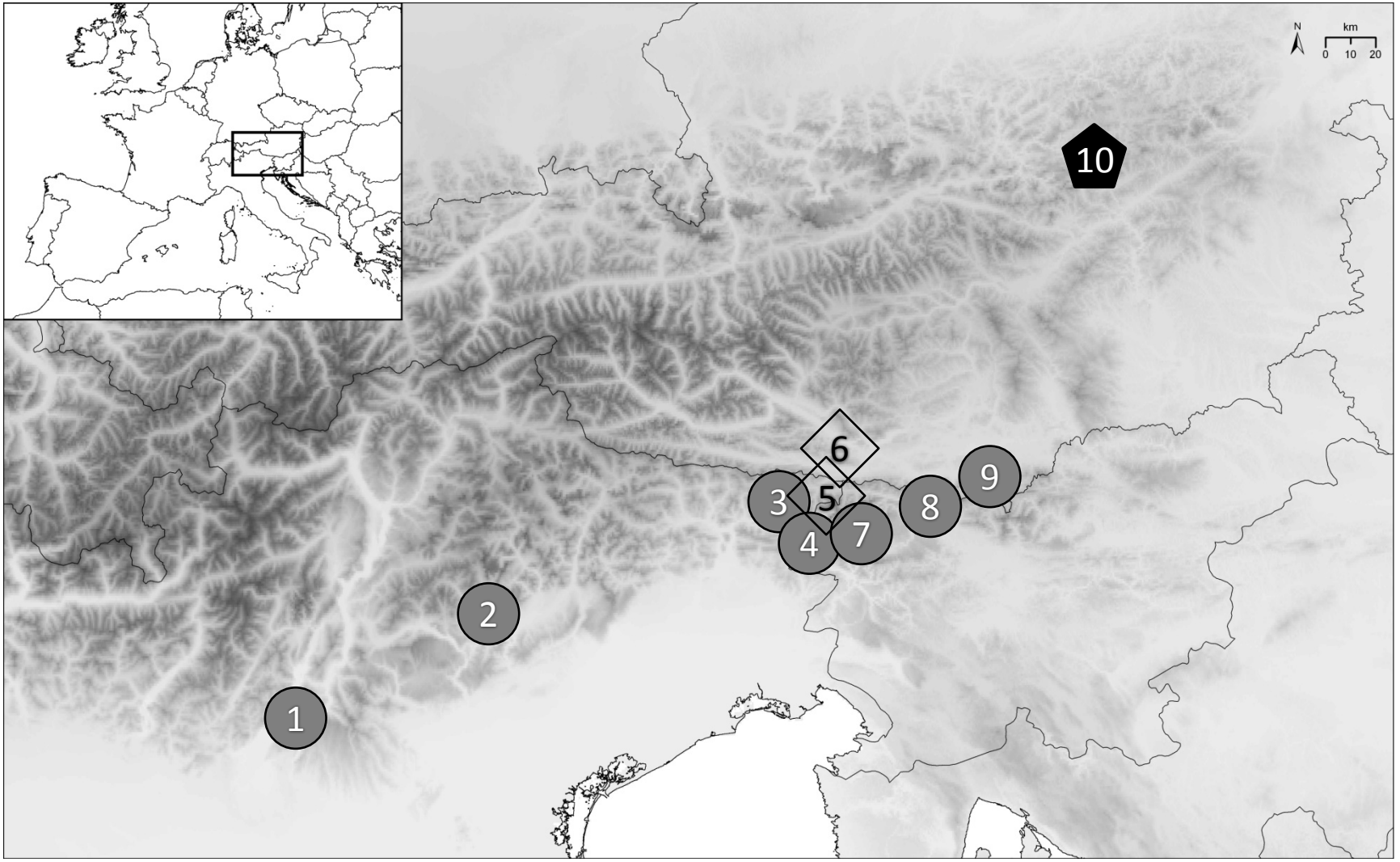
Alyssum wulfenianum

an; ich sah es aber nur in vielen Exemplaren und auch lebend aus der Gegend von Raibl in Unterkärnten, wo sein Hervorgehen aus Alyssum ovirense evident erscheint. In der Tiefe

Eine auffallende, schöne Pflanze! Nicht durch reichen Blattschmuck oder silberweißes Haarkleid ausgezeichnet, kriecht sie bescheiden am Boden oft 2—3 dm hin, ohne nährendes Blatt, und erst an der Spitze erheben sich die Stengel zu kurzen, armblätterigen Trieben. Die ältesten Blätter haben meist kreisrunde Spreiten und sind gestielt, die oberen gehen mehr und mehr in die länglichkeilige Form über; alle prangen im freudigen Grün und wie zerstreute, feine Punkte sehen sich die Sternhärchen an. Im späten Alpenfrühlinge grüßen in doldiger Traube

Baumgartner, 1908

Magauer et al., 2014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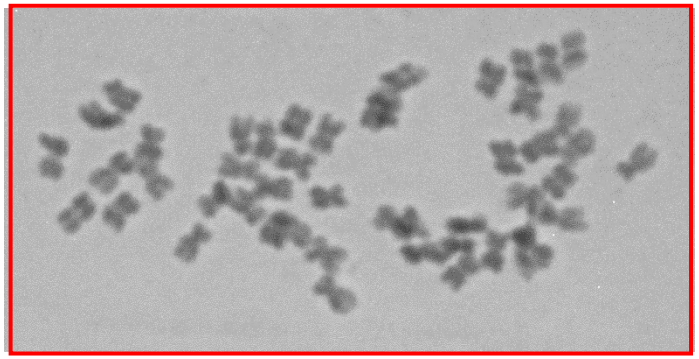
9
10

Alyssum ovirense na Hochschwabu v Severnih Apneniških Alpah

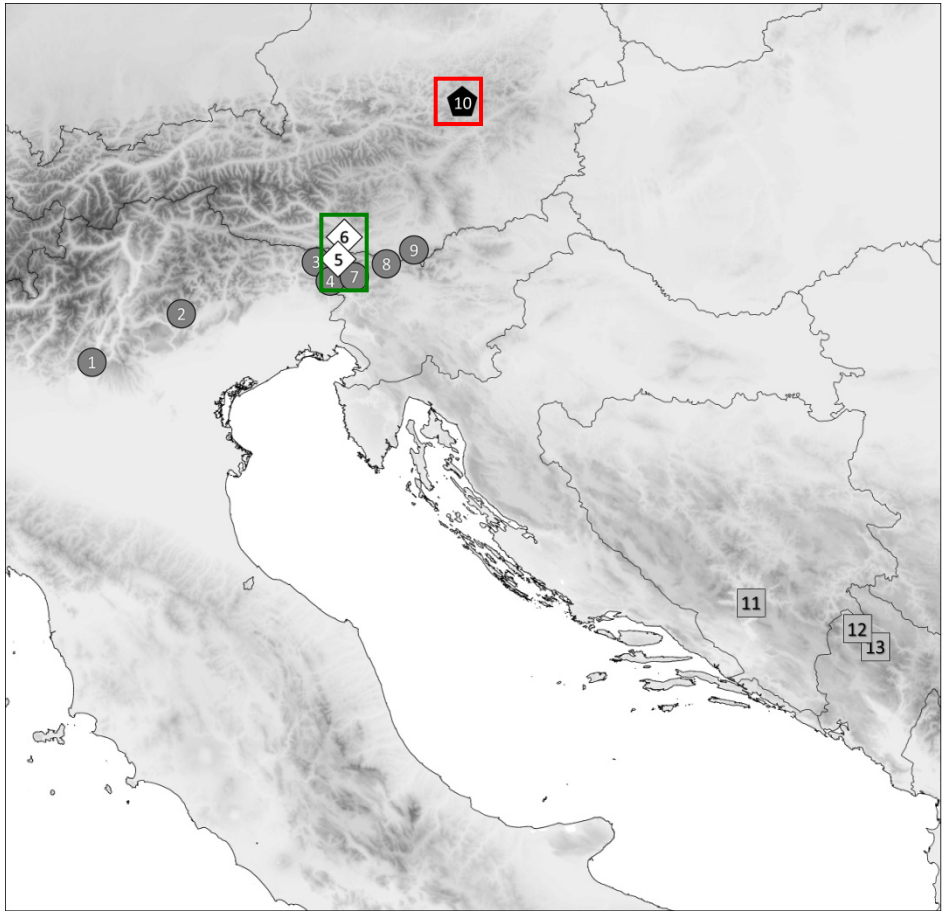
auch selbst beobachtete. Während jedoch Jos. Baumgartner[8]) die Pflanze vom Hochschwab für *Alyssum ovirense* erklärt, möchte ich sie wegen der dichten silberweißen schülfrigen Behaarung lieber zu dem nahe verwandten, auf den höheren Gipfeln des Apennin und der nordwestlichen Balkanhalbinsel nicht gerade seltenen *A. cuneifolium* Ten. zählen.[9])

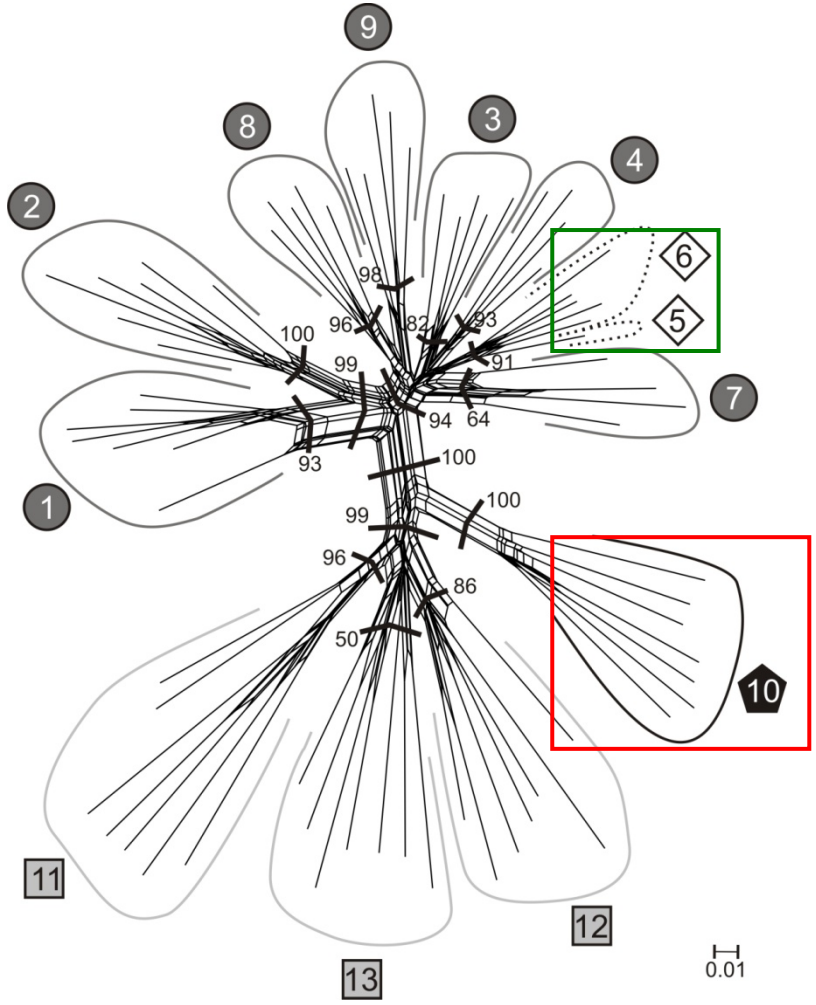
Hayek, 1920

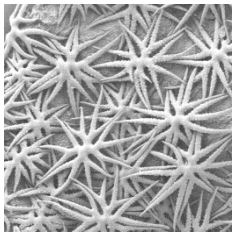


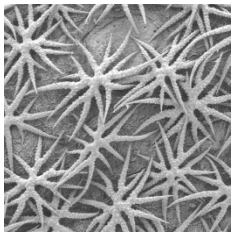
Alyssum ovirense - Hochschwab
2n = 6x = 48

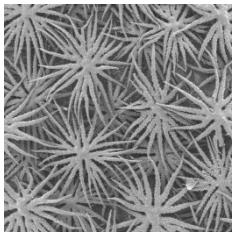
Alyssum ovirense – Obir
2n = 2x = 16









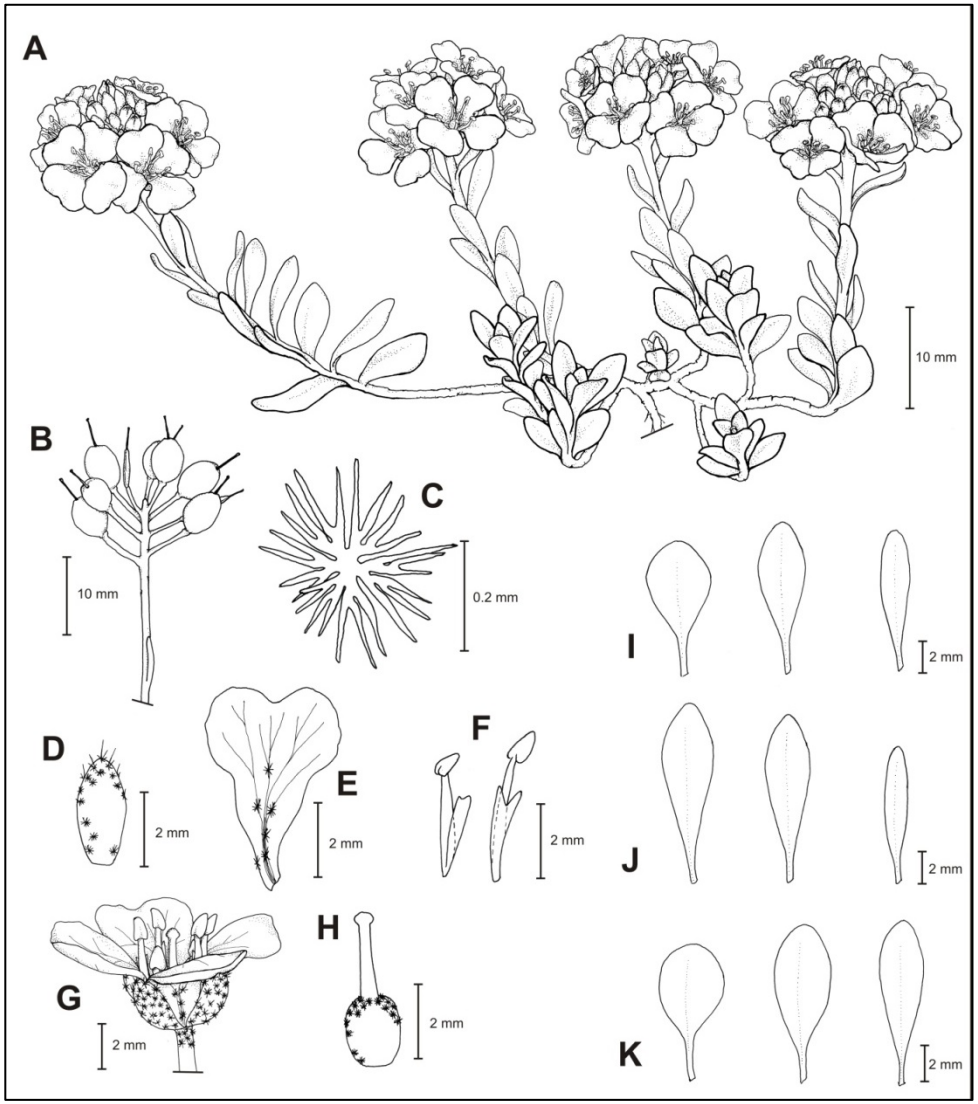


Alyssum ovirense

Alyssum wulfenianum

Alyssum ovirense
(Hochschwab)

Nova vrsta:
Alyssum neglectum

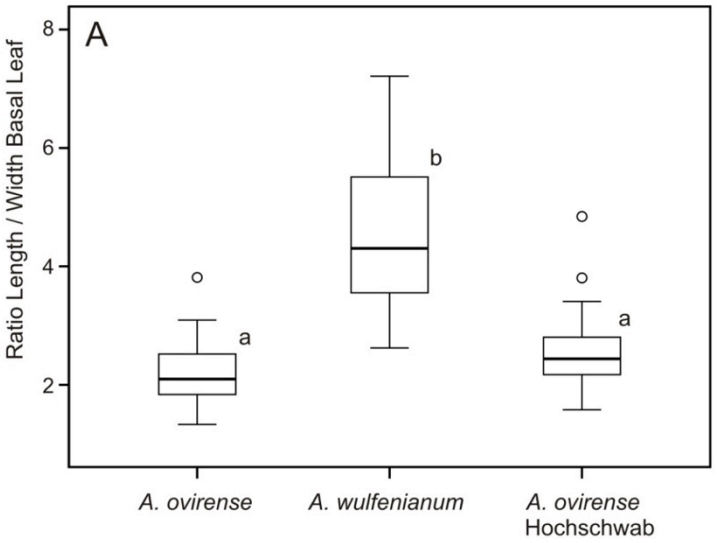


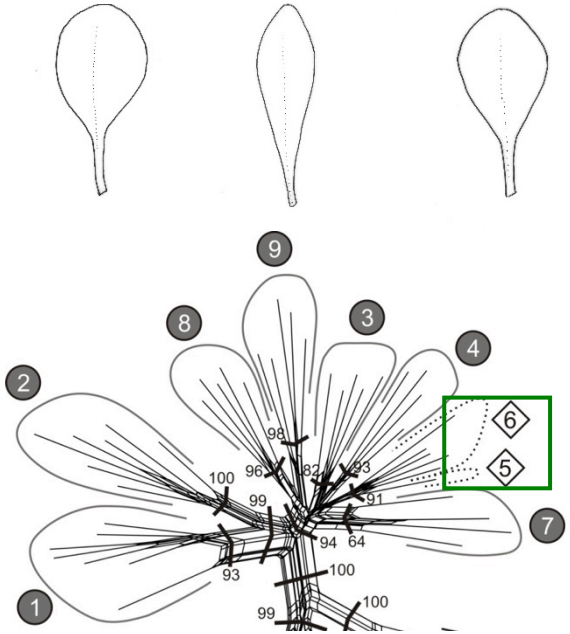
ALYSSUM NEGLECTUM MAGAUER, FRAJMAN & SCHÖNSWETTER, **SP. NOV.**

Diagnosis: Differs from *A. wulfenianum* Willd. in the high trichome coverage on the leaf epidermis with higher numbers of trichomes per mm^2 (15–20 in *A. neglectum* vs. 6–11 in *A. wulfenianum* on the lower epidermis of a mid-stem leaf), which also have an elevated number of rays (18–24 in *A. neglectum* vs. 10–14 in *A. wulfenianum*), causing the silvery white appearance of the plants, which differs from *A. wulfenianum*.

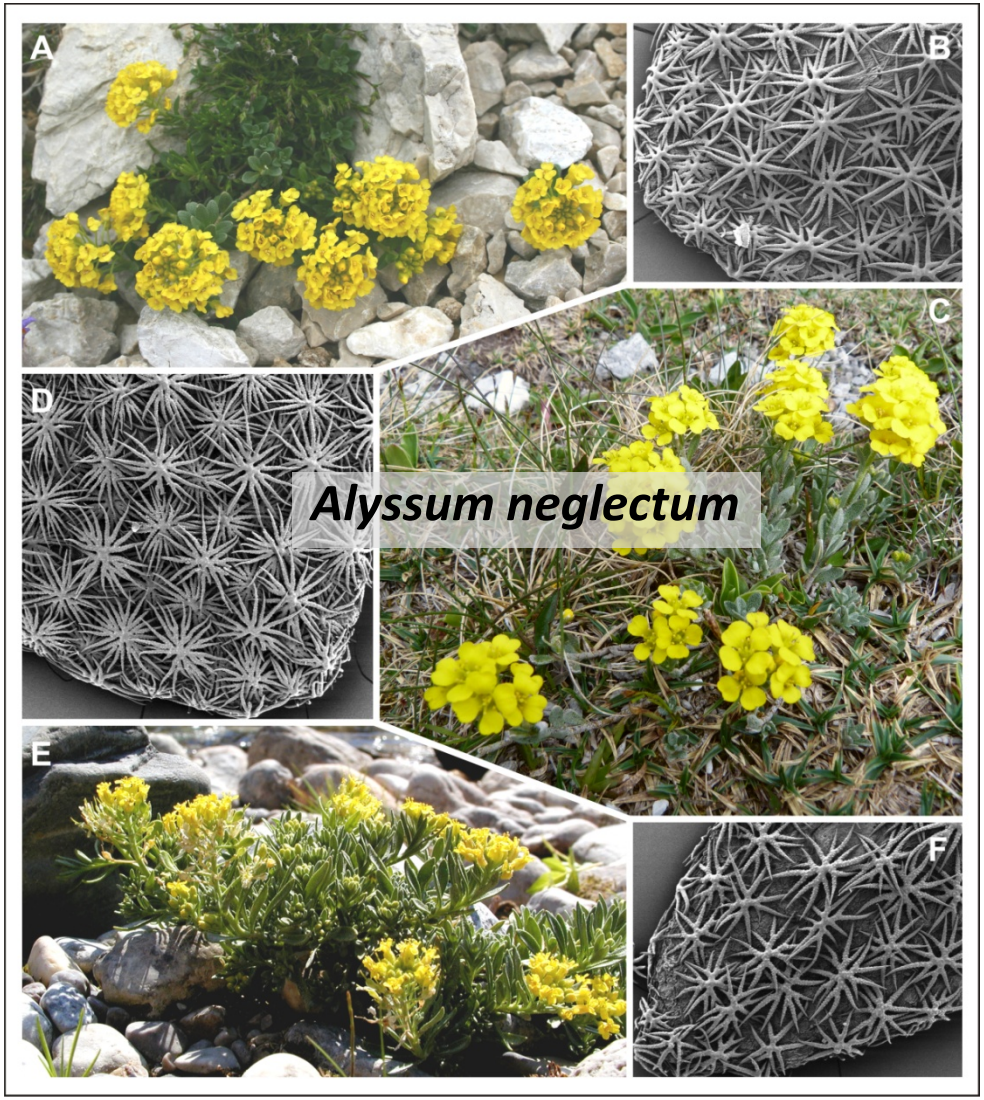
Type: Holotype: 'Steiermark: Hochschwabgebiet, Schutthalden am Abhang des Fölzsteins gegen die Fölzalpe [Hochschwab region, screes on the slopes of Mt. Fölzstein towards Fölzalpe], 29. Juni 1931' *F. J. Widder, GZU 215*! (DigiBota ID 163432); isotypes in W! and WU!.

Kaj pa *Alyssum wulfenianum*?





Alyssum wulfenianum* ssp. *ovirense



Alyssum wulfenianum* ssp. *wulfenianum

Zaključek

• uporaba molekulskih metod (zaporedij DNA) je **revolucionirala** poglede na raznolikost in evolucijo organizmov

• filogenetsko drevo na osnovi zaporedij DNA je **hipoteza** evolucijskih odnosov in nam daje informacijo o **sorodnosti** med organizmi

• omogoča **testiranje klasičnih hipotez** o odnosih med organizmi, npr. na podlagi morfologije, intuitivnega sklepanja, t.j. na podlagi **podobnosti**

• molekulske analize je potrebno **dopolniti** z drugimi vedenji o proučevanih organizmih (morfologija, ekologija,...)

• **sekvenciranje naslednje generacije** prinaša še globlje vpoglede v evolucijo organizmov in predstavlja naslednji velik preskok v evolucijski biologiji

Zahvala

• vsem soavtorjem in sodelavcem za plodno sodelovanje

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• avtorjem nekaterih fotografij

• financerjem in podpornikom mojega znanstvenega delovanja