

REFERTILISING WESTER ROSS



REFERTILISING WESTER ROSS



An Underground Ecologist's Perspective



Fertility = Fertiliser?



Not in the Real World



This talk is about
BIODIVERSITY and Fertility
(not fertiliser)

FERTILITY \rightleftarrows BIODIVERSITY





COMPARE

James Merryweather



NOW YOU SEE IT?
NO YOU DON'T!

SOIL

! WE KNOW ALL THIS !

Biodiversity ✓

Biotic Networks ✓

Biotic Interactions ✓

Food Webs/Cascades ✓

Community Structure ✓

Ecosystem Integrity ✓

'Alive' ✓

Vulnerable to:

Disturbance ✓

Disruption ✓

Desiccation ✓

Intoxication ✓

Smothering ✓

Incineration ✓



MITES
FUNGI
ROOTS
ALGAE
MOLES
INSECTS
SPIDERS
VIRUSES
CILIATES
AMOEBAE
ROTIFERS
BACTERIA
EELWORMS
CENTIPEDES
SPRINGTAILS
FLATWORMS
WATER BEARS
EARTHWORMS
SLIME MOULDS



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SLIME MOULDS



MYCORRHIZA – a brief introduction

“While there are many groups of soil organisms that may be considered to provide ‘keystone’ ecosystem functions, mycorrhizal fungi are arguably among the most important because of their direct access to the plant-derived carbon that fuels below-ground microbial communities.” Leake, J.R. *et al.* (2005). In Badgett, R.D., Usher, M.B. & Hopkins, D.W. eds *Biological Diversity and Function in Soils*. Cambridge University Press.

“Mycorrhizas, not roots, are the chief organs of nutrient uptake by land plants.” Smith, S.E. & Read, D.J. (2008). *Mycorrhizal symbiosis*. 3rd ed. Academic Press.

MYCORRHIZA is a symbiosis, that is: two or more different organisms living together. It is arguably one of the most important life processes on land, but being subterranean, microscopic, invisible and poorly understood, it is not an easy concept to comprehend or to share with others. To invisibility we can add the perplexingly complicated and obscure ecology of mycorrhiza, which is just too much hassle for many of the scientists in whose studies it ought to be relevant, even ecologists. Some simply can't cope with including it in their comfortably simplified description of the world, and they just leave it out. That is a shame, because it matters a great deal (gross understatement – above). This handout tries to make mycorrhiza accessible to all, providing some clarity in advance of the talk.

This tongue twister combines two Greek words, *μυκός-ριζα (mikas-ryza)*, literally ‘fungus-root’. In a mycorrhizal state, fungi and the plant roots together form an interface for the exchange of nutrients. From the ‘phytcentric’ (plant's) viewpoint, its most usual function is to facilitate the supply of phosphate. This essential nutrient generally occurs at extremely low concentrations in natural soils and is mostly held tightly by soil clays, unavailable. Don't worry, *‘was ever thus*, and mycorrhiza is the remedy. No, remedy is the wrong word. It's the norm. For instance, the roots of Britain's favourite wild flower, bluebell (*Hyacinthoides non-scripta*), operate in an environment where phosphate is available at less than 0.1 part per million in soil solution. Bluebells cannot survive if non-mycorrhizal, for their short, thick roots are incapable of exploring the soil for inaccessible nutrients. Long ago evolution and symbiosis took care of what would have otherwise have been a fatal problem for bluebells. At Pretty Wood in Yorkshire, bluebell roots are colonised by at least eleven different mycorrhizal fungi, most of which are unculturable, unidentifiable and new or unknown to science. They range out beyond the root system, some of them gathering otherwise inaccessible phosphate on the behalf of their plant partners, others working with bluebell in different ways. It works very well.

This is not a new idea, even in evolutionary terms. In the primeval, aquatic habitat, primitive plants found phosphate acquisition uncomplicated, but it was not so when they experimented with life on land. When they first embarked upon their land-based lifestyle together around 500 million years ago, plants and mycorrhizal fungi were already collaborating in the form of a novel symbiosis which enabled them both to live on land and diversify. From the start, mycorrhiza was the normal way of life for land plants, and it still is for an estimated 90-95% of plants in all ecosystems on every continent. Mycorrhiza was, always has been and still is ubiquitous. *Please read the last two sentences again to absorb what they imply about the universal ecological importance of this symbiosis!*

We tend to focus our attention on the above-ground organisms with which we are familiar, the ones that occupy the same living space as ourselves. Therefore, we overlook the ‘mycocentrically’ (fungal viewpoint) important function of mycorrhiza: what do the fungi get out of it?

I'm told you've read...

MYCORRHIZA

MYCO – (R)RHIZA

μυκας - ριζα

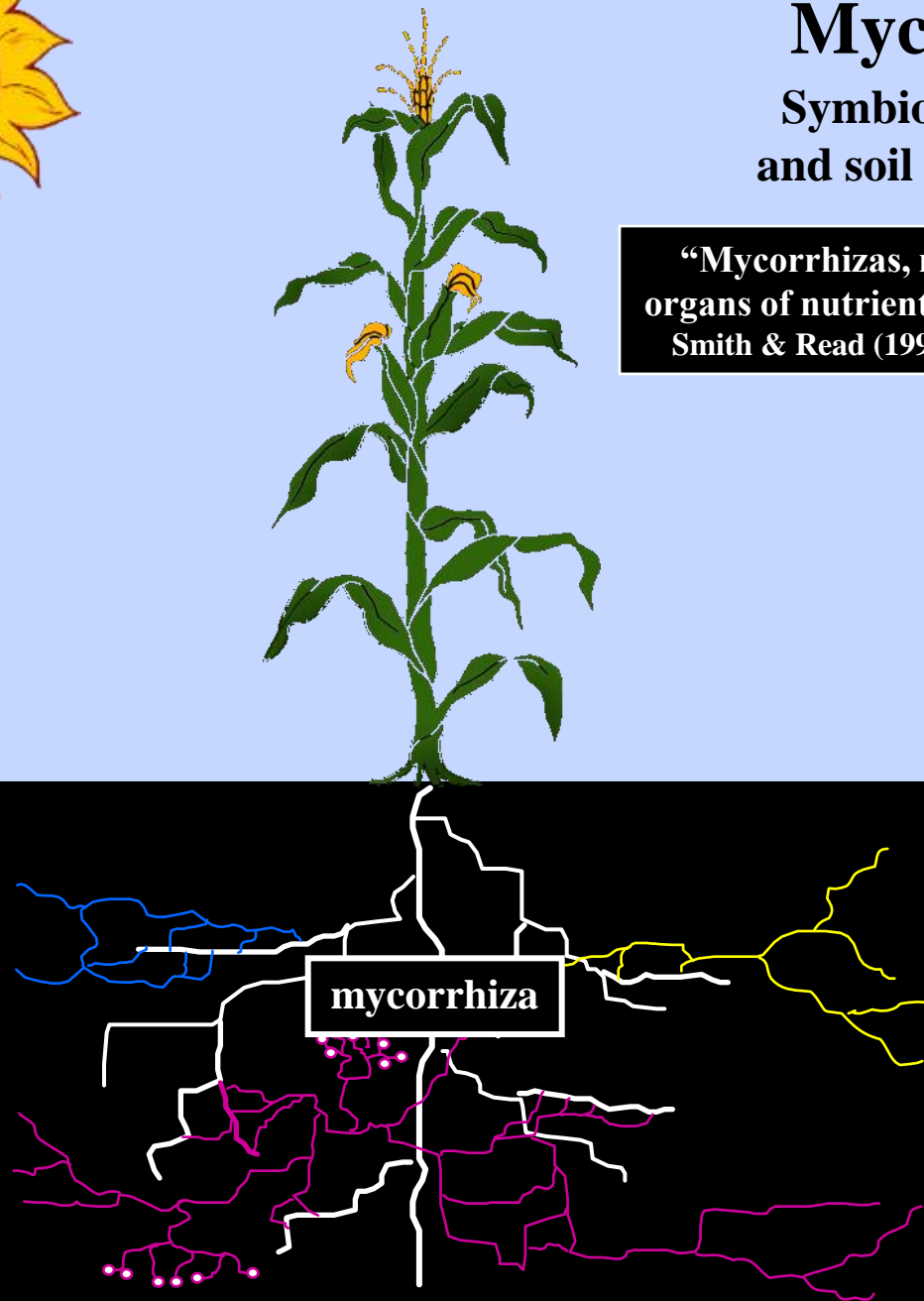
FUNGUS - ROOT



Mycorrhiza

Symbiosis of plants
and soil fungi in roots

“Mycorrhizas, not roots, are the chief organs of nutrient uptake by land plants.”
Smith & Read (1997). *Mycorrhizal Symbiosis*.





PHOTOSYNTHESIS



Mycorrhiza

Symbiosis of plants
and soil fungi in roots

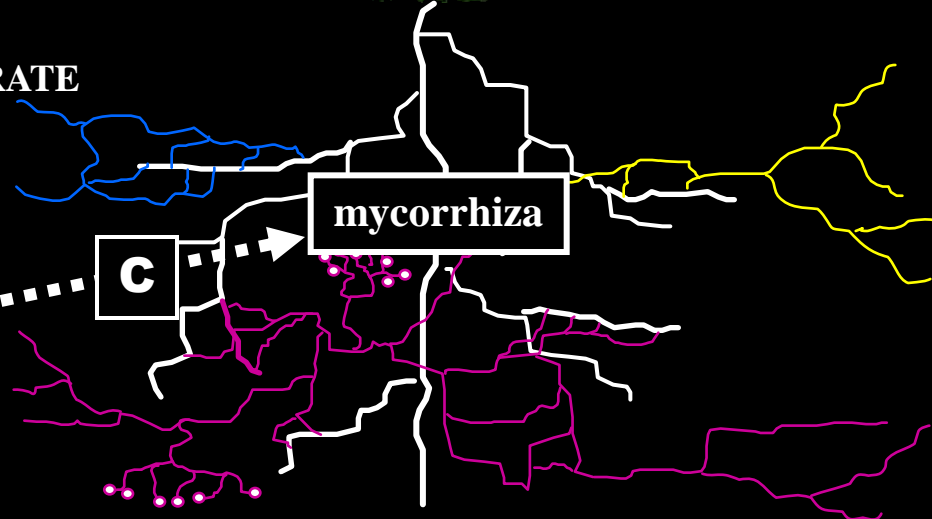
“Mycorrhizas, not roots, are the chief organs of nutrient uptake by land plants.”
Smith & Read (1997). *Mycorrhizal Symbiosis*.

CARBOHYDRATE

FUNGI

C

mycorrhiza





PHOTOSYNTHESIS



Mycorrhiza

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CARBOHYDRATE

FUNGI

mycorrhiza

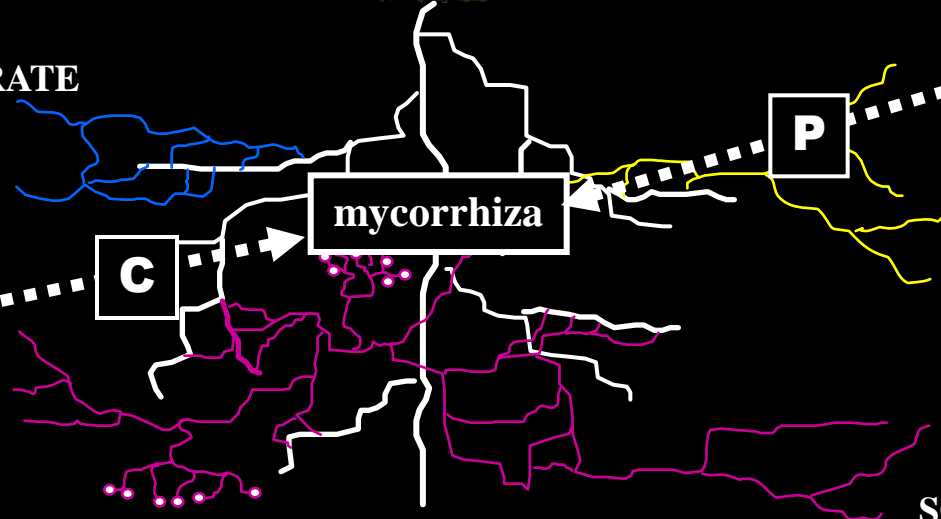
C

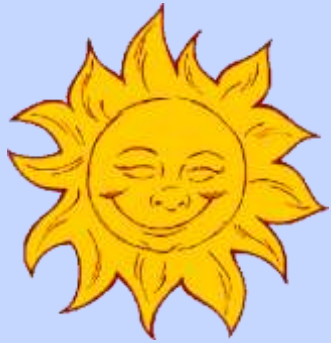
P

PLANT

FUNGI

SOIL PHOSPHATE

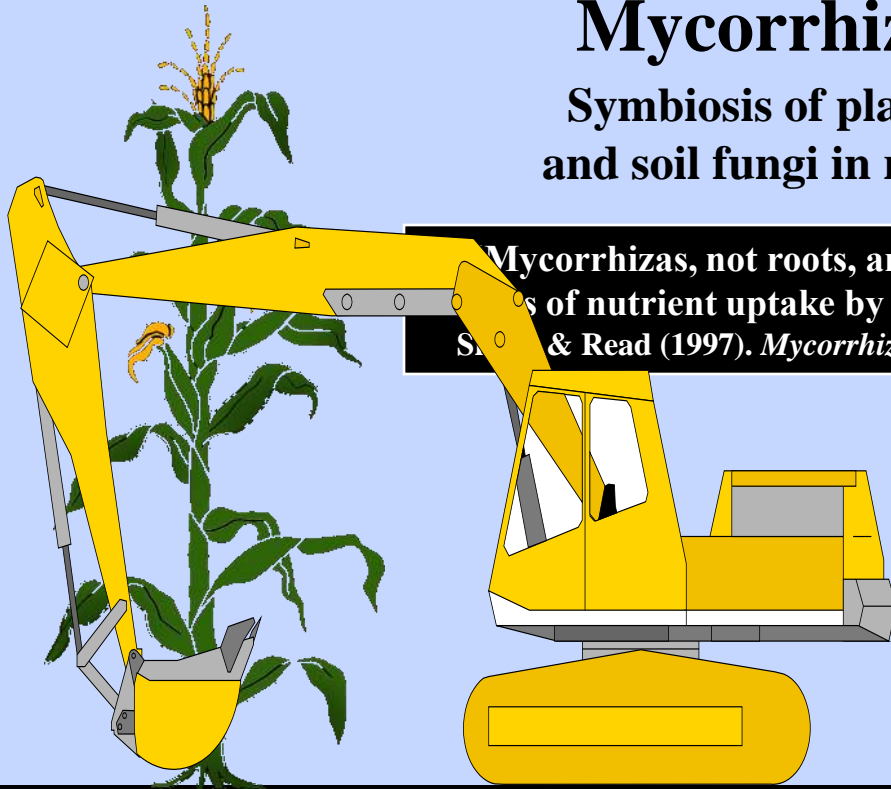




Mycorrhiza

Symbiosis of plants and soil fungi in roots

"Mycorrhizas, not roots, are the chief sources of nutrient uptake by land plants."
S. W. Smith & Read (1997). *Mycorrhizal Symbiosis*.



PHOTOSYNTHESIS

CARBOHYDRATE

FUNGI

mycorrhiza

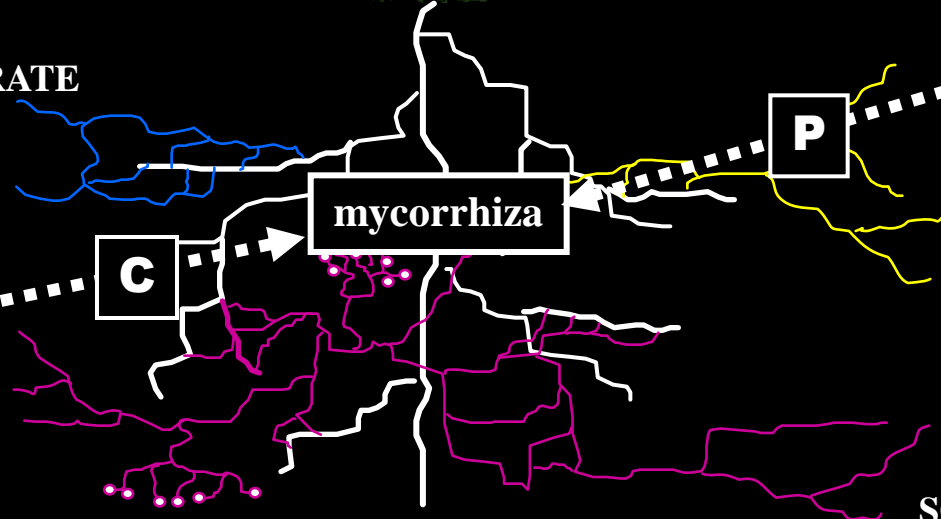
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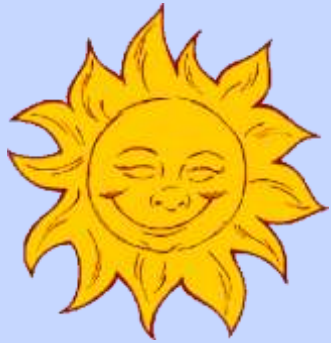
PLANT

FUNGI

SOIL PHOSPHATE

C



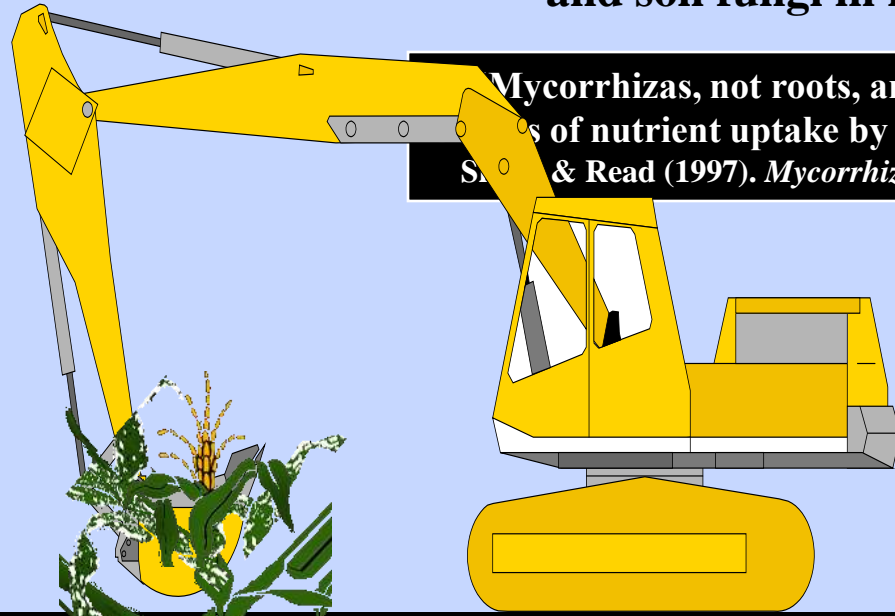


Mycorrhiza

Symbiosis of plants and soil fungi in roots

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S. W. Smith & Read (1997). *Mycorrhizal Symbiosis*.

PHOTOSYNTHESIS



CARBOHYDRATE

FUNGI

C

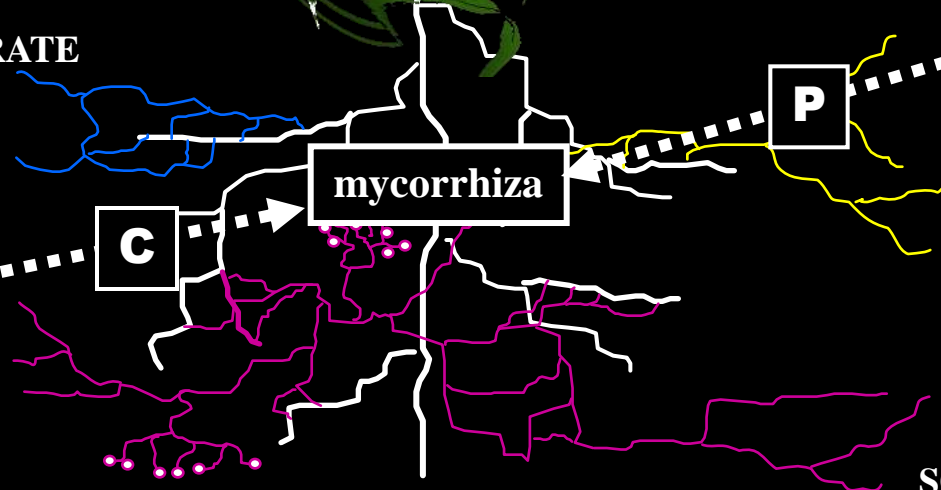
mycorrhiza

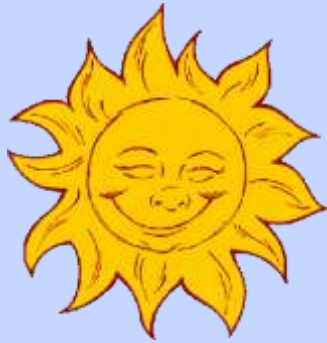
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PLANT

FUNGI

SOIL PHOSPHATE





Mycorrhiza

Symbiosis of plants and soil fungi in roots

PHOTOSYNTHESIS

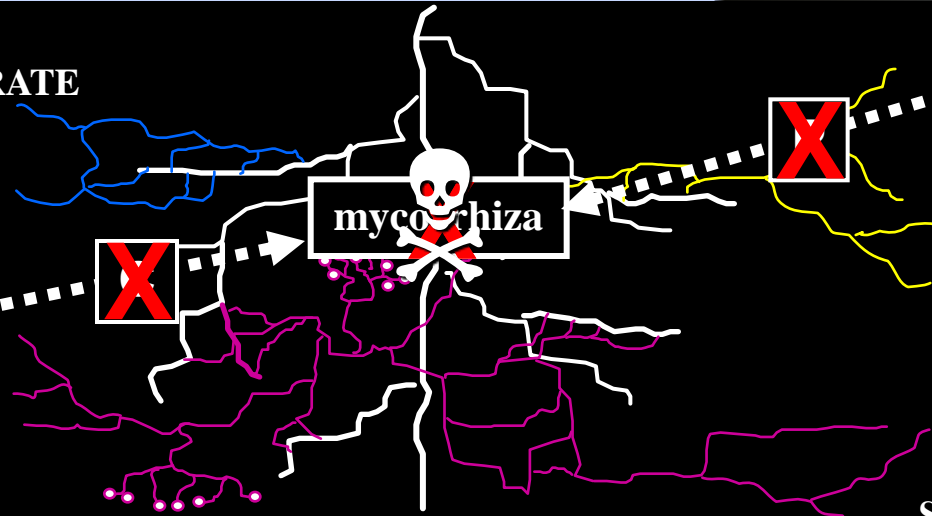


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CARBOHYDRATE



FUNGI



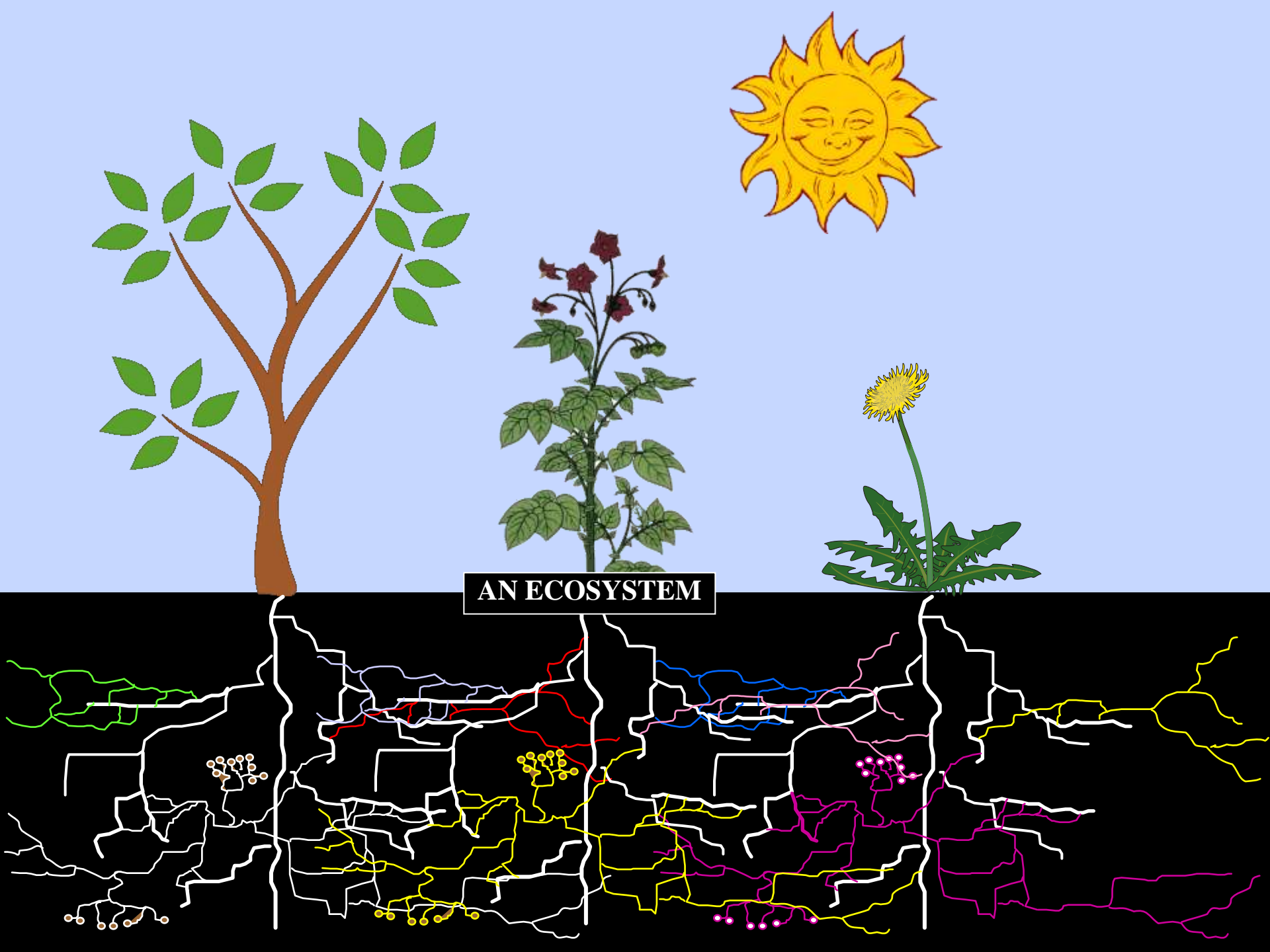
PLANT



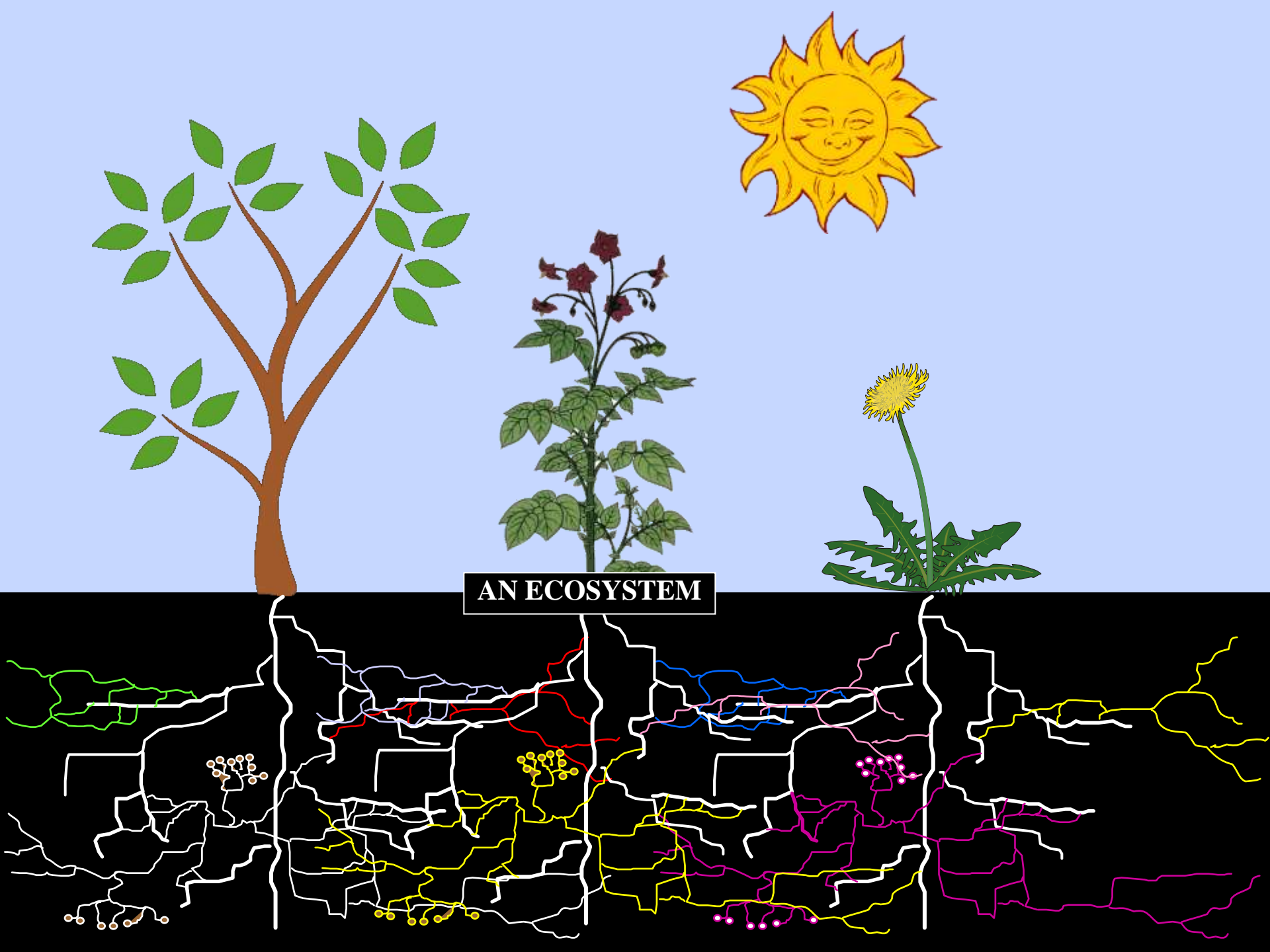
FUNGI



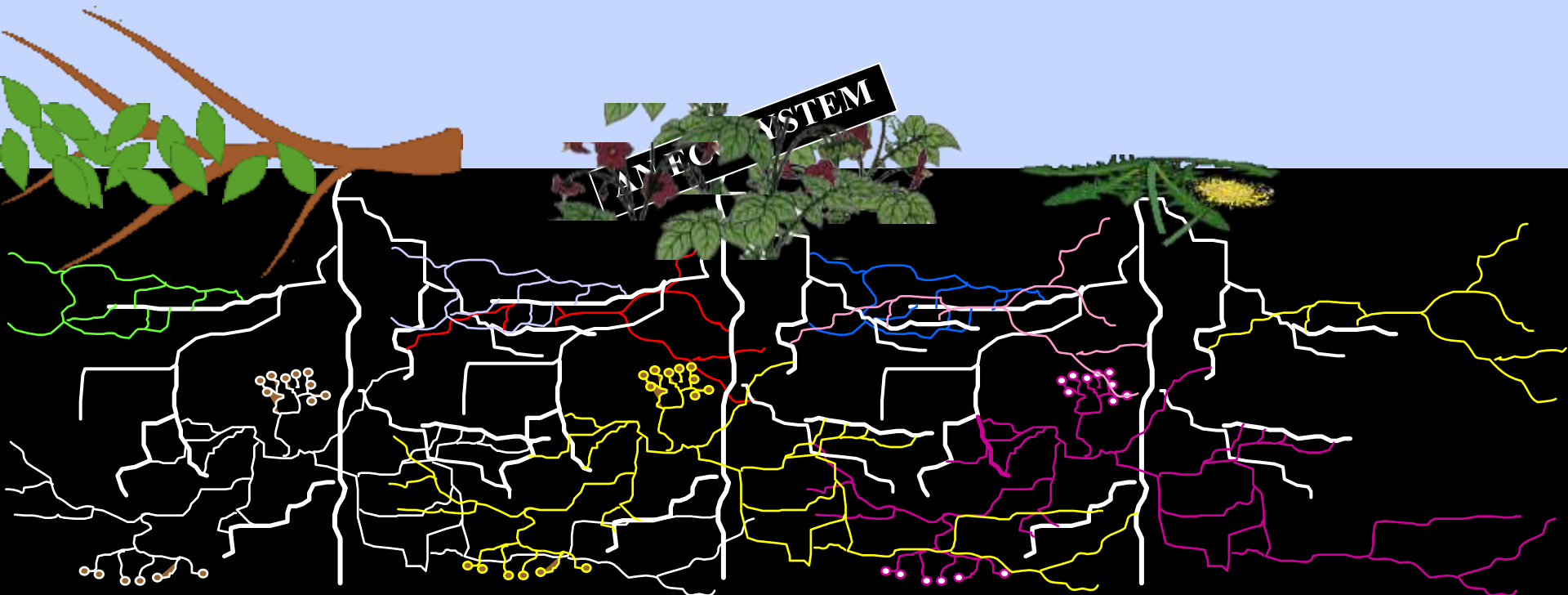
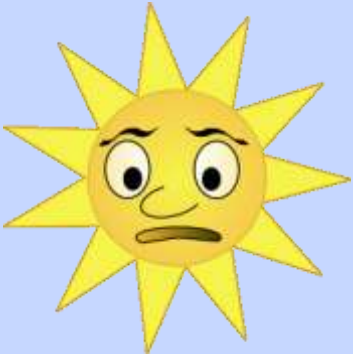
SOIL PHOSPHATE

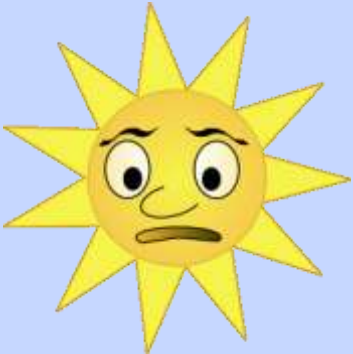


AN ECOSYSTEM

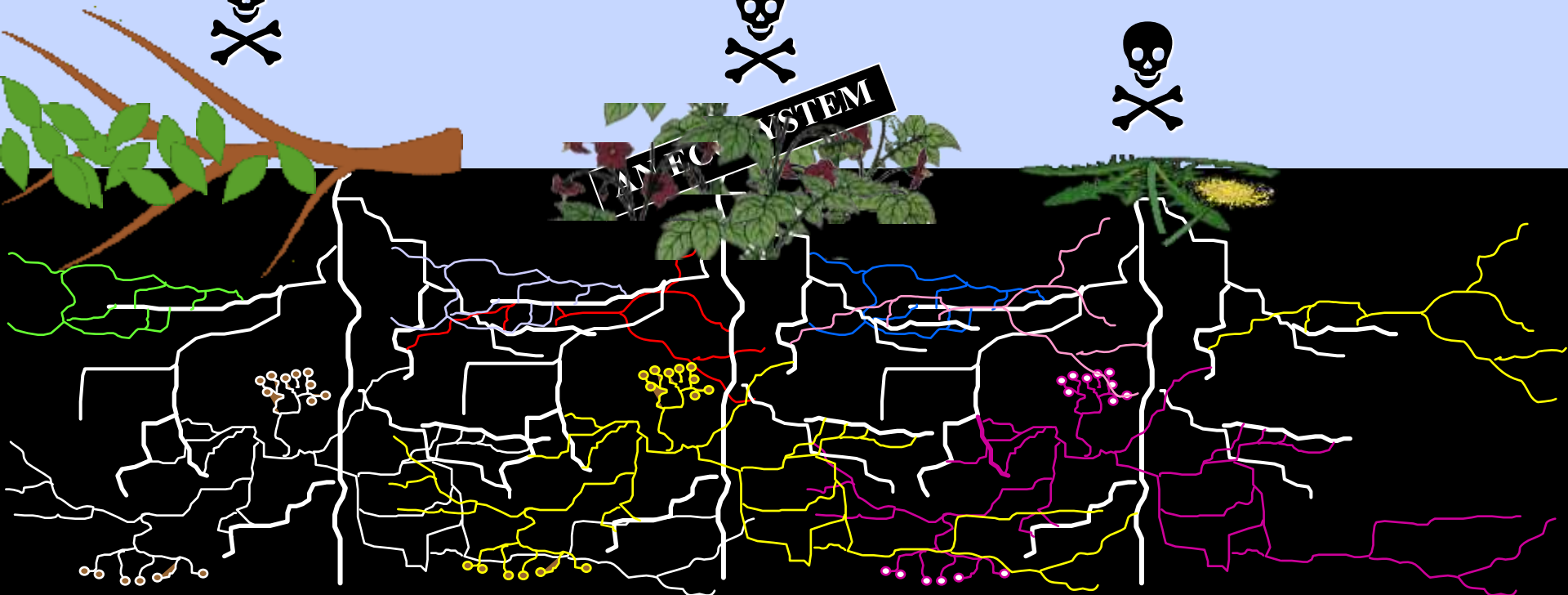


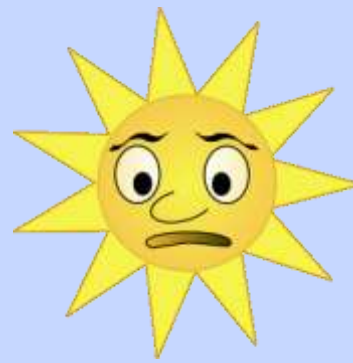
AN ECOSYSTEM



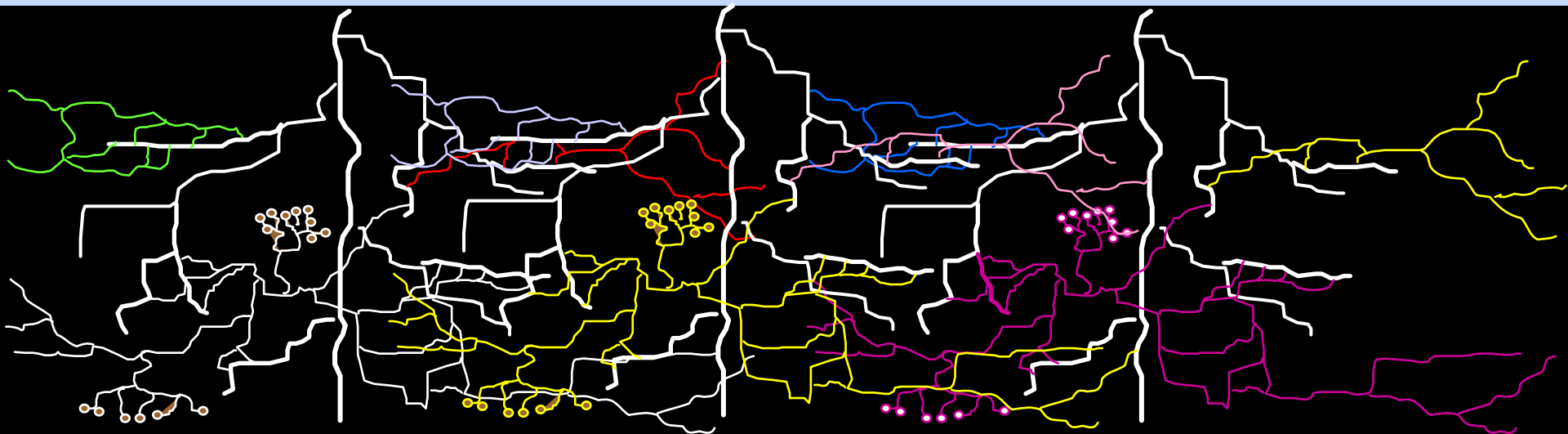


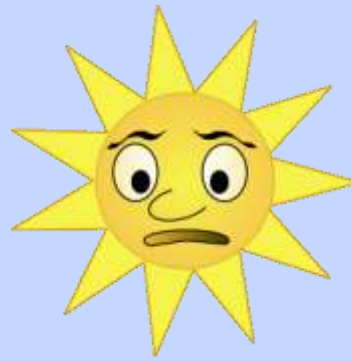
ANFC SYSTEM





EXTINCTIONS



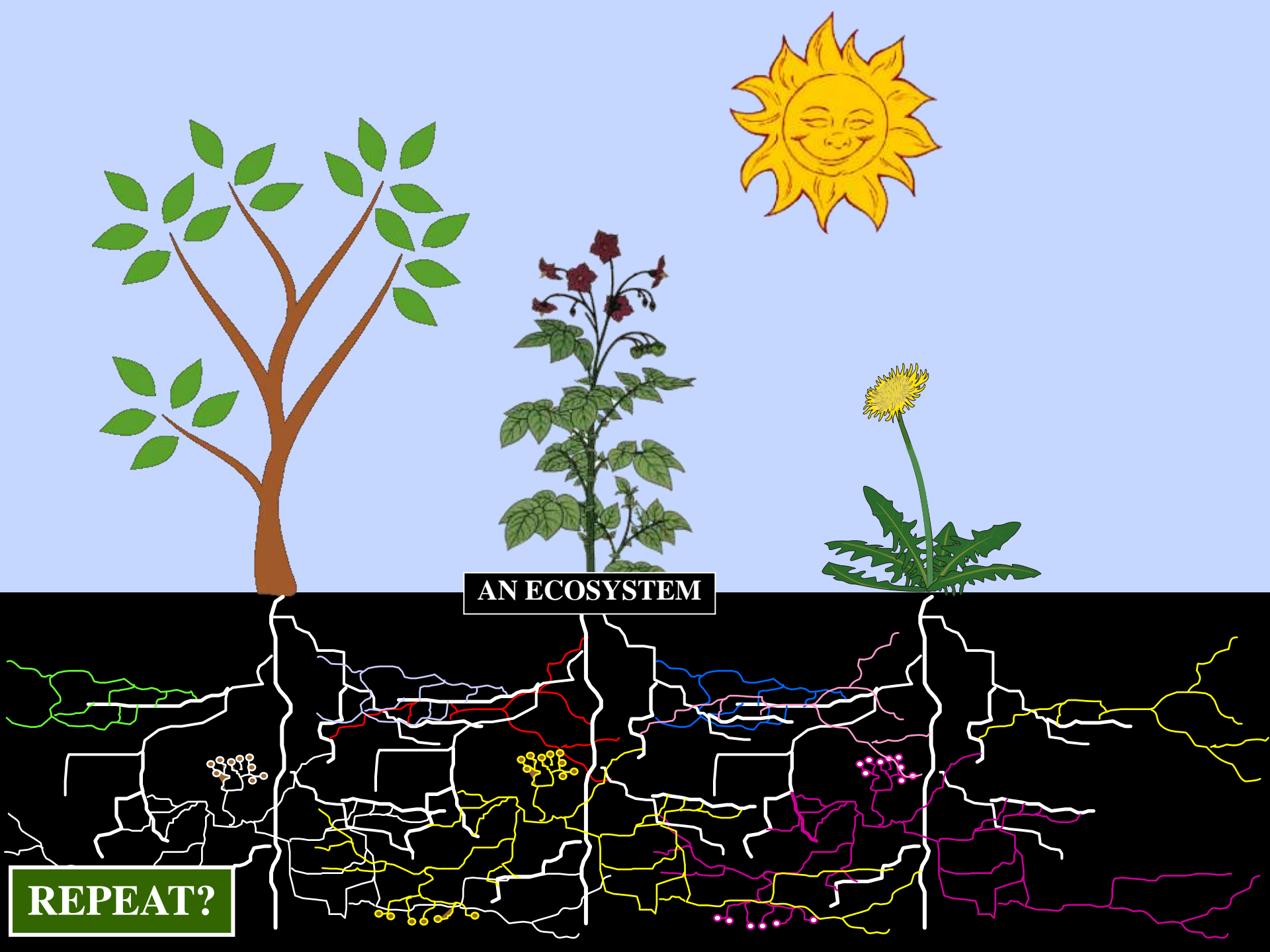


EXTINCTIONS



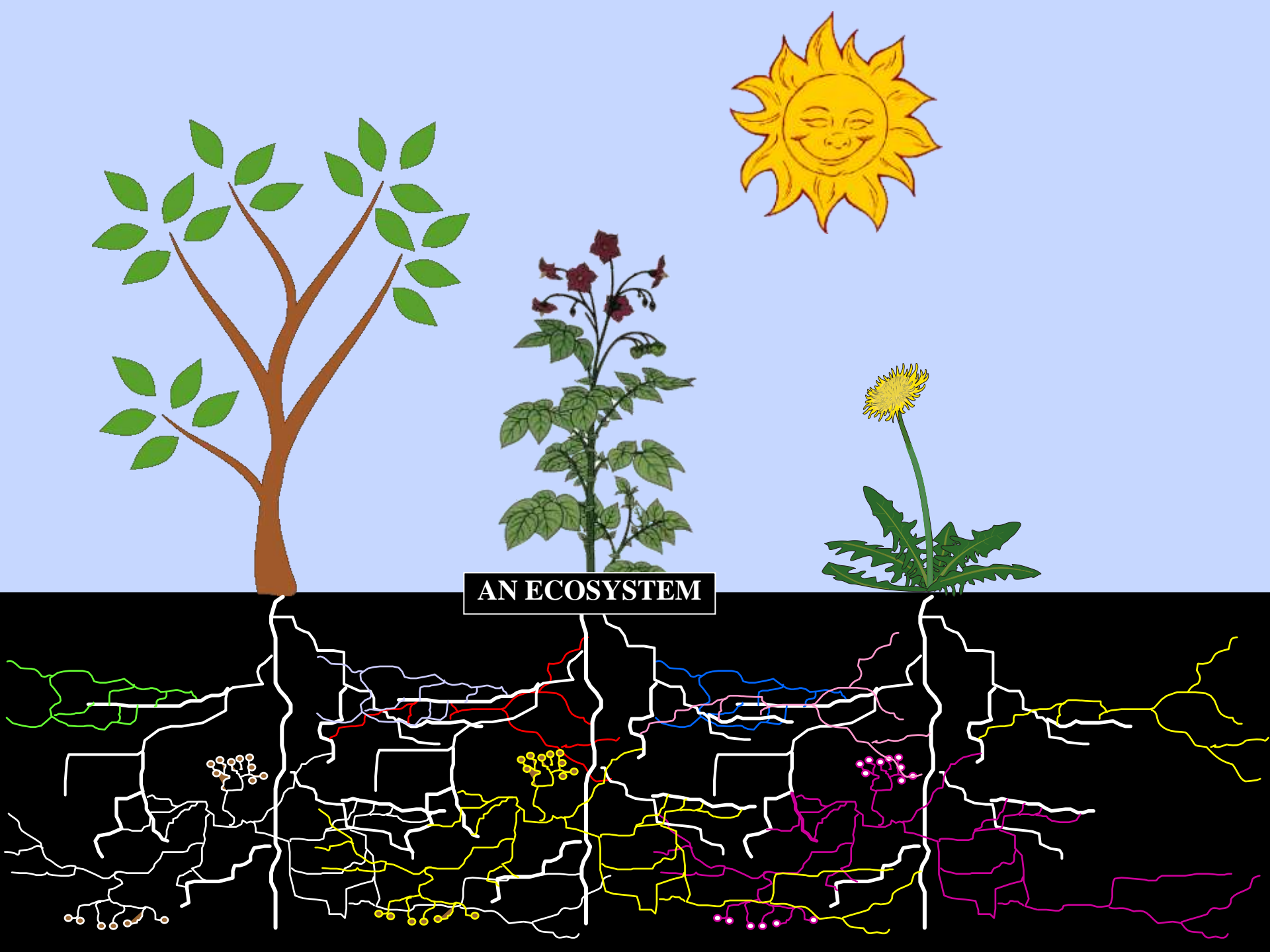
EXTINCTIONS



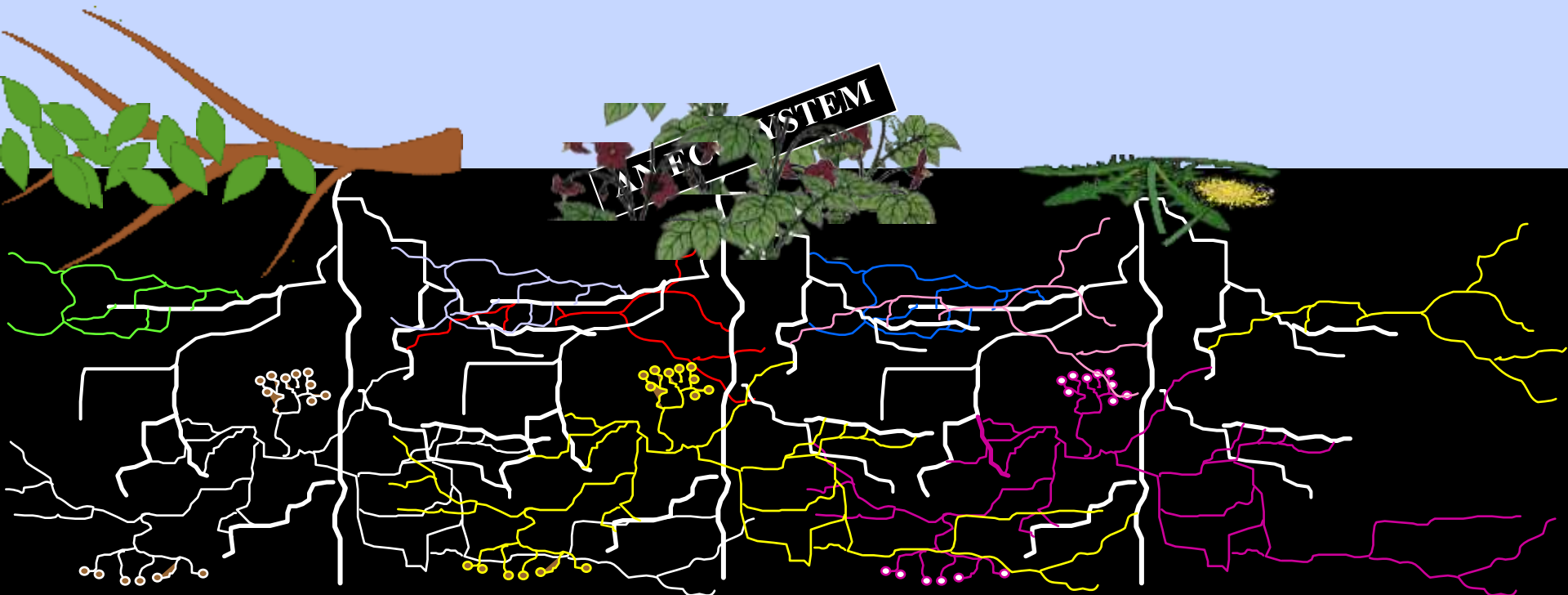
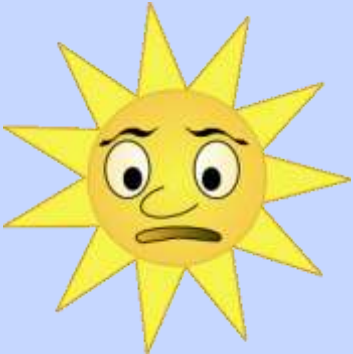


AN ECOSYSTEM

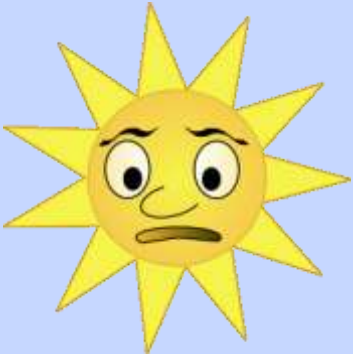
REPEAT?



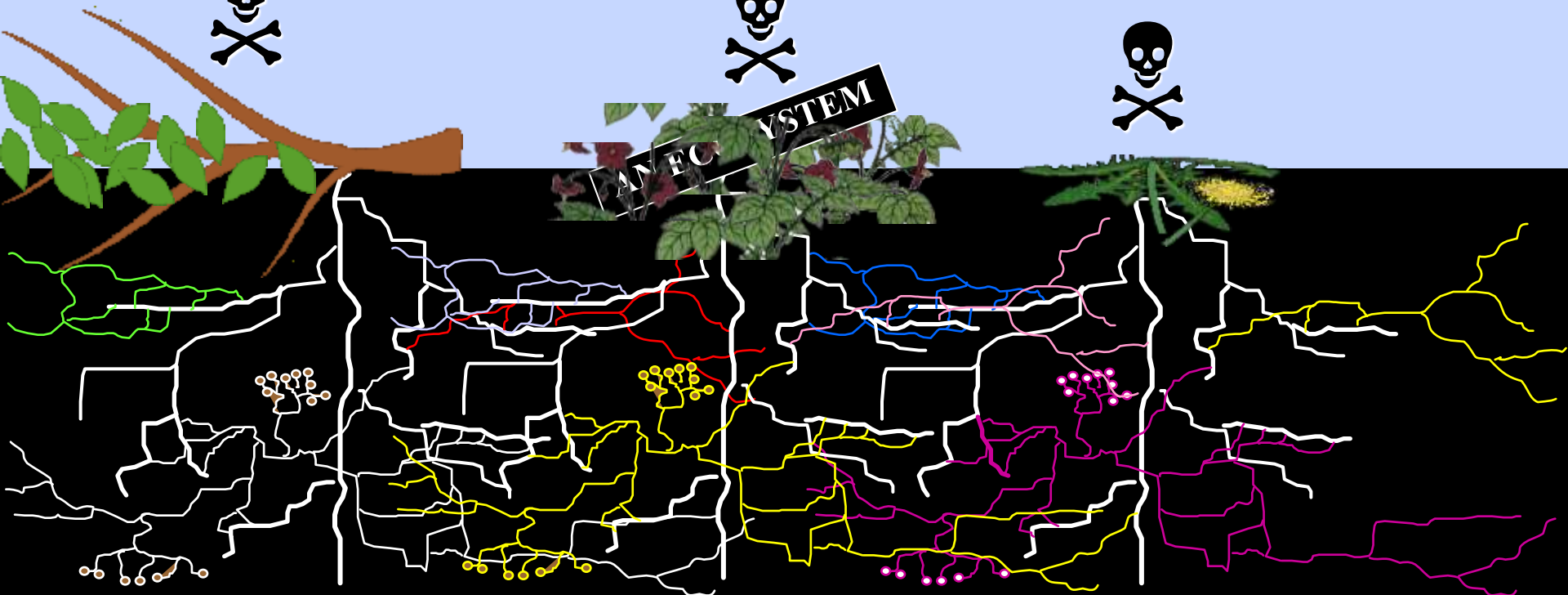
AN ECOSYSTEM

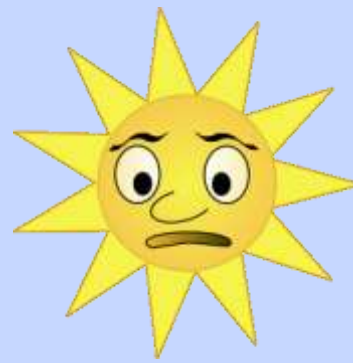


ANFC SYSTEM

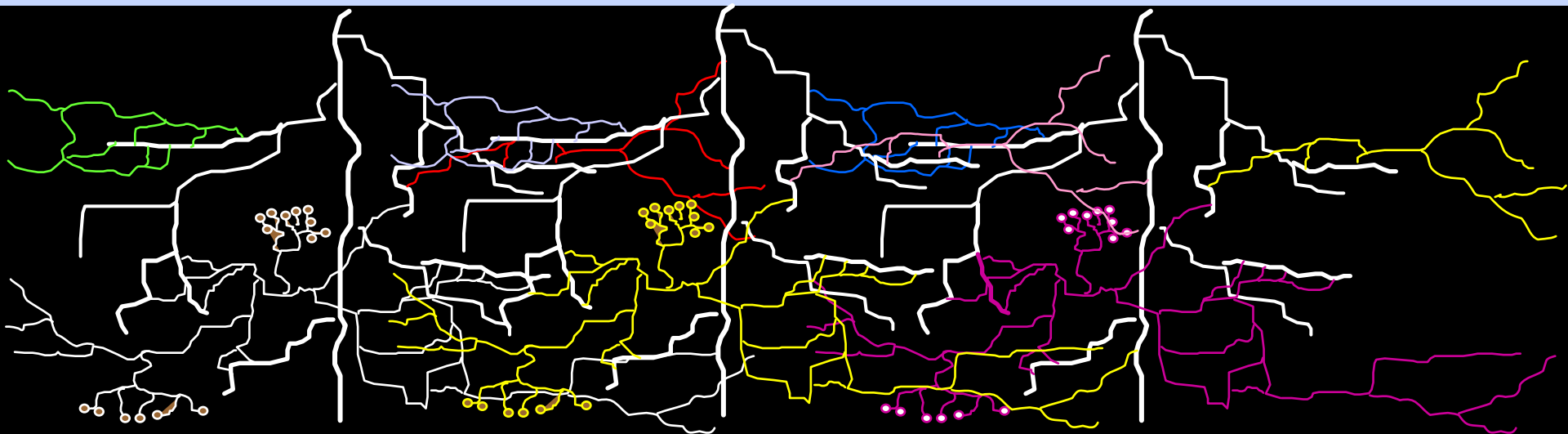


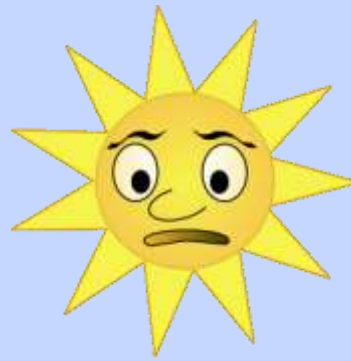
ANFC SYSTEM





EXTINCTIONS



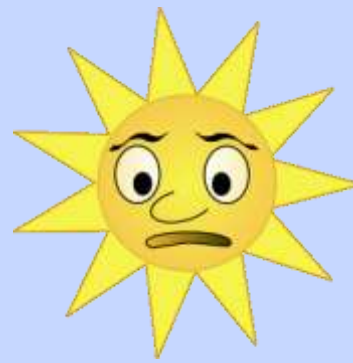


EXTINCTIONS



EXTINCTIONS





EXTINCTIONS



ABOVE GROUND



BELOW GROUND



EXTINCTIONS











1504 LC





P930 HTS



PHOTOSHOPPED









INERT STUFF



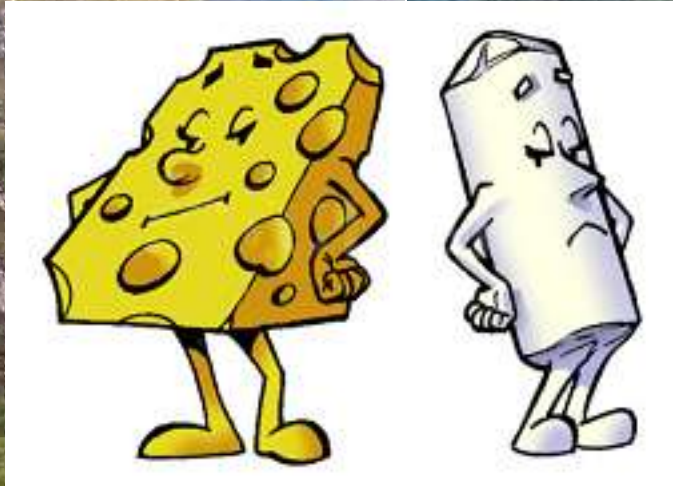
INERT STUFF



Twenty-Ten-Ten
20-10-10
BIG BAGS
400 kg net

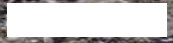


INERT STUFF?

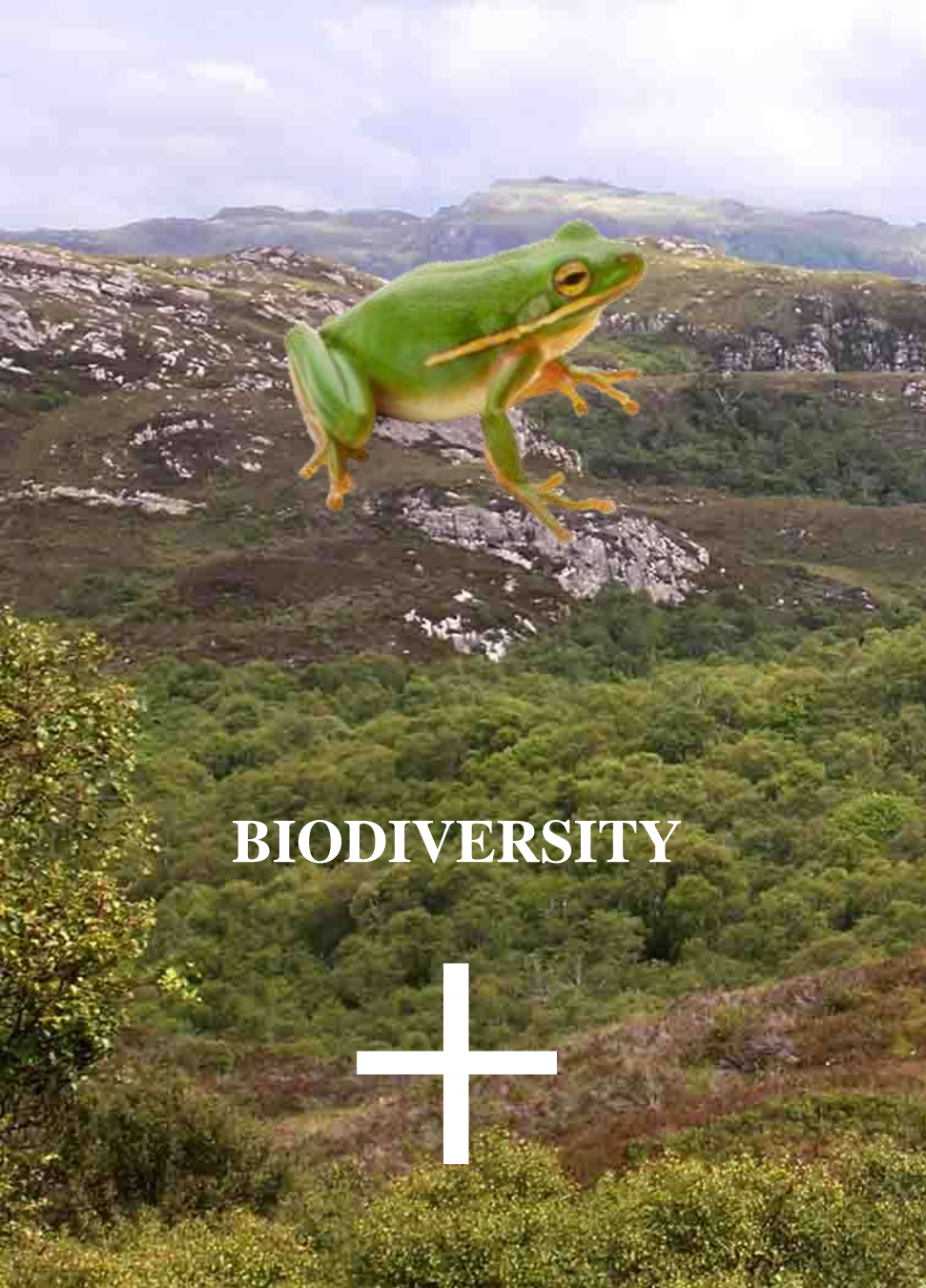


BIODIVERSITY

BIODIVERSITY



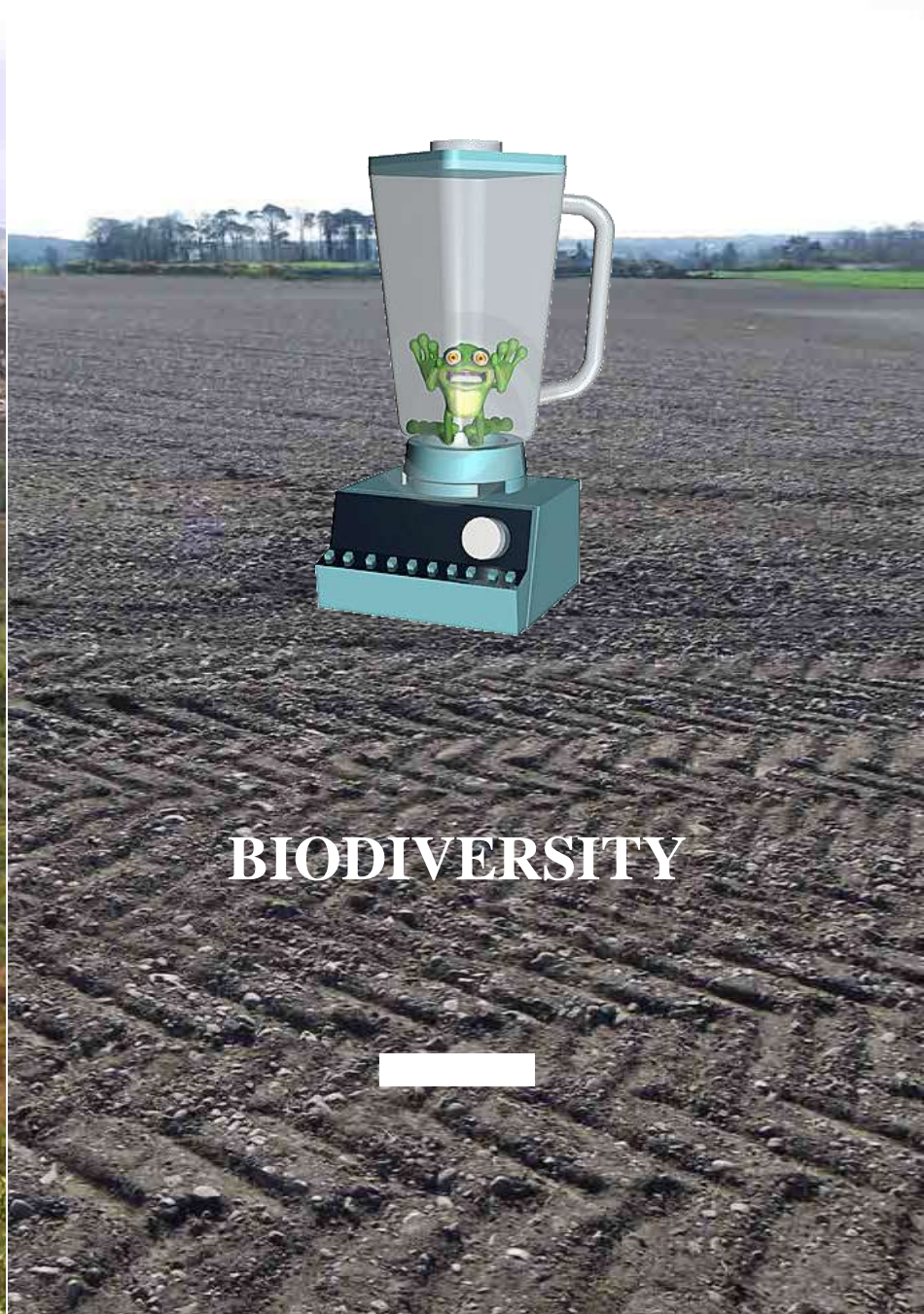
ECOLOGICALLY



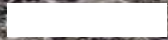
BIODIVERSITY



FUNCTIONALLY



BIODIVERSITY





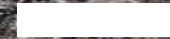
BIODIVERSITY



FUNCTIONALLY

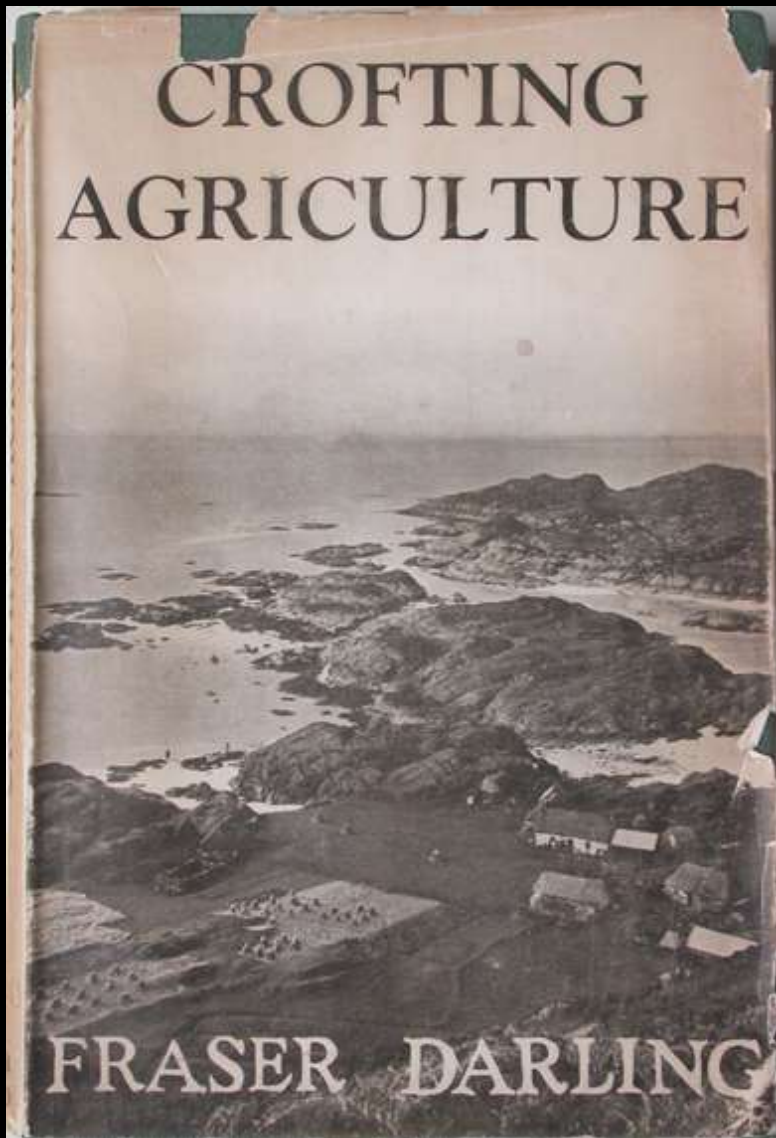


BIODIVERSITY

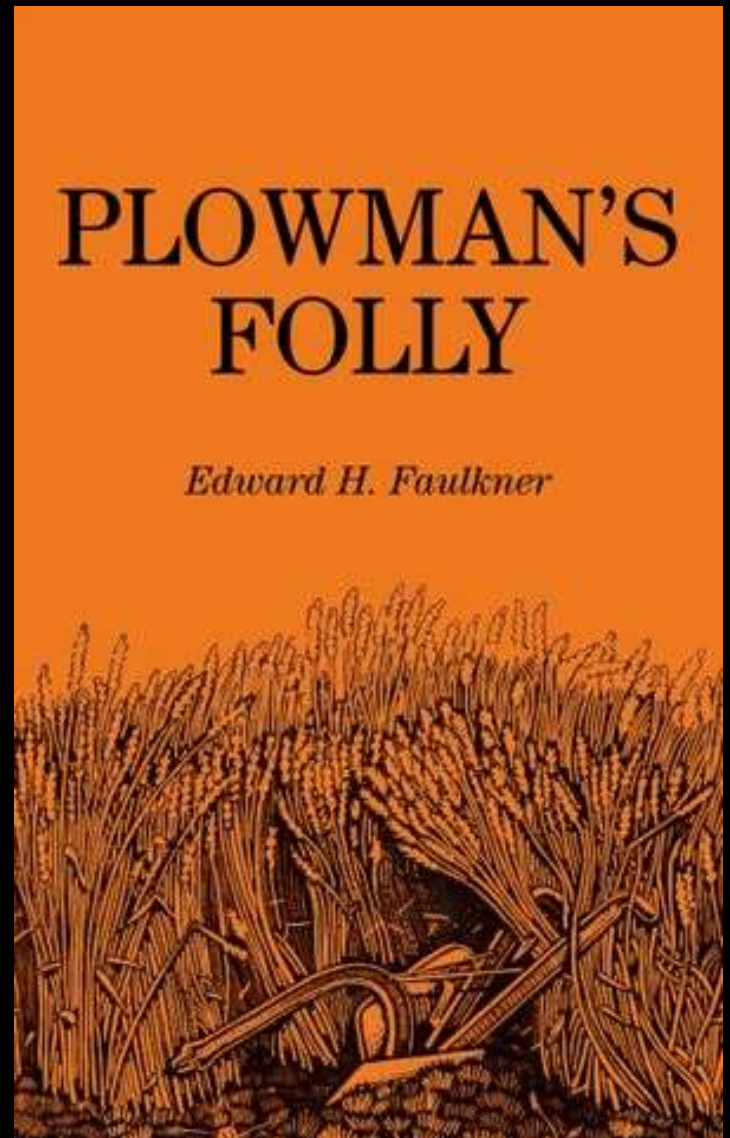




OBSERVE



1945



1943

READ



~~BIODIVERSITY~~
~~BIODIVERSITY~~



THINK



BIODIVERSITY

BIODIVERSITY

IMAGINE



BIODIVERSITY

BIODIVERSITY

IMAGINE

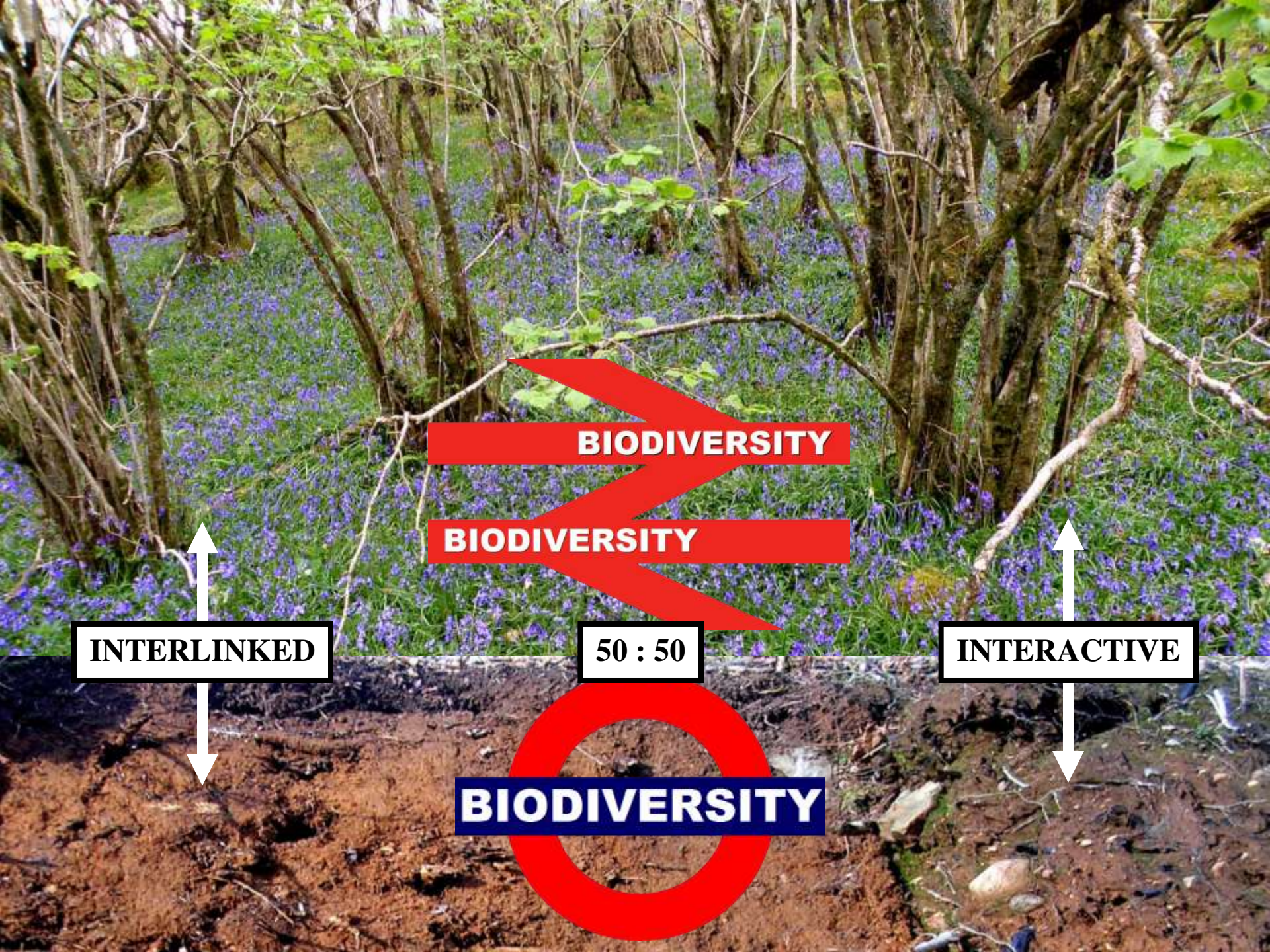


BIODIVERSITY

BIODIVERSITY



BIODIVERSITY



BIODIVERSITY

BIODIVERSITY

INTERLINKED

50 : 50

INTERACTIVE

BIODIVERSITY



~~BIODIVERSITY~~
~~BIODIVERSITY~~

BIODIVERSITY

IMAGINE



BIODIVERSITY

BIODIVERSITY

**50 : 50
INTERACTIVE**

BIODIVERSITY

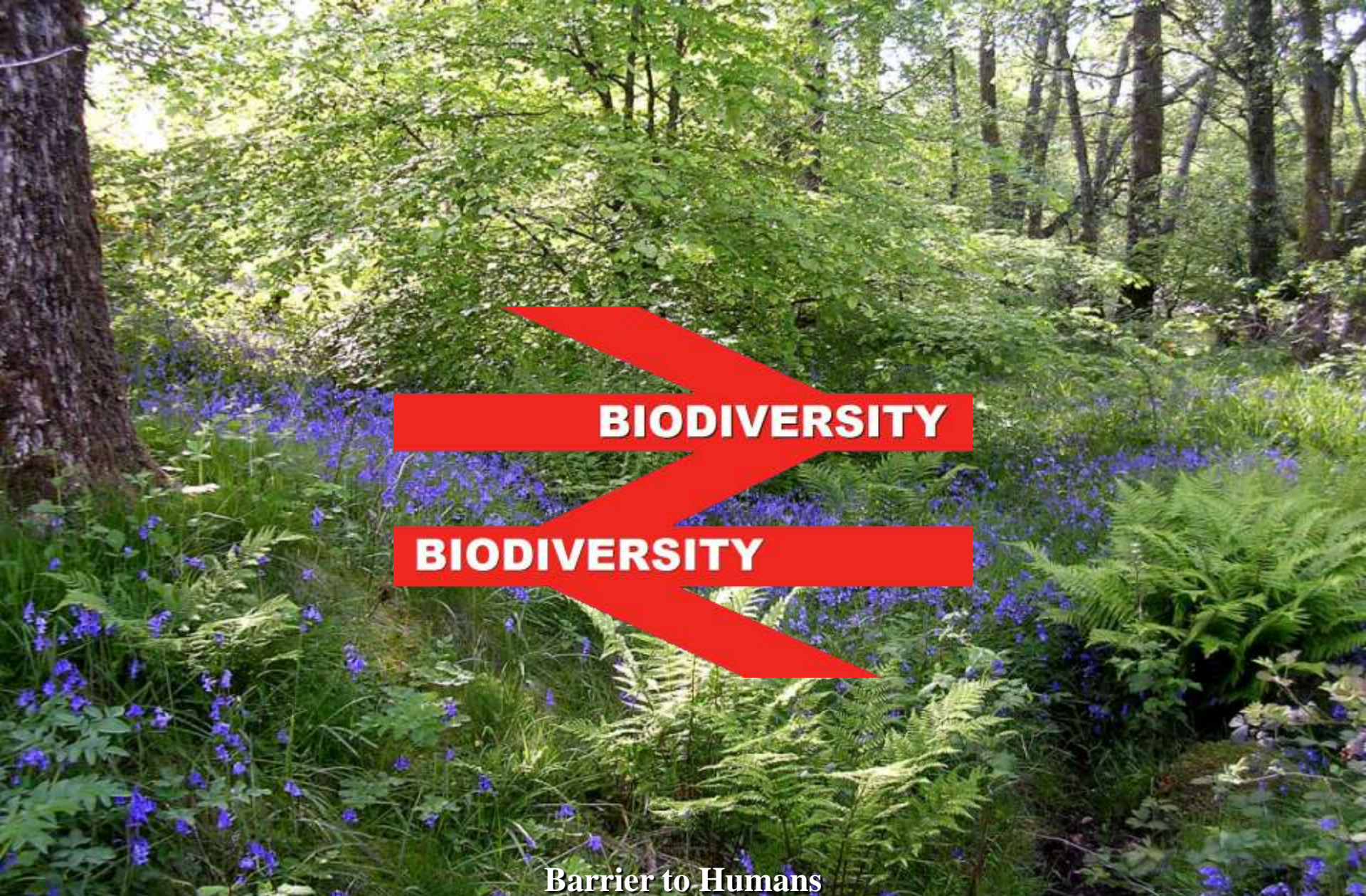
Mycorrhiza and other symbioses

INTERLINKED

IMAGINE

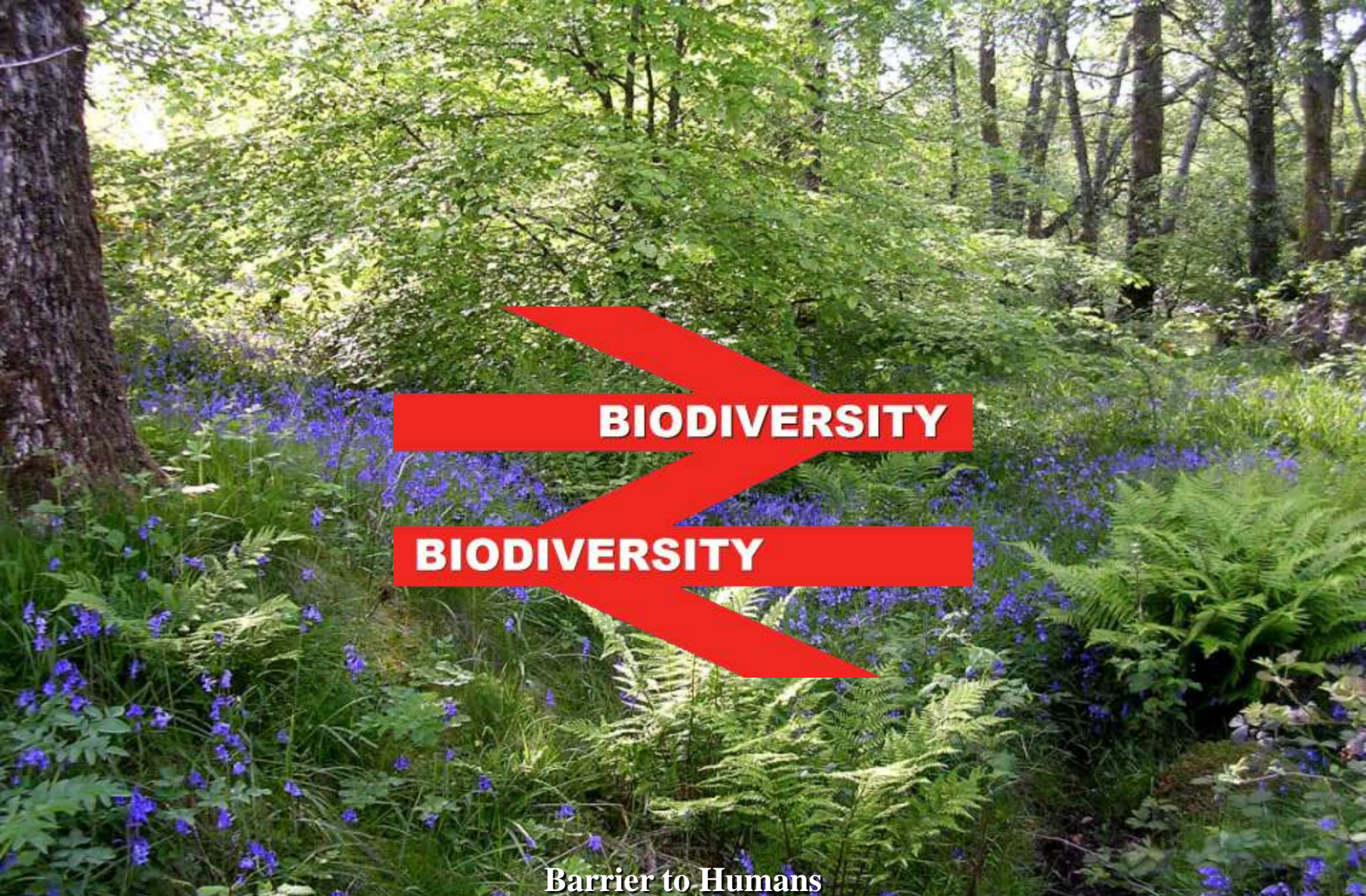


John Whitfield (2007).
Fungal roles in soil ecology:
Underground networking.
Nature 449, 136-138.



Barrier to Humans





BIODIVERSITY

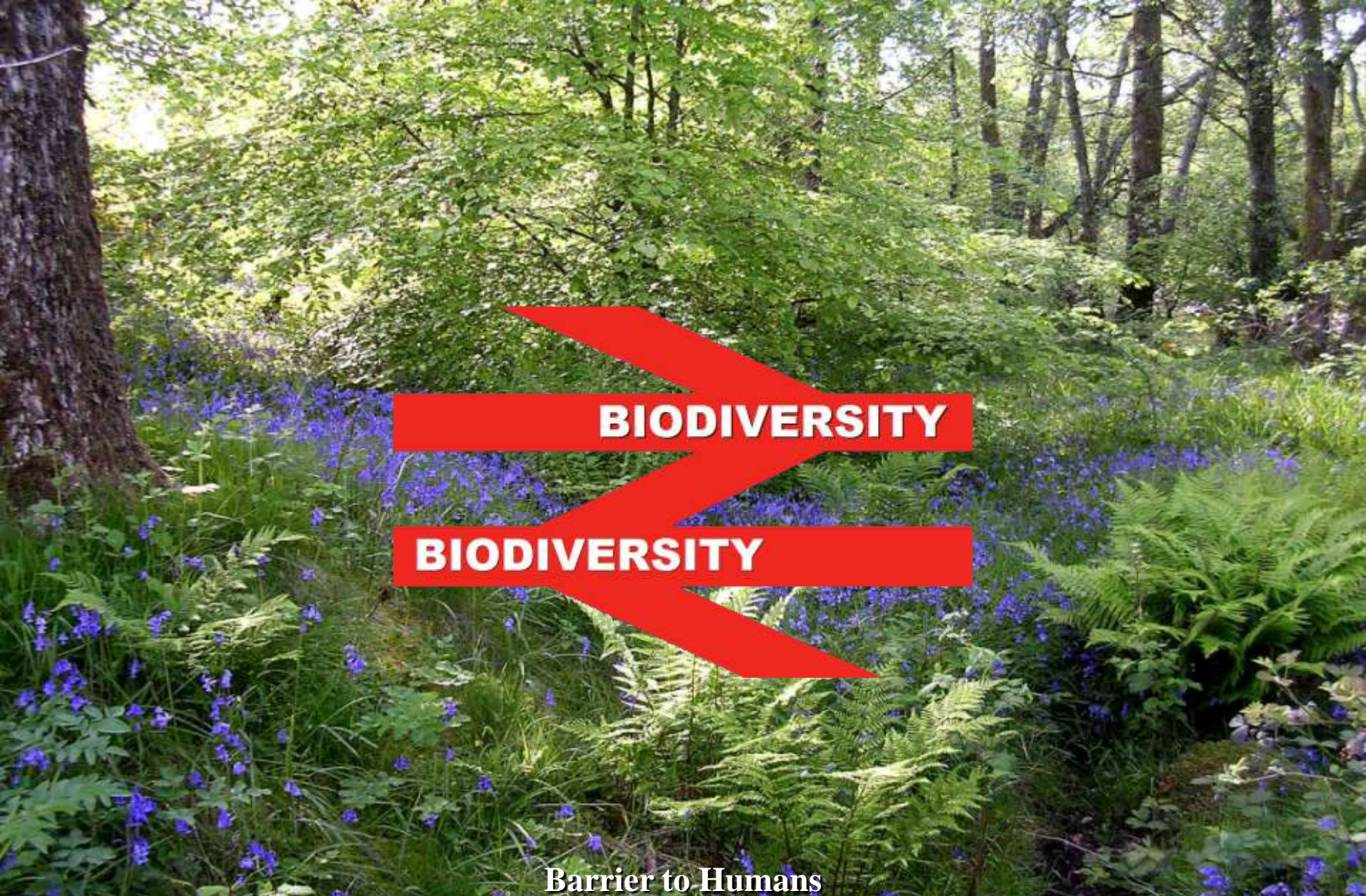
BIODIVERSITY

Barrier to Humans



BLACK BOX





BIODIVERSITY

BIODIVERSITY

Barrier to Humans



+



+



+



+



=





OBSERVE & IMAGINE



+



+



+



+



=






OLD ADAGE
"The mind is the
window on the soil"



=



A landscape photograph showing a valley with a mix of green and brown vegetation, including a line of trees and a dirt path.

I'll say what I think (as far as it goes) and you say what you think.

SO WHAT'S GOING ON HERE?



Beinn Eighe, yesterday



Beinn Eighe, yesterday



AND WHAT'S GOING ON HERE?



TWO ERICOID MYCORRHIZAL PLANTS CO-OPERATE?



WOODLAND & MYCORRHIZAL SUCCESSION IN TANDEM



WOODLAND & MYCORRHIZAL SUCCESSION IN TANDEM



Downy Birch
Betula pubescens

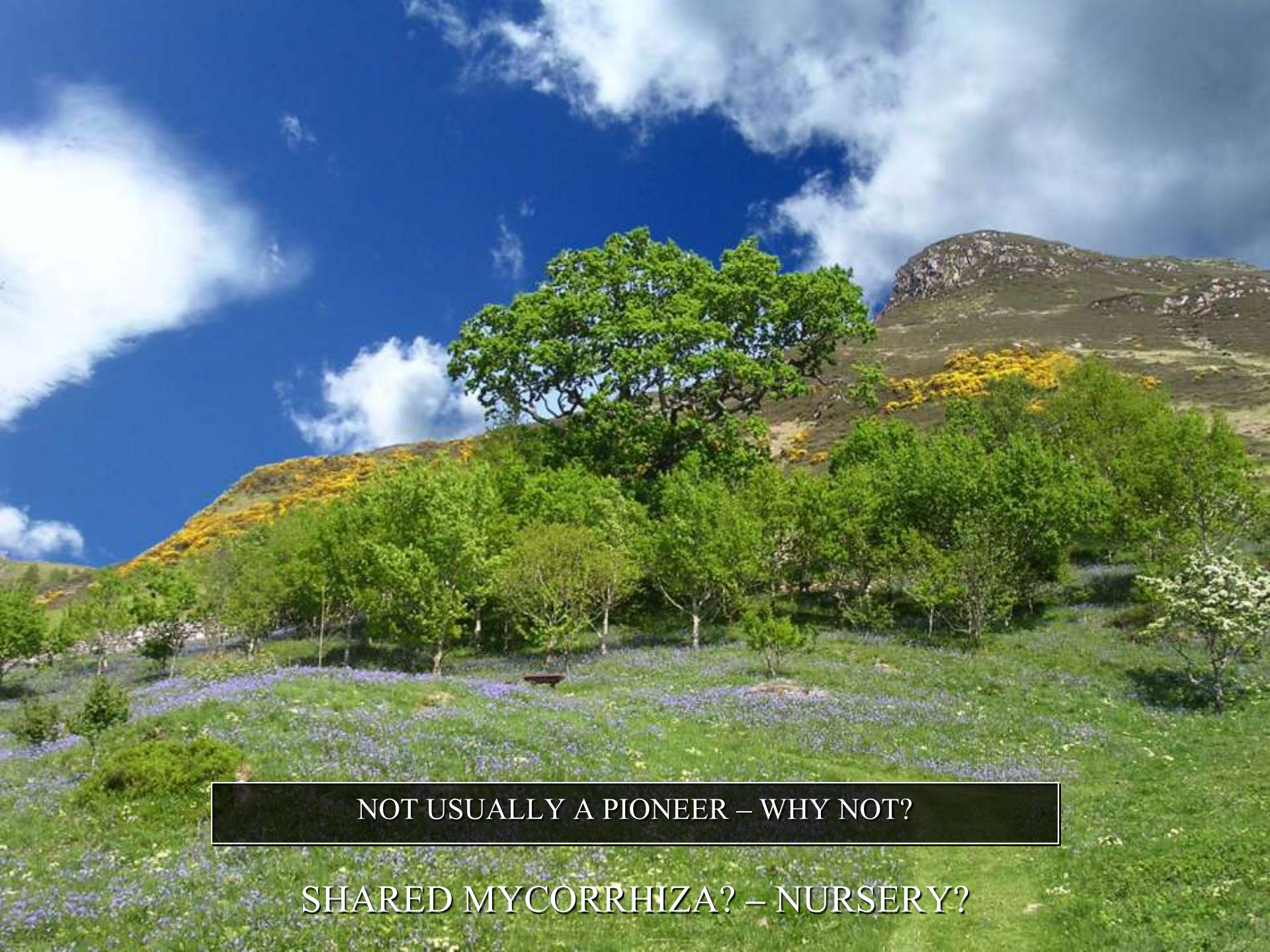
A close-up photograph of Downy Birch (Betula pubescens) leaves. The leaves are ovate with serrated margins and are attached to thin, brownish stems. The foliage is dense and green, with some leaves showing slight discoloration or damage.



Sallow
Salix capraea

A close-up photograph of Sallow (Salix capraea) leaves. The leaves are ovate with serrated margins and are attached to thin, brownish stems. The foliage is dense and green, with some leaves showing slight discoloration or damage.

PIONEERS – WHY?



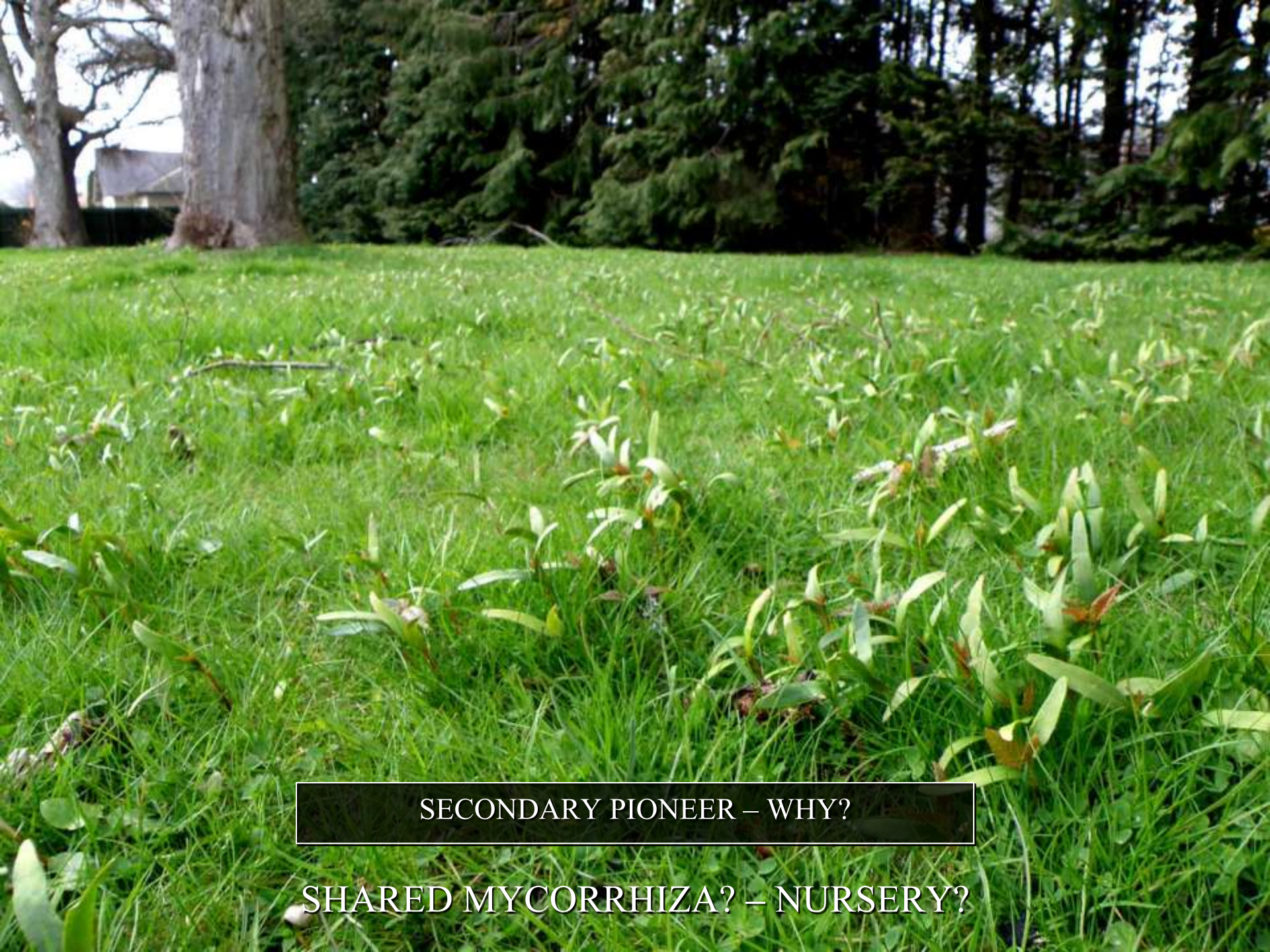
NOT USUALLY A PIONEER – WHY NOT?

SHARED MYCORRHIZA? – NURSERY?



SECONDARY PIONEER – WHY?

SHARED MYCORRHIZA? – NURSERY?



SECONDARY PIONEER – WHY?

SHARED MYCORRHIZA? – NURSERY?



SHARED MYCORRHIZA? – NURSERY?



WRONG MYCORRHIZAS – DOOMED?



+ 0 years

2006

+ 8 years



2014

SHARED MYCORRHIZA? – NURSERY?



+ c. 5 years

2005



+ c. 16 years

2016

WRONG MYCORRHIZAS – DOOMED?



1.

2.

The Plock of Kyle

GORSE



1.





2.

The Plock of Kyle



2.





THEN

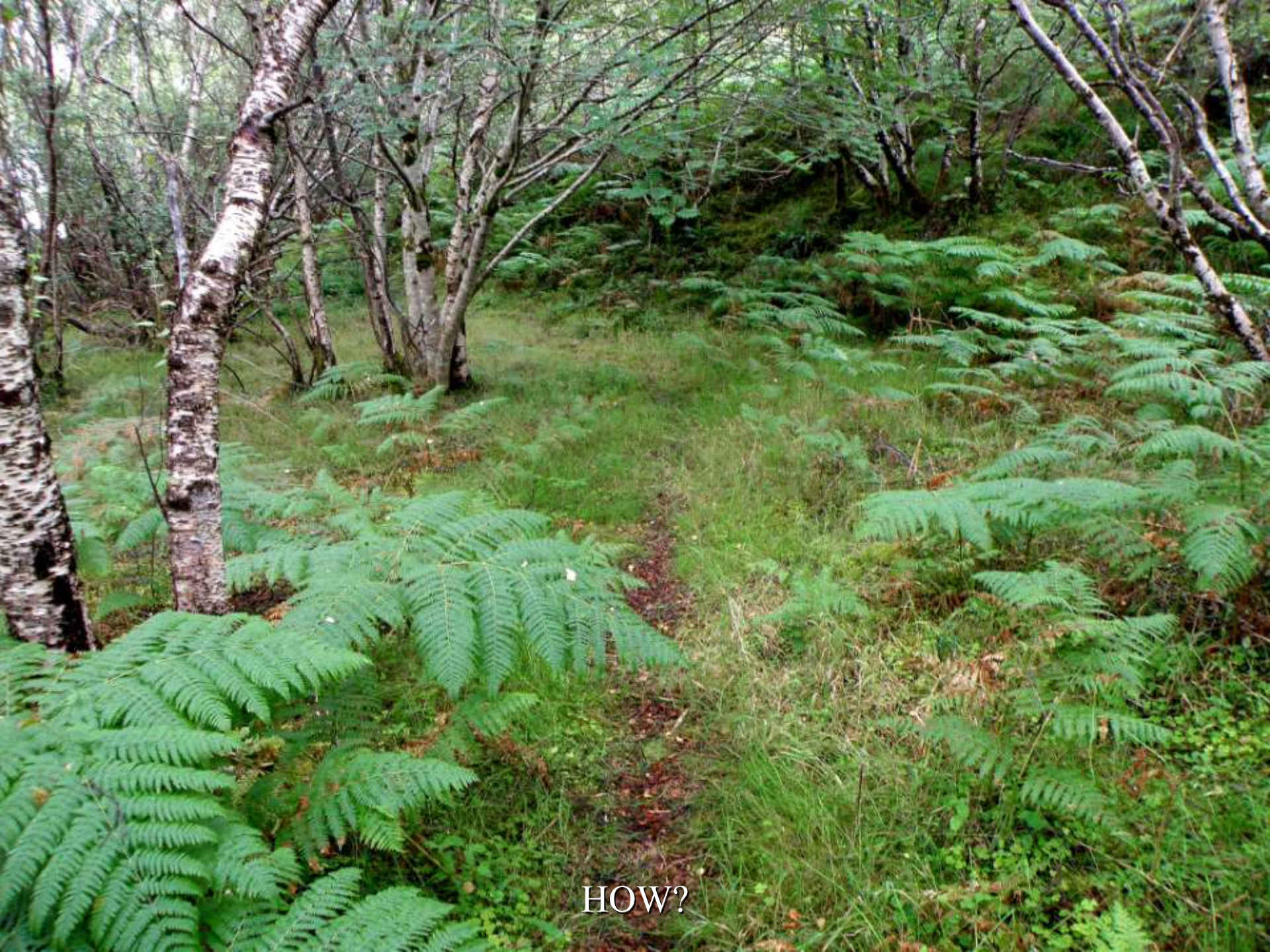


THEN



< 20 years

NOW



HOW?













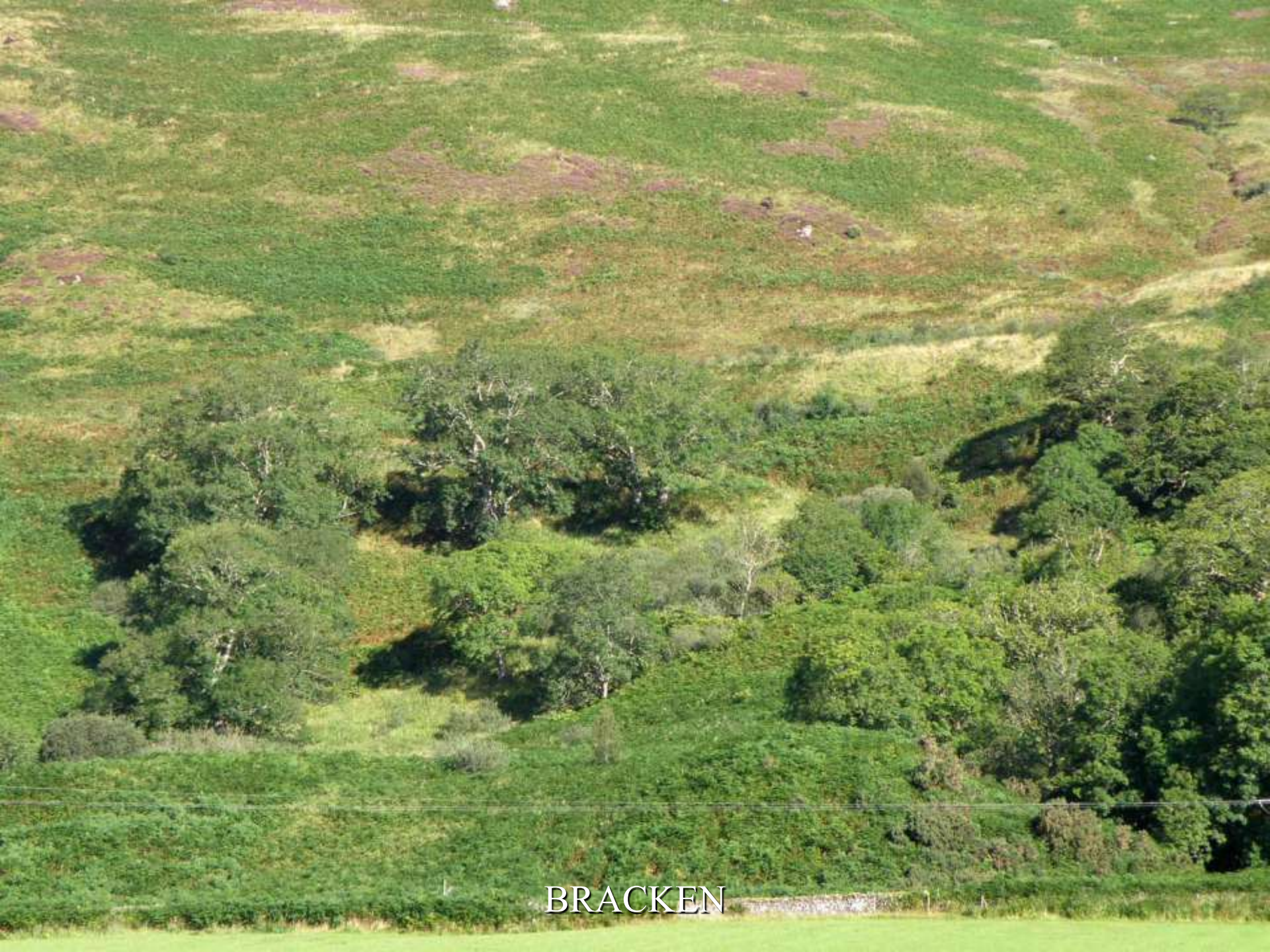




NOW

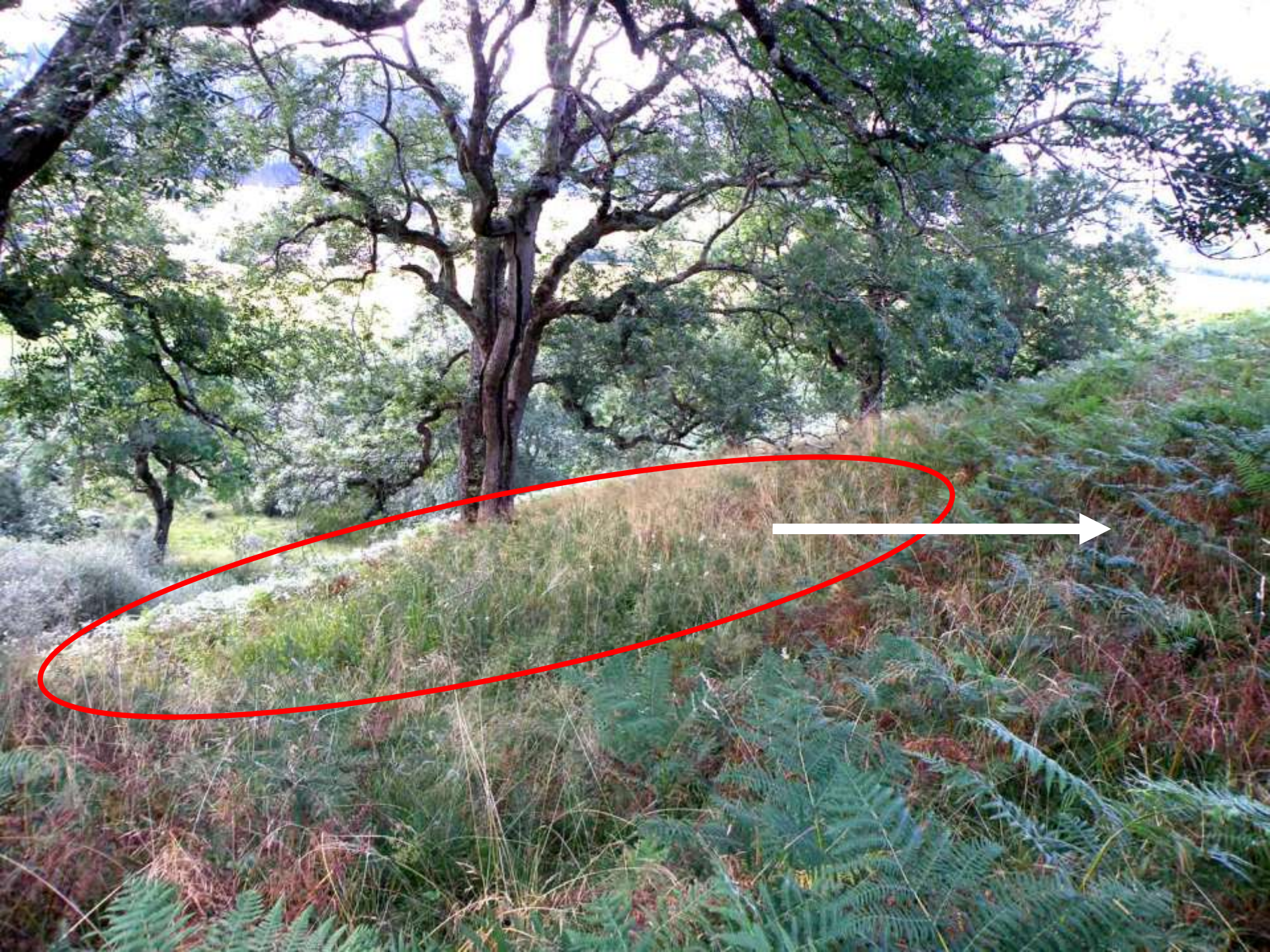


BRACKEN



BRACKEN









2006



2012



3-4th April 2013



5th April 2013



13th February 2015



Auchtertyre Hill

Welcome!

By agreement
with the owner
you are welcome
to walk here.

A new woodland
is being created
for your enjoyment
and that of future
generations, with
the help of the
Forestry
Authority.





Auchtertyre Hill

**A new woodland
is being created
for your enjoyment**



Auchtertyre Hill

**A new woodland
is being created
for your enjoyment**



Auchtertyre Hill

**A new woodland
is being created
for your enjoyment**

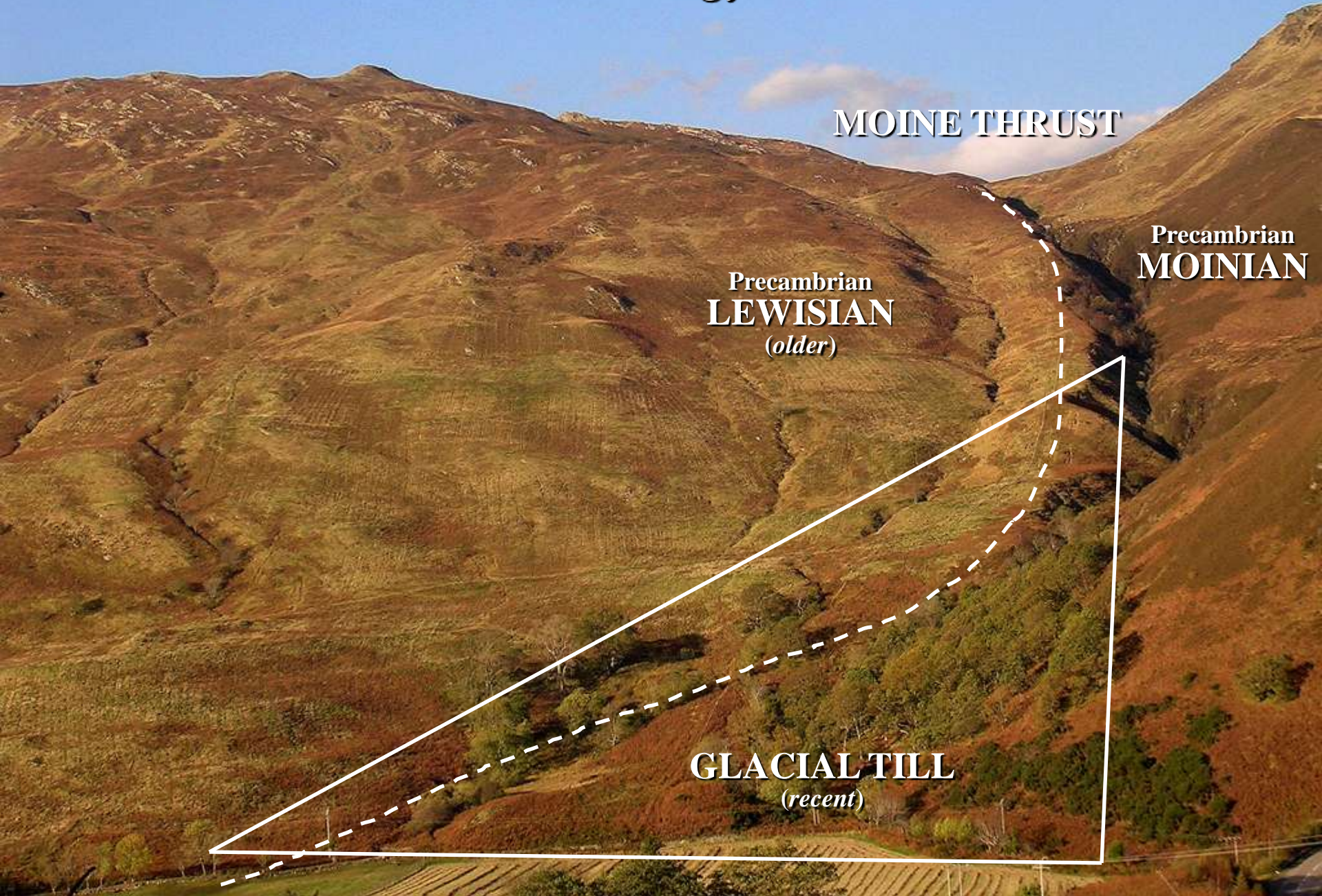
Geology

MOINE THRUST

Precambrian
LEWISIAN
(older)

Precambrian
MOINIAN

GLACIAL TILL
(recent)

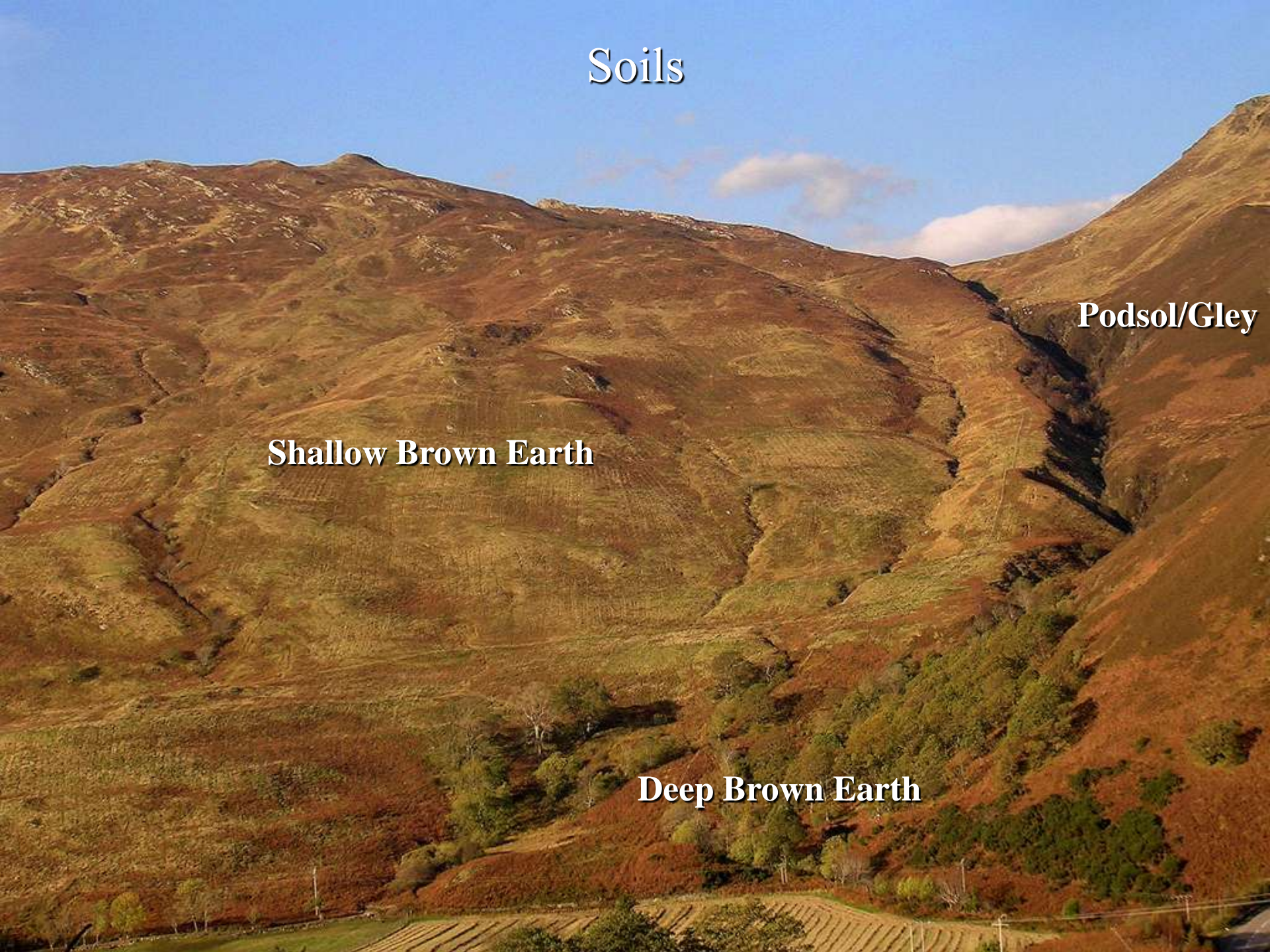


Soils

Podsol/Gley

Shallow Brown Earth

Deep Brown Earth



Vegetation

No Trees

No Trees

No Trees

No Trees

Natural Regen.

Natural Regen.

Natural Regen.

Woodland

Woodland





**Failed
Planting**

**Failed
Planting**

**Failed
Planting**

Regen.

Regen.

Regen.

2005



2010



2012



LEWISIAN
grassland

MOINIAN
moorland

GLACIAL
woodland

3 distinct geo-/ecological zones



Arbuscular
(not much)

Ericoid + Arbuscular
(not much)

Ecto + Arbuscular
(plentiful, diverse)

3 distinct mycorrhizal zones

All Trees Are Mycorrhizal

Ectomycorrhizal (EcM)

Ash - Oak - Beech - Hazel - Pine
Birch - Chestnut - Willow - Larch - Spruce

Arbuscular mycorrhizal (AM)

Elm - Sycamore - Cherry - Birch - Willow - Lime
Horse Chestnut - Rowan - Holly - Hawthorn - Yew

Ericoid mycorrhizal

None (*Rhododendron ponticum*)

Non-mycorrhizal

None

So Are Most Woodland Understorey Plants

Arbuscular mycorrhizal (AM)

Poa trivialis - Lysimachia nummularia - Viola riviniana
Allium ursinum - Anemone nemorosa - Galanthus nivalis
Narcissus pseudonarcissus - Primula vulgaris - Carex spp.
Prunella vulgaris - Circaea lutetiana - Galeobdolon luteum
Rubus fruticosus - Glechoma hederacea - Oxalis acetosella
Teucrium scorodonia - Mercurialis perennis - Ajuga reptans
Hyacinthoides non-scripta - Pteridium aquilinum - Holcus mollis

Ericoid mycorrhizal

Calluna vulgaris - Erica spp. - Vaccinium spp.

Non-mycorrhizal

Silene dioica - Stellaria holostea



+



Welcome!

By agreement with the owner you are welcome to walk here.

A new woodland is being created for your enjoyment and that of future generations, with the help of the Forestry Authority.




Forestry Authority
Forestry Commission



A good idea?



Auchtertyre Hill

A Great Place for Learning



2007



2007



2016



2016



SHARED MYCORRHIZA? – NURSERY?



SHARED MYCORRHIZA? – NURSERY?



Learn, Then Think Before You Plant



and some poor little saplings

Schist + Thin Mud & Rubble + Tubes = Woodland?
^



WOODLAND



Nobody's there.



Nobody digs.



Nobody ploughs.



Nobody fertilises.



Nobody sprays.



Yet it works!



WE may plough the fields and scatter ...



... but Nature doesn't.



“There are only a few hundred species of *tree* on the planet, maybe a thousand, but *forests* house millions of other species, and that diversity is what stabilises the systems.” – Kirsten Marhaver



BIODIVERSITY STABILISES ECOSYSTEMS



“The wild is self-creating, self-maintaining, self-propagating and self-reliant.” – Gary Snyder, 2006
[4 Billion years or so!]



BIODIVERSITY STABILISES ECOSYSTEMS



INTERFERENCE IMPOVERISHES ECOSYSTEMS



FERTILISER IMPOVERISHES AGRI-ECOSYSTEMS



FERTILISER IMPOVERISHES NATURAL ECOSYSTEMS



BIODIVERSITY MAINTAINS FERTILITY AUTOMATICALLY



FERTILITY?

Understand Ecology

Permit, Encourage & Maintain Biodiversity



**"But this landscape is
already impoverished &
it lacks biodiversity."**

WHAT ARE WE GOING TO DO NOW?



The END



• Sir J.W. Merryweather R.A. *Epitaph to Naïve Countryside Management* •