



Millions of years without sex and still happy

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Rock-inhabiting black fungi



Atacama desert



Monuments



Cliff, Sardinia, Italy



La Cabrera, Spain



Battleship Promontory, Antarctica



Monte Rosa, Italy



Mount Aconcagua, Argentina



Linnaeus Terrace, Antarctica

Rock-inhabiting life style in Dothideomycetes



Shift to rock-inhabiting life style is recurrent in the Dothideomycetes but the life-style is polyphyletic within the Class

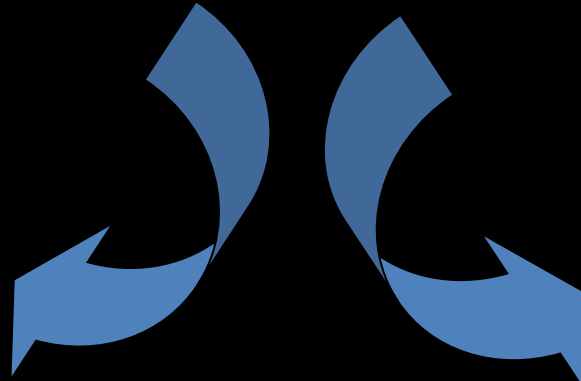
Unknown lineages of rock-inhabiting fungi in ancestral positions ...

... but also more recent

EXTREMOTOLERANCE IS A BASAL TRAIT, THE ANCESTOR MIGHT BE ALREADY EQUIPPED TO ADAPT ROCK ENVIRONMENT HAVING A BASIC SET OF CHARACTERISTICS AND POTENTIALITIES



Success on rocks



Resistance

Simplification

Ancestral condition enabling extremotolerance

Oligotrophism
Osmotolerance, compatible solutes
Mycosporin antioxidants
Melanin, carotenoids
Unsaturated fatty acids, EPS
Meristematic development

Poikilotolerance



Poor competitors

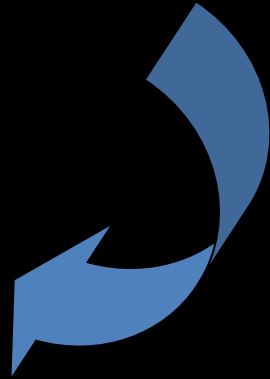


Pushed away to the edge of life



Specialization (extremotolerance/extremophily)

Success on rocks



Resistance

General traits

CCFEE
5187

CCFEE 534

CCFEE
5211

CCFEE
514

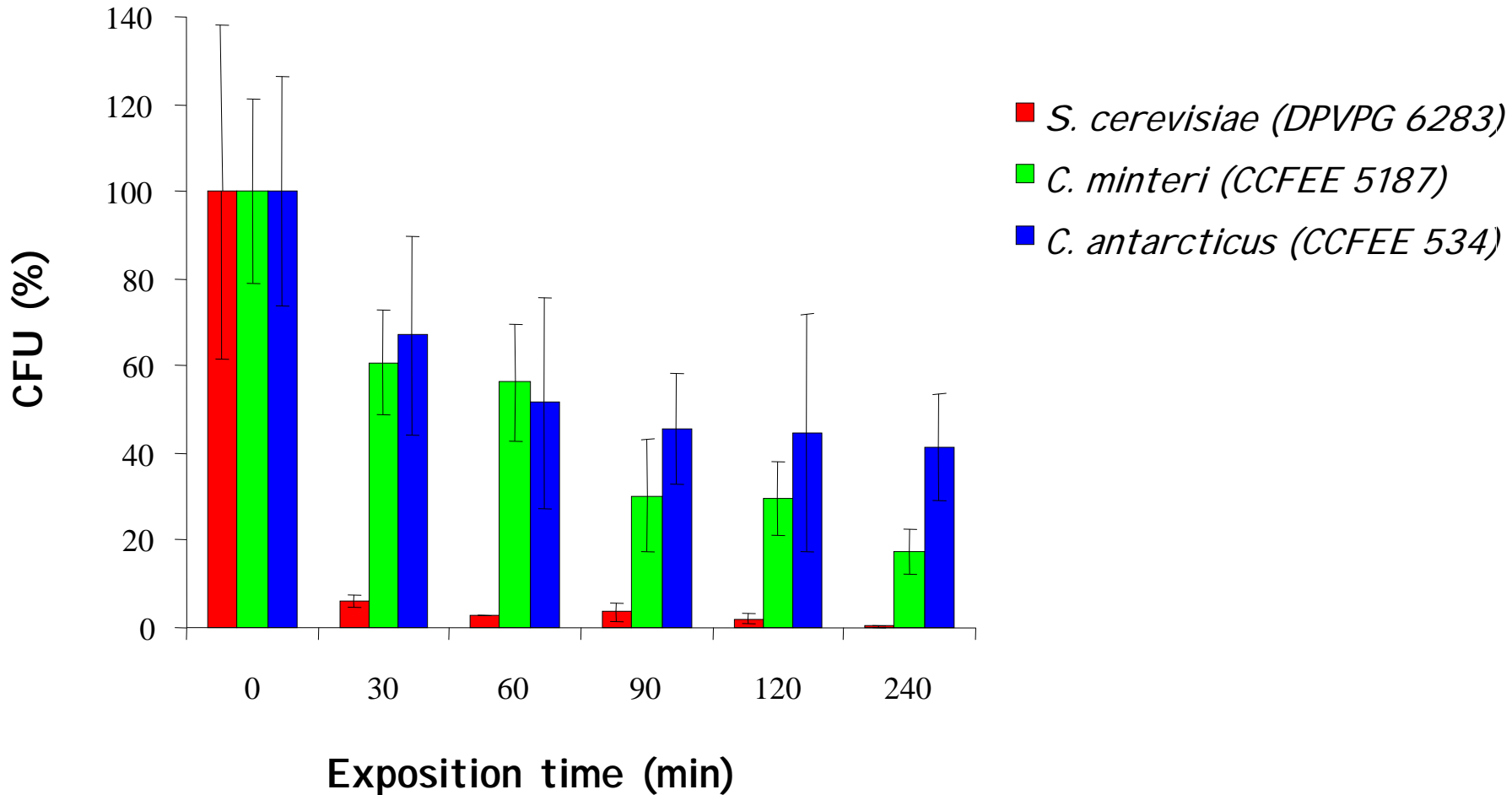
Meristematic growth,
melanization,
thick cell wall,
EPS,

RESISTANCE

CCFEE
5208

CCFEE
515

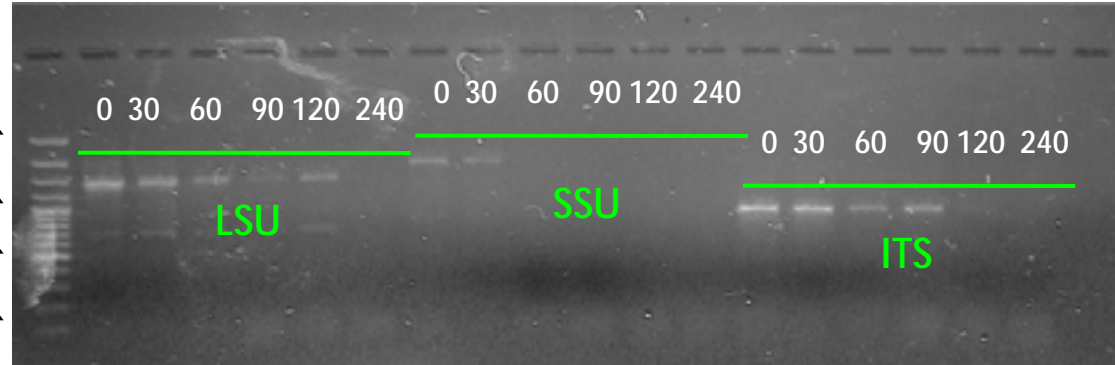
Germination after UV-B irradiation (3.0 W/m²)



DNA (LSU, SSU, ITS) damage after UV-B irradiation 0-240 min

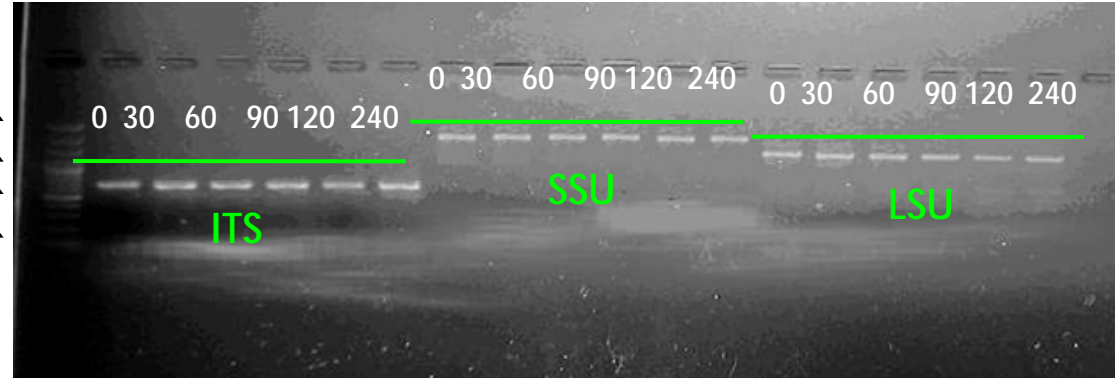
Saccharomyces cerevisiae

3000 bp
1200 bp
600 bp
100 bp



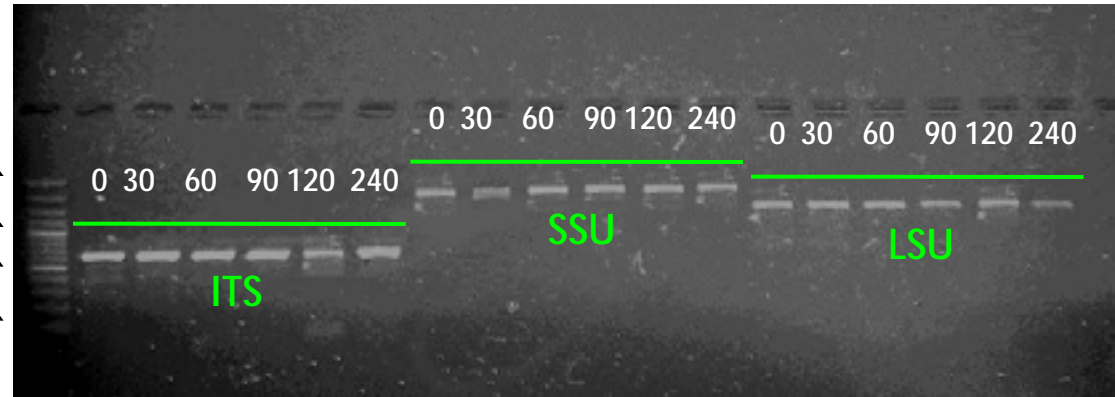
Cryomyces minteri

3000 bp
1200 bp
600 bp
100 bp

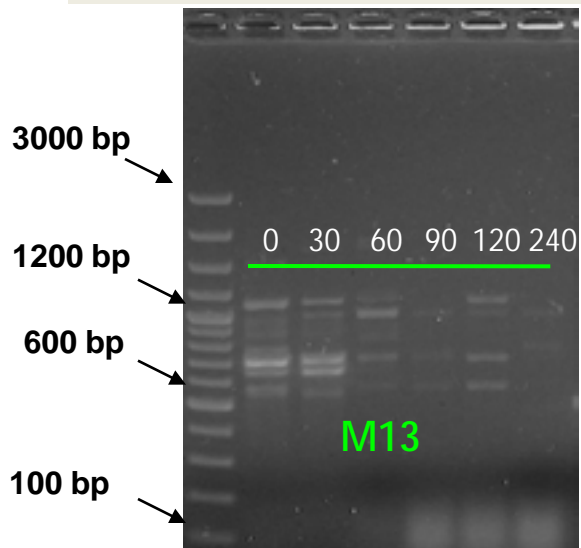


Cryomyces antarcticus

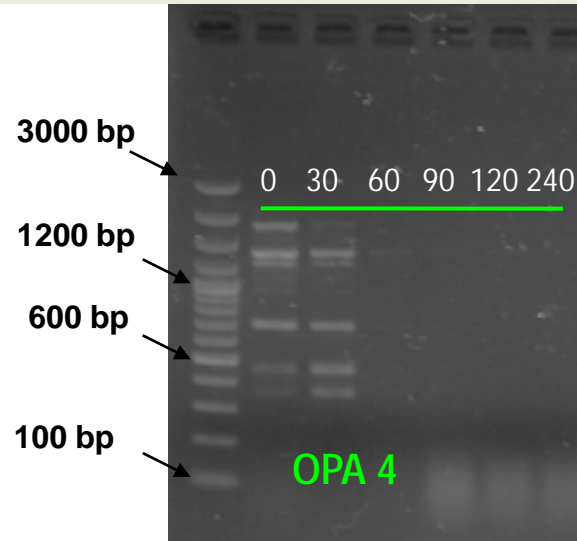
3000 bp
1200 bp
600 bp
100 bp



DNA (RAPD) damage after UV-B irradiation 0-240 min

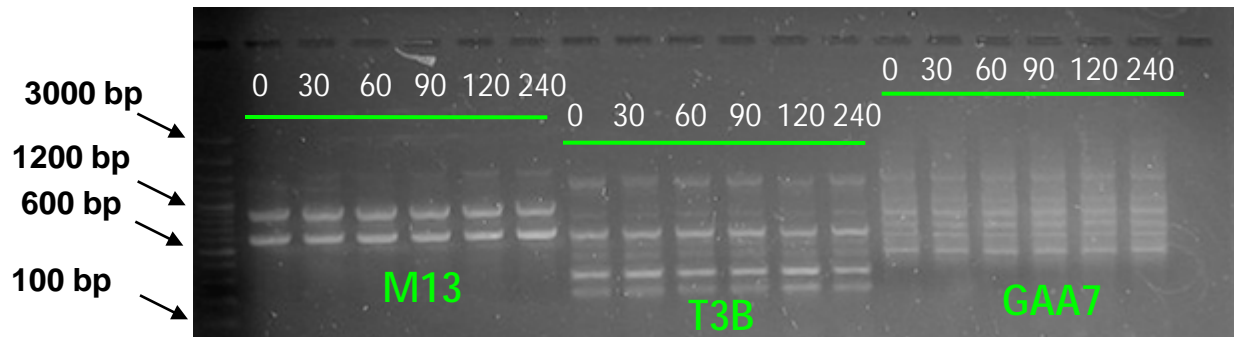


Saccharomyces cerevisiae

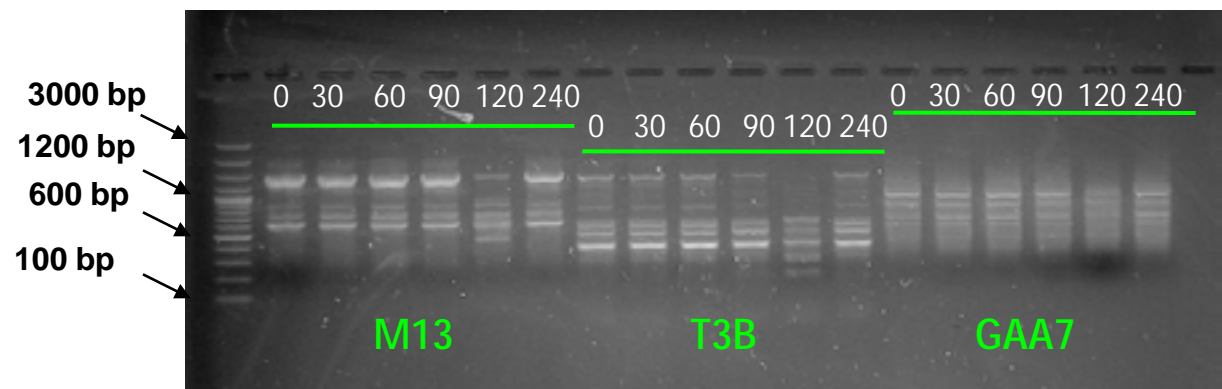


Saccharomyces cerevisiae

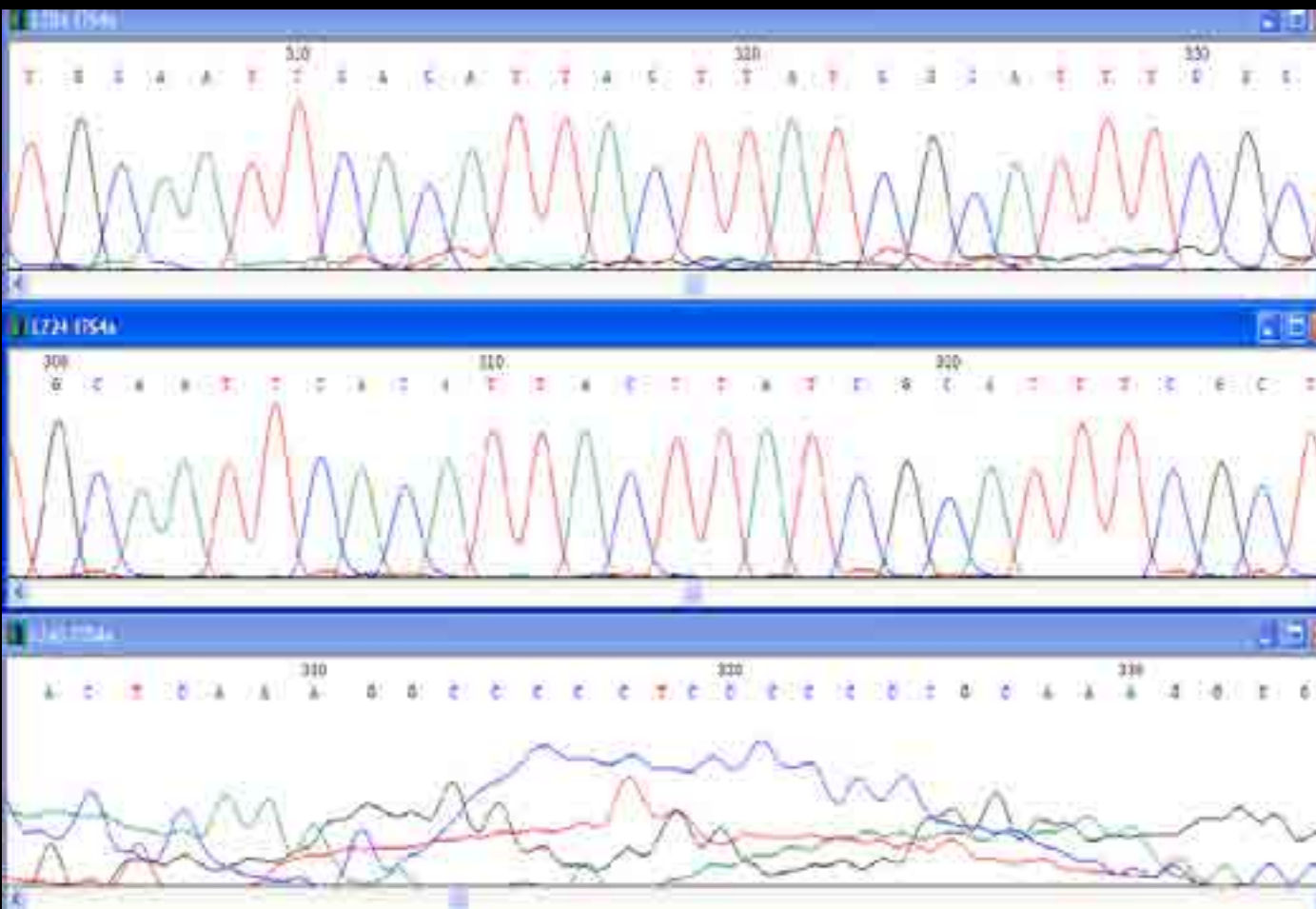
Cryomyces minteri



Cryomyces antarcticus



DNA (ITS position 304-333) damage UV-B irradiation 240 / 90 min



C. minteri 240 min

C. antarcticus 240 min

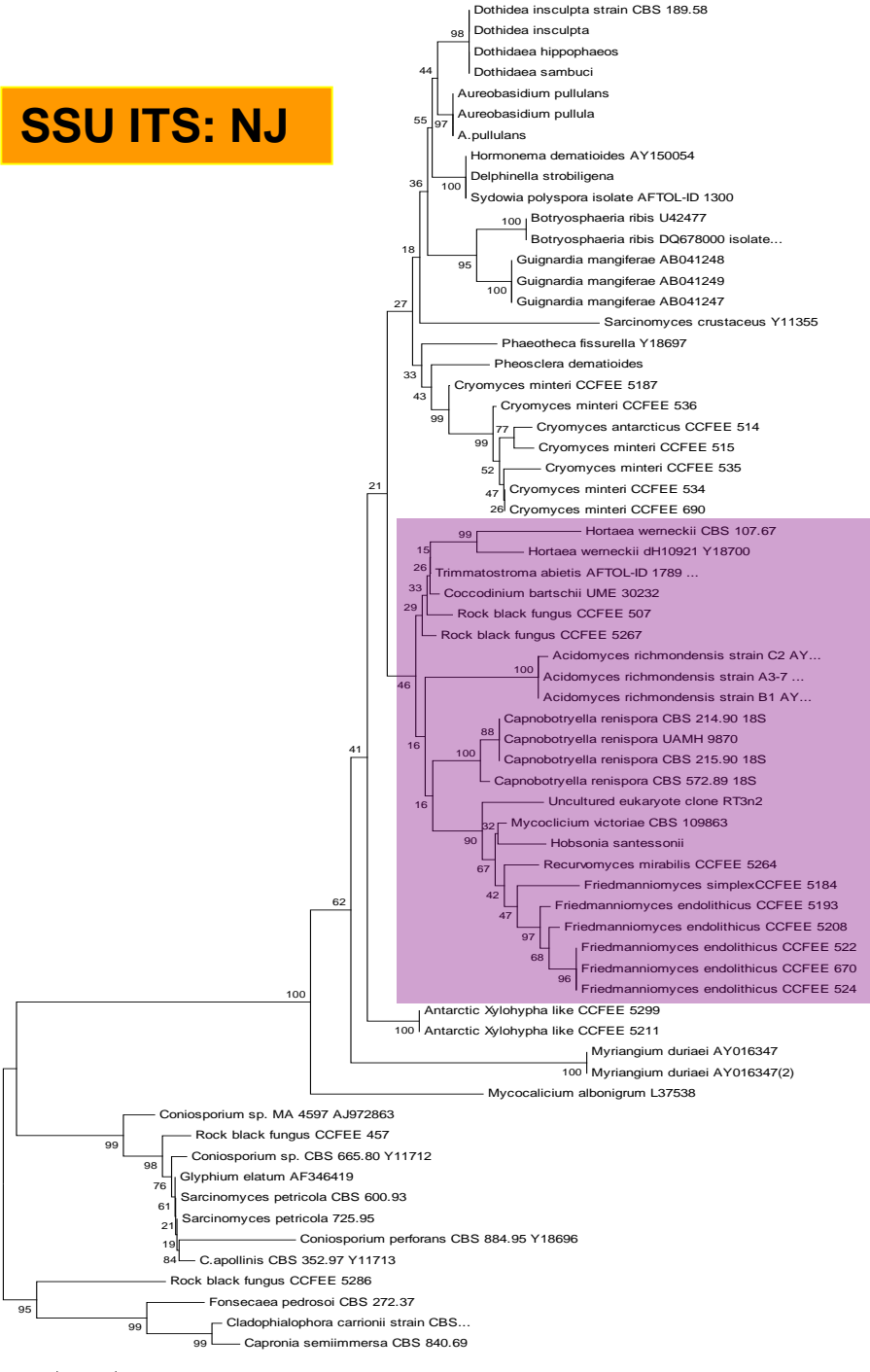
S. cerevisiae 90 min

Success on rocks



Simplification

SSU ITS: NJ



Dothideales

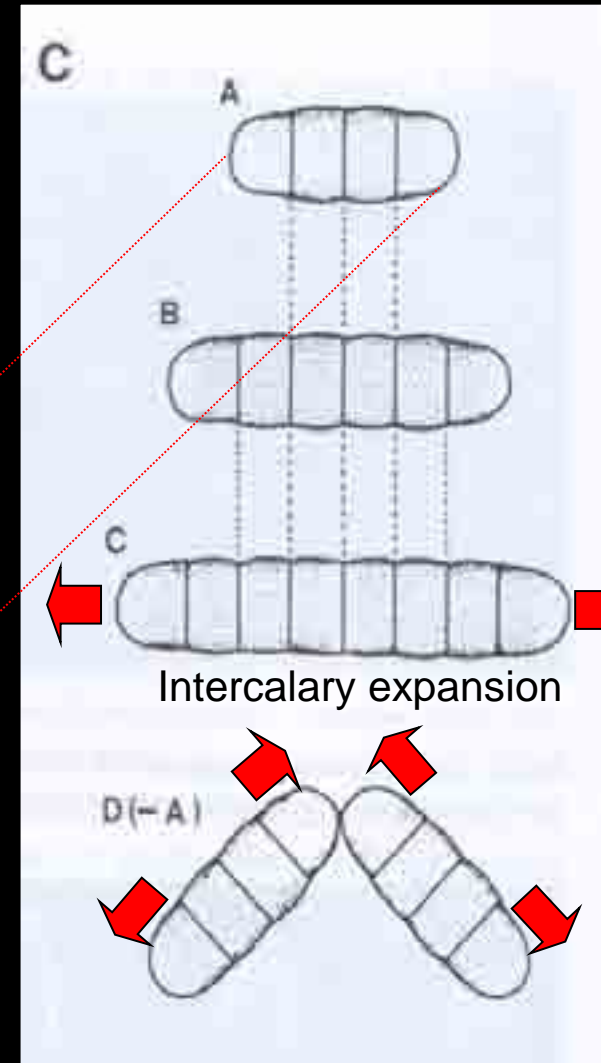
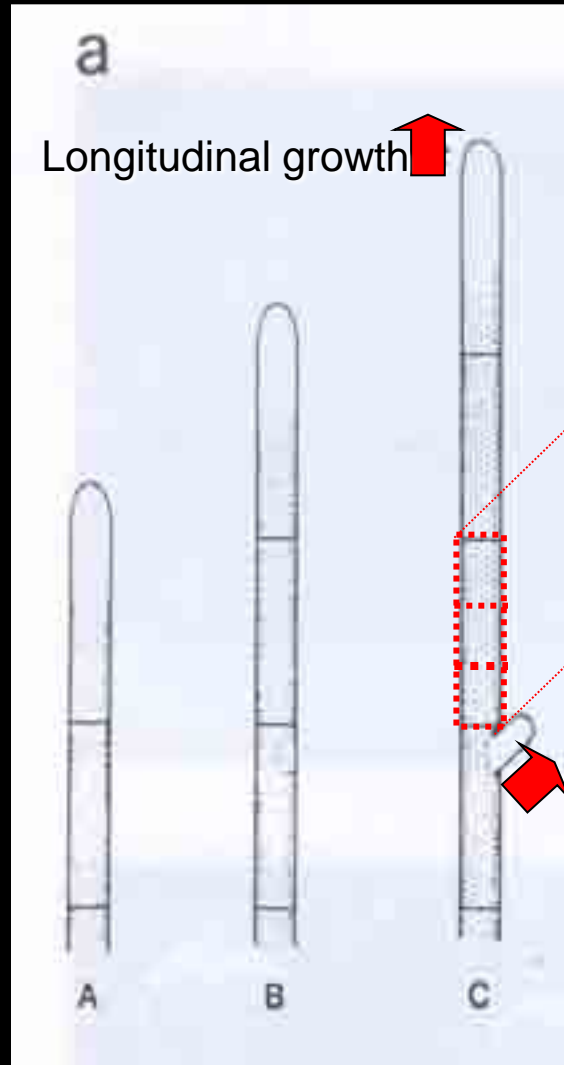
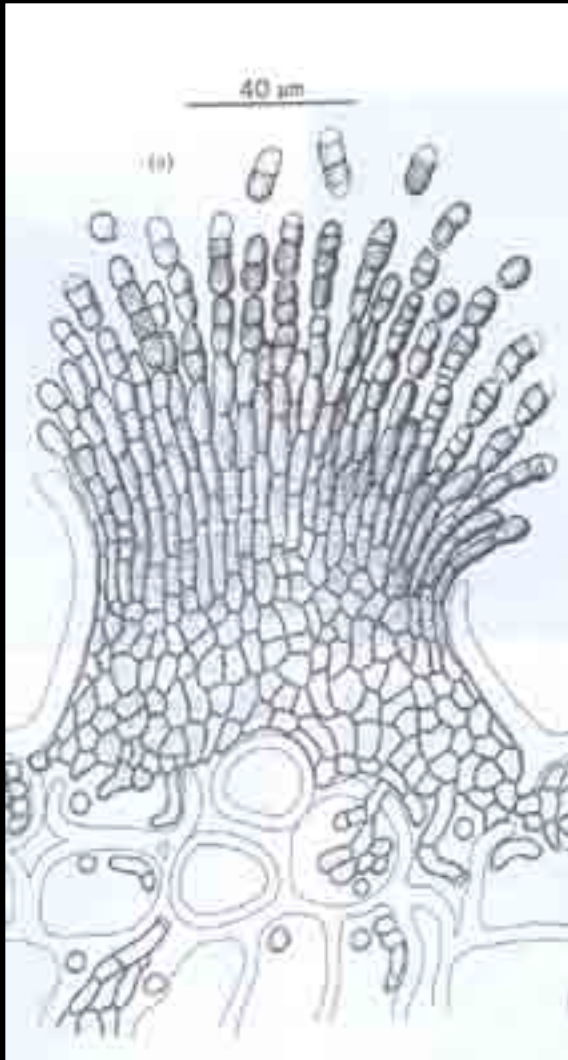
Capnodiales,
Teratosphaeriaceae:
plant in semi-arid
climates, rock

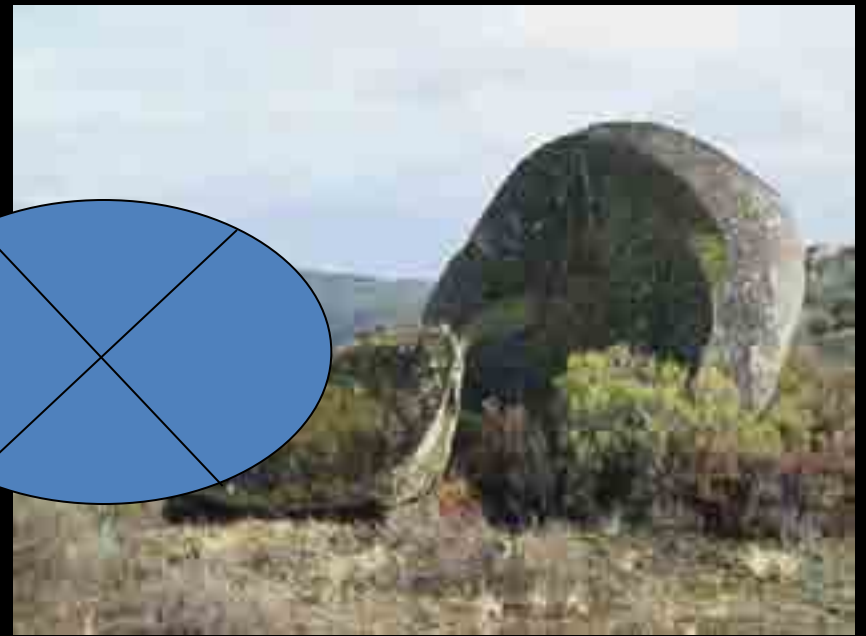
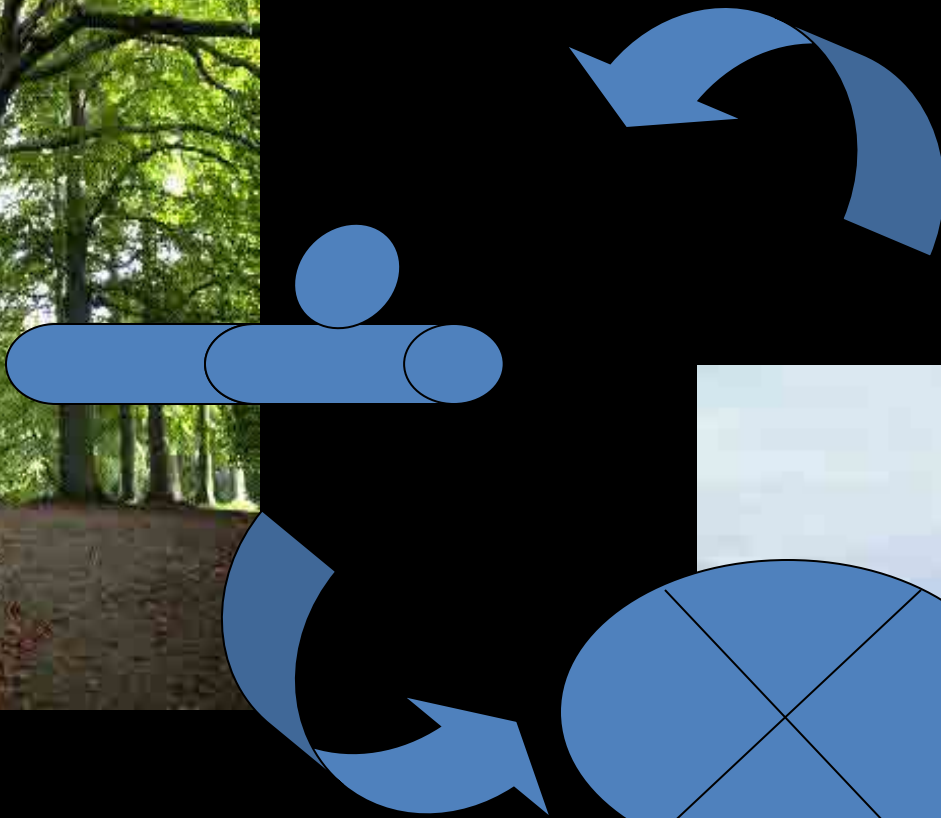
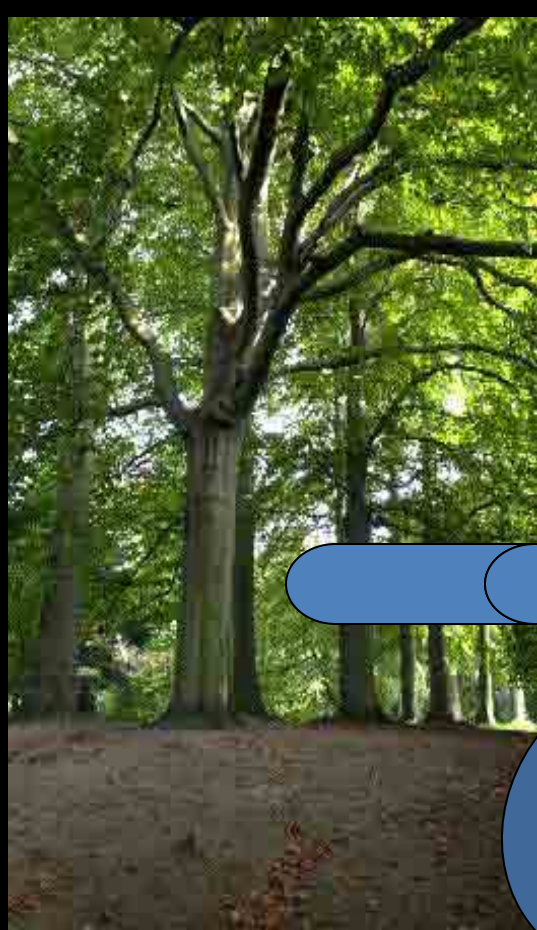
Myriangiales
Mycocaliciales

Coniosporium

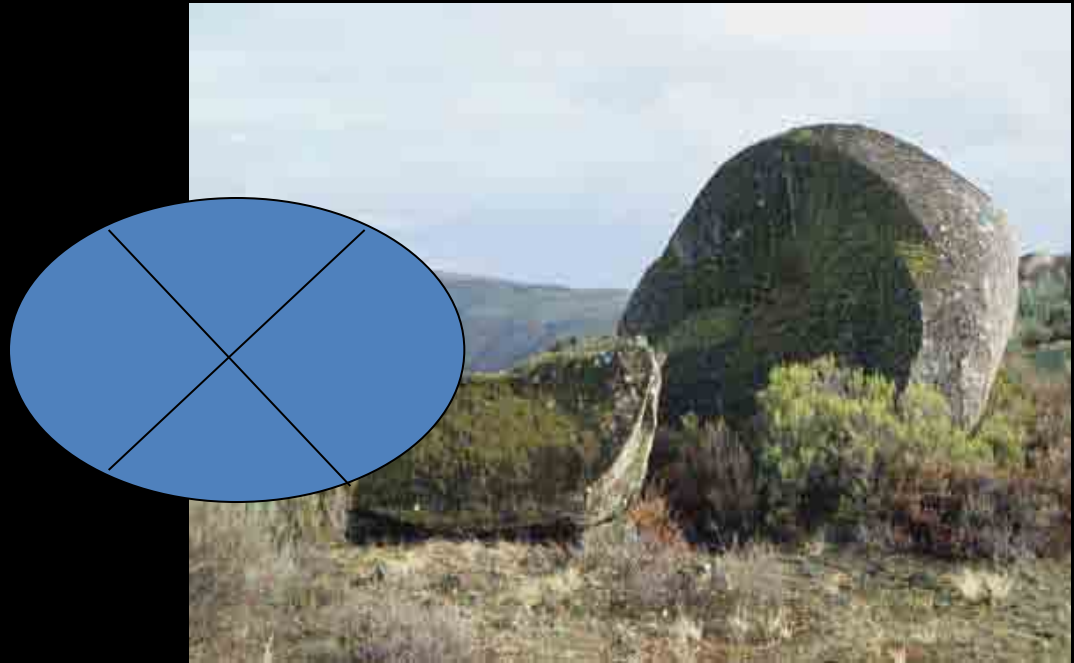
Chaetothyriales
(outgroup)

Catenulostroma abietis





Double life cycle ...

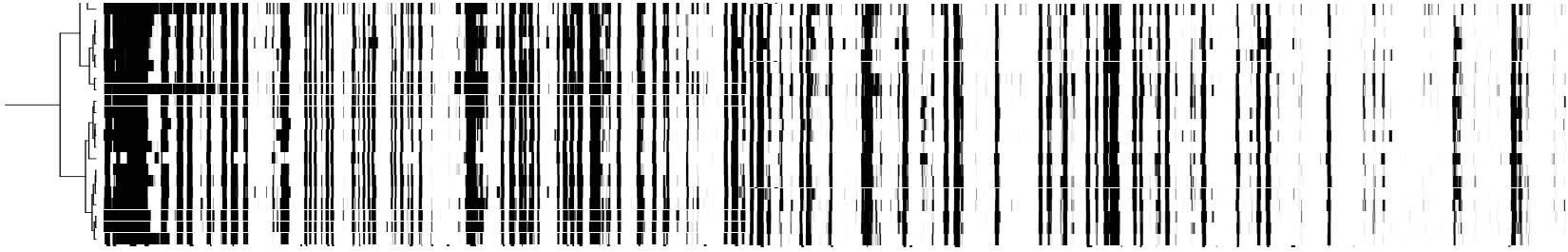


... may lead to fixation of partial cycle

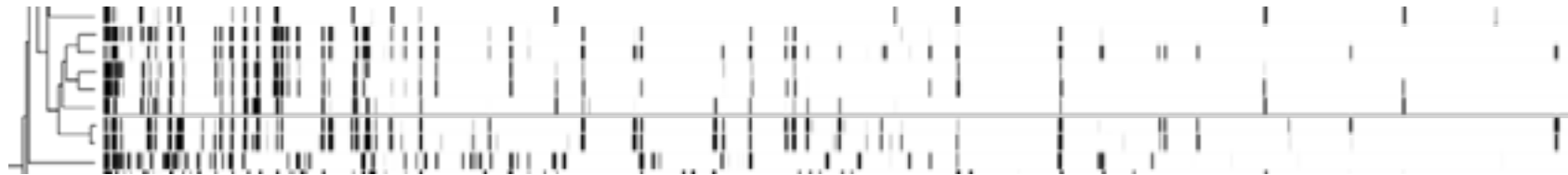
	Rock fungi (32 strains)	Cosmopolitan fungi (Strain of <i>Aspergillus</i> , <i>Fusarium</i> , <i>Penicillium</i> , <i>Cladosporium</i>)
Positive answers (%)	21.1 ± 4.7	67.5 ± 12.6

1. Cellulase,
2. DNase,
3. Polygalacturonase,
4. Pectin lyase,
5. Amylase,
6. Gelatin hydrolysis,
7. Acid production,
8. Lignin degradation,
9. Casein hydrolysis,
10. Lipase.

Comparative AFLP C-A



Exophiala



Friedmanniomyces



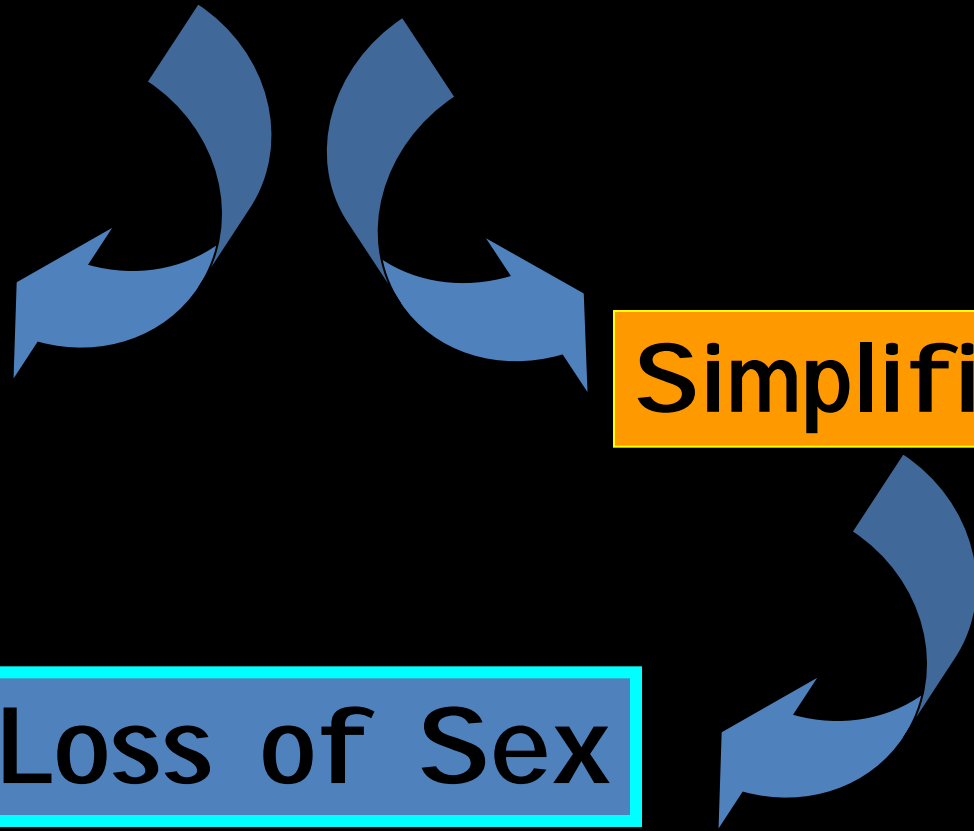
Cryomyces

Success on rocks

Resistance

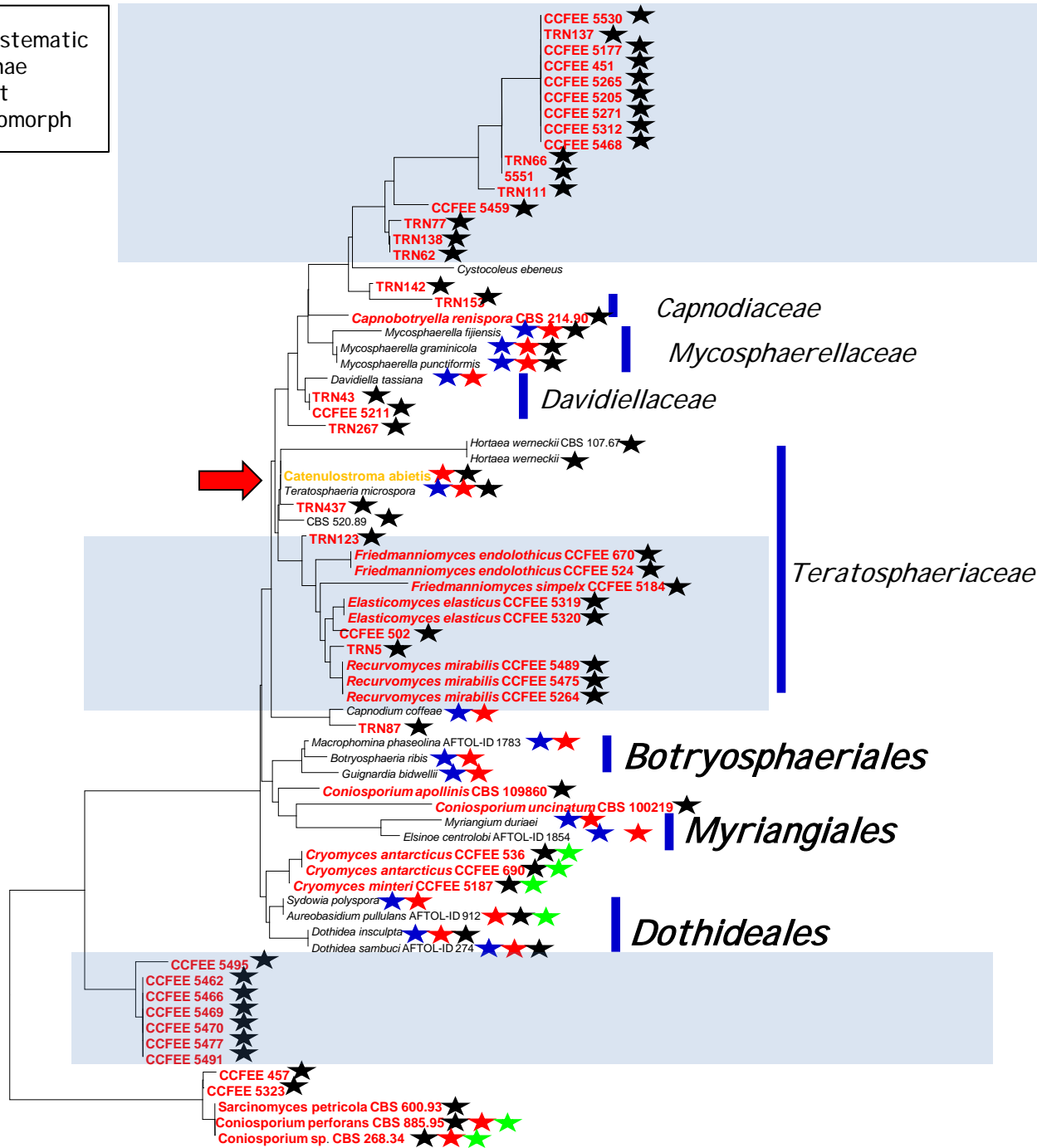
Simplification

Loss of Sex



No-return lineages
have no teleomorphs
and are monomorphic
clumpy

- ★ Meristematic
- ★ Hyphae
- ★ Yeast
- ★ Teleomorph



Capnodiales

NJ of SSU, LSU and mtSSU

Sex is costly but is evolutionary advantageous

§ Genetic variability promotes adaptation, particularly under variable and extreme conditions (Fisher, 1930; Muller, 1932)

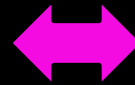
§ Recombination reduces the deleterious mutational burden (Kondrashov, 1988)



Purely asexual lineages become extinct in the long run because of the accumulation of deleterious mutation (Muller, 1964)

Loss of sex

Absence of sexual
reproductive structures



Are we simply unable to observe
or are they really absent?



Are rock fungi just
recent lineages?

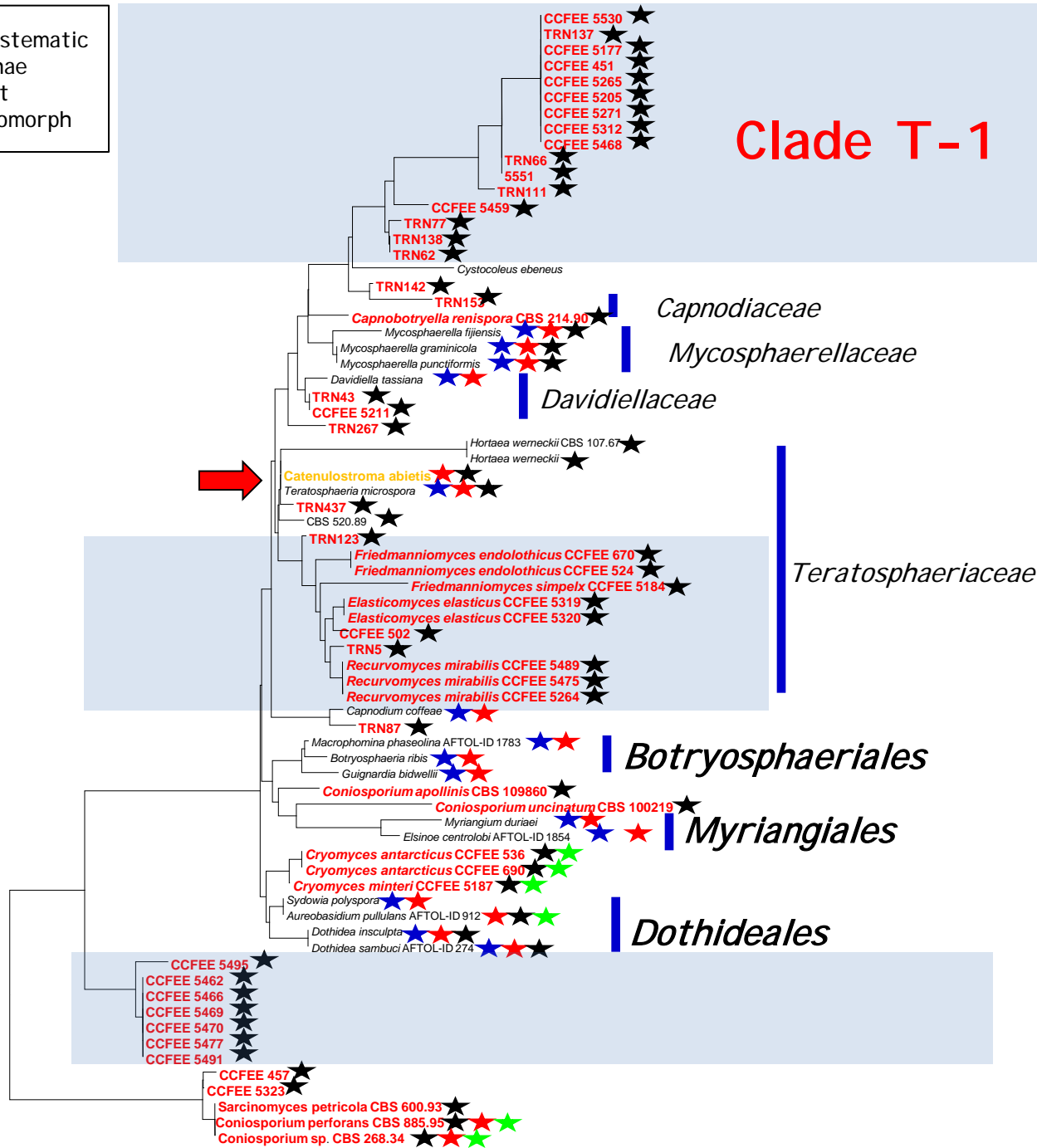


Otherwise how they do not
became extinct?

No-return lineages have no teleomorphs and are monomorphic clumpy

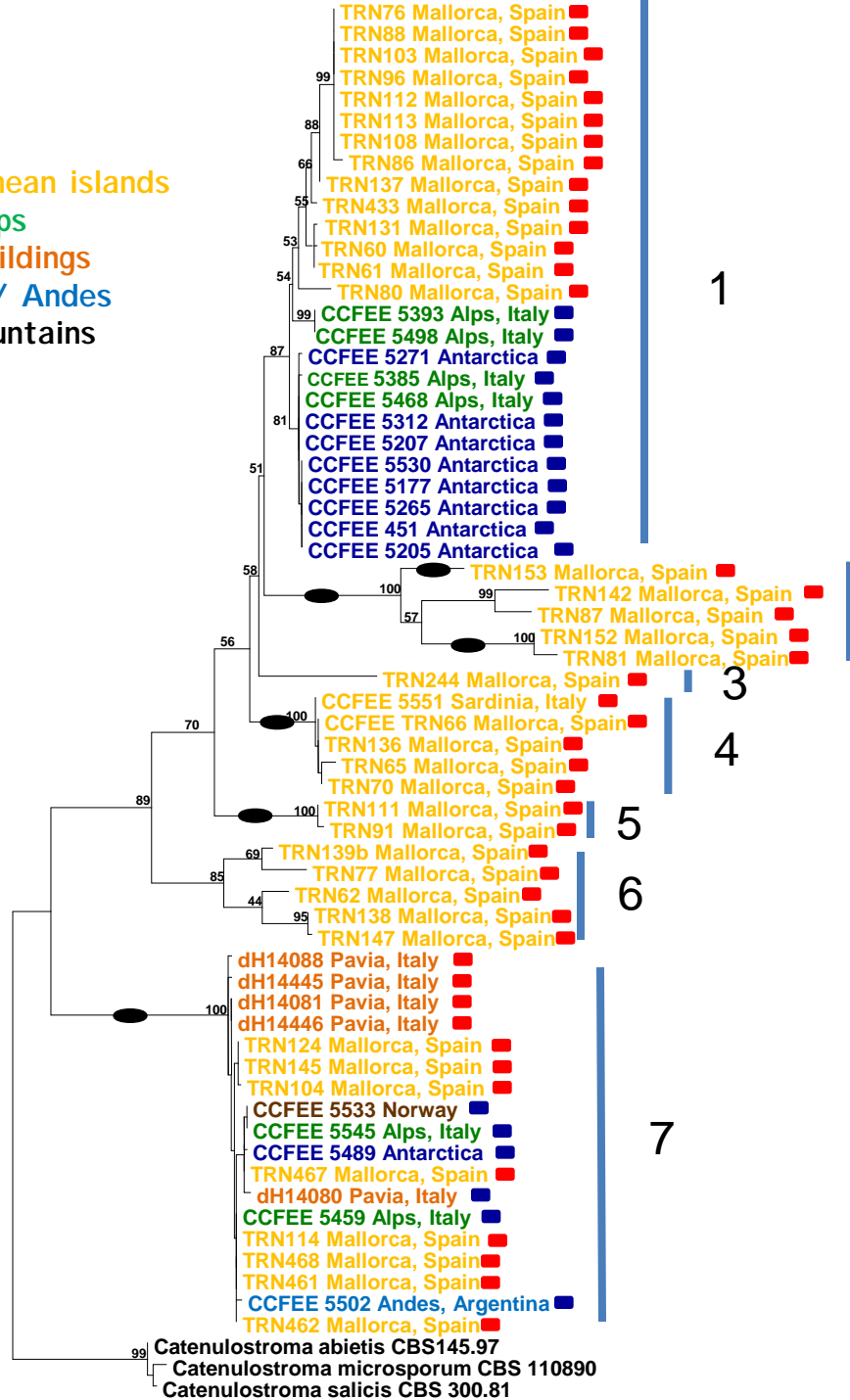
Clade T-1

Capnodiales



- Hot
- Cold

- Mediterranean islands
- Italian Alps
- Italian buildings
- Antarctic / Andes
- Nordic mountains



Clade T-1

1

2

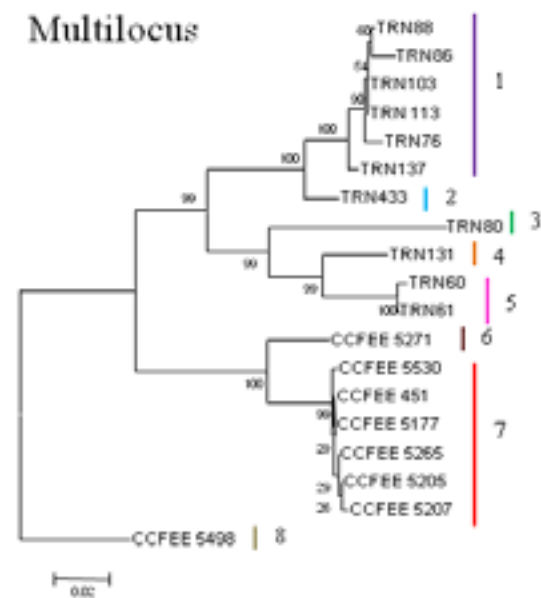
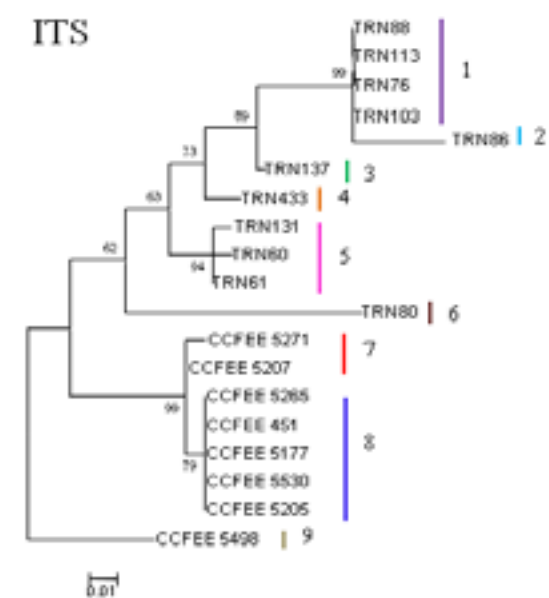
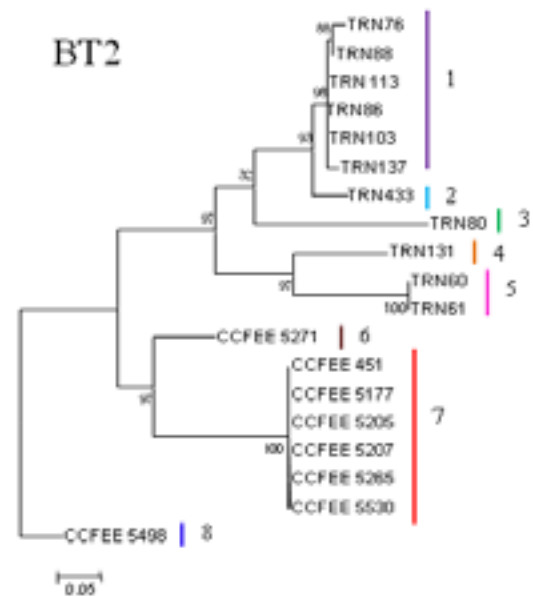
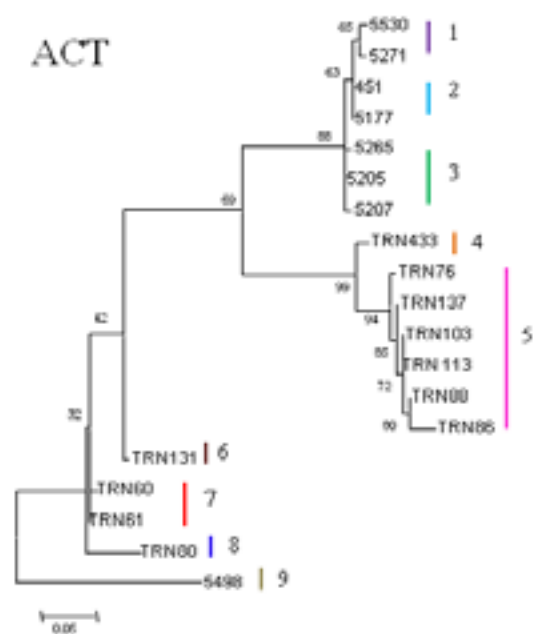
3

4

5

6

7



Clade T-1

	ITS	BT-2	ACT	Multilocus
V_D	0.5403	0.5403	0.5403	0.6237
V_E	0.3253	0.3253	0.3253	0.3294
I_A^S	0.6612	0.6612	0.6612	0.8932

LIAN: Index of Association (I_A) and Variability observed / expected (V_D , V_E) calculated by LIAN v 3.5 program on the basis of grouping obtained on single and combined genes.

Multilocus v.1.0:

$$\text{Theta } (\theta) = 0.84$$

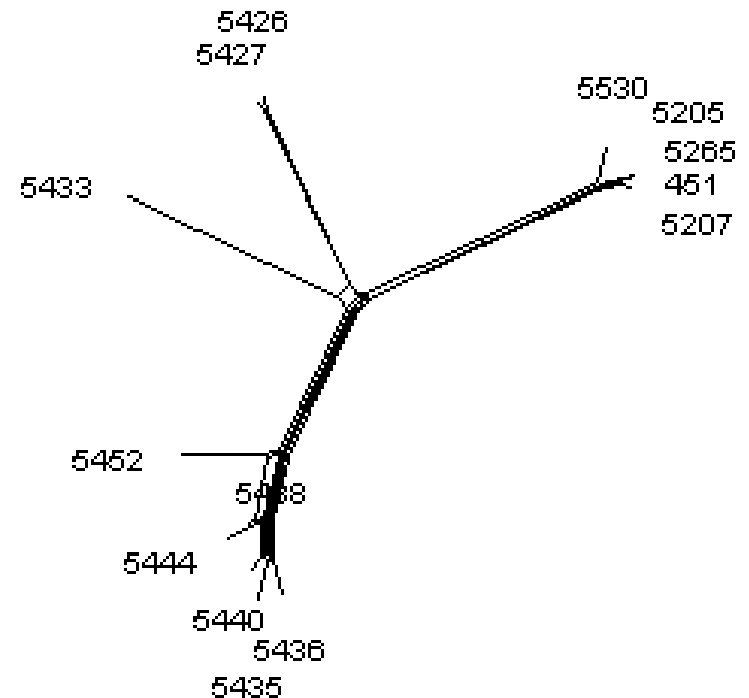
SplitsTree v. 4.8:

phi test (Φ_w)

$$p = 0.059$$

Star-like tree generated using
SplitsTree v. 4.8.
Recombination events are absent

Recombination is
absent



Conclusions and hypotheses

Extreme conditions lead to Darwinian evolution with recombination and adaptation

Close to the edge of life an entirely different process becomes apparent

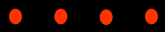


Loss of sexuality: Clonal reproduction with long-term survival (safe energy)

Change over time through mutation only

Accelerated under stress

Müllers ratchet not applicable: no accumulation of mutations - deleterious mutations are immediately negatively selected



Gradual focus from C- to S-strategy

Large parts of genome become superfluous

Energetic efficiency: loss

Narrowing ecological amplitude

Extinction through change of environment



Celibatery life in the super-extreme is in the long run more successful than life with sex



Thank you for
your attention