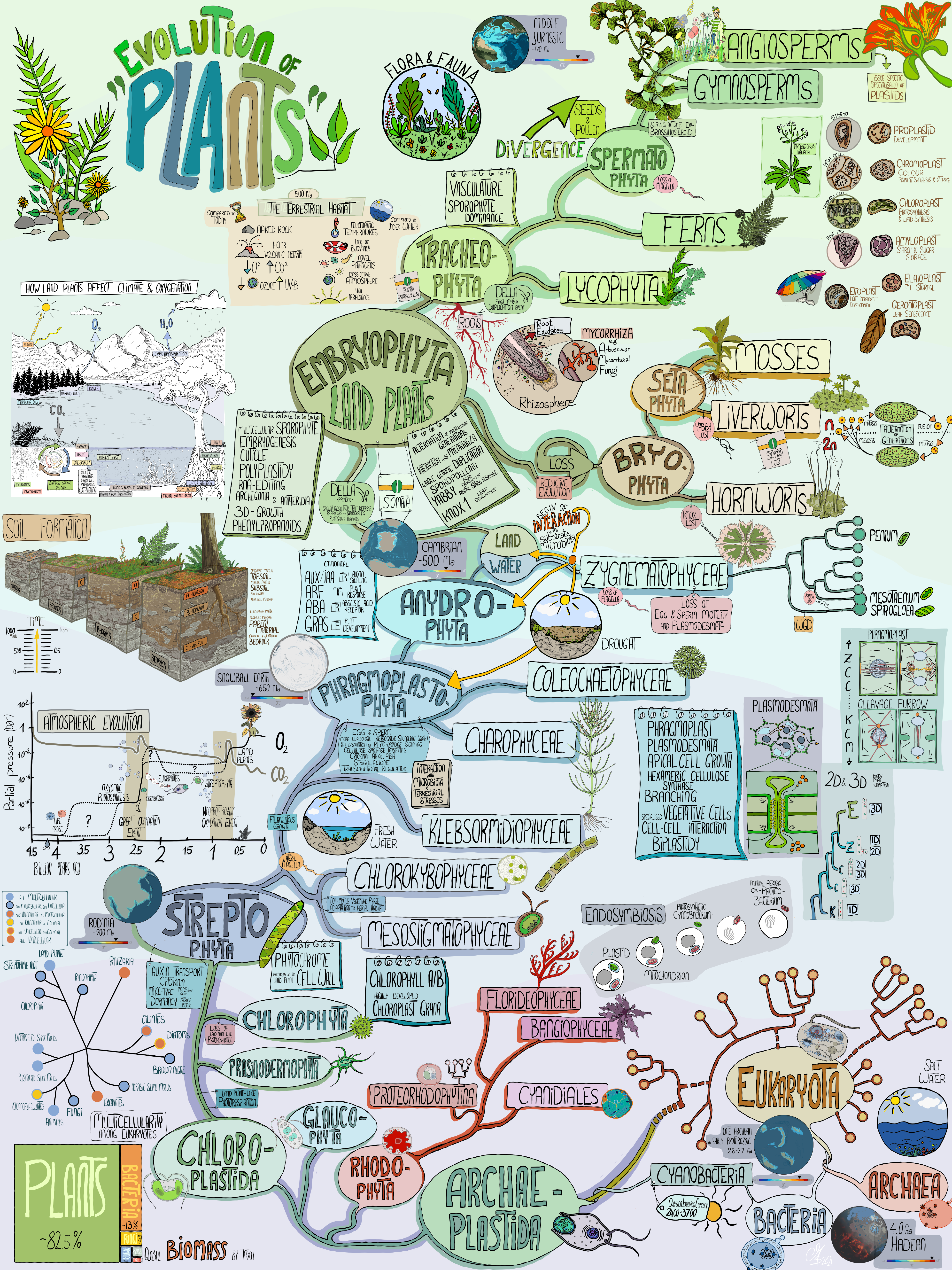
EVOLUTION OF "PLANTS"



FLORA & FAUNA

MIDDLE JURASSIC
~170 Ma

500 Ma

THE TERRESTRIAL HABITAT

COMPARED TO TODAY
- NAKED ROCK
- HIGHER VOLCANIC ACTIVITY
- ↓O² ↑CO²
- ↓ OZONE ↑ UV-B

COMPARED TO UNDER WATER
- FLUCTUATING TEMPERATURES
- LACK OF BUOYANCY
- NOVEL PATHOGENS
- DESSICATIVE ATMOSPHERE
- HIGH IRRADIANCE

HOW LAND PLANTS AFFECT CLIMATE & OXYGENATION

O_2
H_2O
CO_2
ALBEDO
EVAPOTRANSPIRATION
RUNOFF
OVERLAND FLOW
MEANDERING STYLE
EROSION
UPLIFT
SOIL STABILITY
NUTRIENT INPUT
SILICATE, CARBONATE, OXYDATIVE, PHOSPHOROUS WEATHERING
EXUDATES
MYCORRHIZA
BIOMASS STORAGE ON LAND
ORGANIC C BURIAL IN SEDIMENTS
ORGANIC CARBON PRESERVATION
LITTER
RESPIRATION
ACIDS
WATER RETENTION
CLAY FACTORY
MINERAL SURFACE AREA

SOIL FORMATION

ORGANIC MATTER
TOPSOIL
MINERAL PARTICLES
SUBSOIL
RICH IN CLAY
INSOLUBLE MINERALS
LITTLE ORGANIC MATTER
DISSOLVED MINERALS
PARENT MATERIAL
CRACKED & WEATHERED
BEDROCK

A-HORIZON
B-HORIZON
C-HORIZON
A
C
BEDROCK

TIME
1000 YEARS — 1 cm
500 — 0.5
0 — 0

ATMOSPHERIC EVOLUTION

Partial pressure (bar): 10^2, 1, 10^{-2}, 10^{-4}, 10^{-6}, 10^{-8}

BILLION YEARS AGO: 4.5, 4, 3.5, 3, 2.5, 2, 1.5, 1, 0.5, 0

WATER
LIFE AROSE
?
OXYGENIC PHOTOSYNTHESIS
O_2
GREAT OXYDATION EVENT
CYANOBACTERIA
EUKARYOTES
?
STREPTOPHYTA
NEOPROTEROZOIC OXYDATION EVENT
LAND PLANTS
O_2
CO_2

DIVERGENCE
SEEDS & POLLEN

ANGIOSPERMS
→ TISSUE SPECIFIC SPECIALISATION OF PLASTIDS

GYMNOSPERMS

STRIGOLACTONE D14
BRASSINOSTEROID

SPERMATO PHYTA
LOSS OF FLAGELLA

ARABIDOPSIS THALIANA

EMBRYO — PROPLASTID: DEVELOPMENT
PETAL CELLS — CHROMOPLAST: COLOUR, PIGMENT SYNTHESIS & STORAGE
MESOPHYLL CELLS — CHLOROPLAST: PHOTOSYNTHESIS & LIPID SYNTHESIS
ROOT TIPS — AMYLOPLAST: STARCH & SUGAR STORAGE
ETIOPLAST: LIGHT DEPENDENT DEVELOPMENT
ELAIOPLAST: FAT STORAGE
GERONTOPLAST: LEAF SENESCENCE

VASCULATURE
SPOROPHYTE DOMINANCE

TRACHEO-PHYTA
STOMATA PARTIALLY LOST

FERNS

LYCOPHYTA

DELLA
FIRST MAJOR DUPLICATION EVENT

ROOTS

Root Exudates
MYCORRHIZA
e.g. Arbuscular Mycorrhizal Fungi
Rhizosphere

EMBRYOPHYTA
LAND PLANTS

MULTICELLULAR SPOROPHYTE
EMBRYOGENESIS
CUTICLE
POLYPLASTIDY
RNA-EDITING
ARCHEGONIA & ANTHERIDIA
3D-GROWTH
PHENYLPROPANOIDS

ALTERNATION OF MULTICELLULAR GENERATIONS
INTERACTION WITH MYCORRHIZA
WHOLE GENOME DUPLICATION
SPOROPOLLENIN
YABBY — ORGAN DEVELOPMENT, ABIOTIC STRESS RESPONSE
KNOX 1 — LEAF DEVELOPMENT

DELLA
· PROTEINS ·
GROWTH REGULATOR THAT REPRESS RESPONSES TO GIBBERELINS
PLANT GROWTH HORMONES

STOMATA

SETA PHYTA
MOSSES
LIVERWORTS
YABBY LOST
STOMATA LOST

n
2n
MITOSIS
MEIOSIS
ALTERNATION OF GENERATIONS
FUSION
MITOSIS

LOSS
REDUCTIVE EVOLUTION

BRYO. PHYTA
HORNWORTS
KNOX I LOST

CAMBRIAN
~500 Ma

CANONICAL
- AUX/IAA — TR — AUXIN SIGALING
- ARF — TF — AUXIN RESPONSE
- ABA — TR — ABSCISIC ACID RECEPTOR
- GRAS — TF — PLANT DEVELOPMENT

LAND
WATER
BEGIN OF INTERACTION with substrate microbiota

ZYGNEMATOPHYCEAE
LOSS OF FLAGELLA
LOSS OF EGG & SPERM MOTILITY AND PLASMODESMATA
PENIUM
MESOTAENIUM
SPIROGLOEA
YABBY LOST
WGD

ANYDRO-PHYTA

DROUGHT

SNOWBALL EARTH
~650 Ma

PHRAGMOPLASTO-PHYTA

EGG & SPERM
MORE ELABORATE RETROGADE SIGNALING (GUN1)
& ELABORATION OF PHYTOHORMONE SIGNALING
CELLULOSE SYNTHASE ROSETTES
CYTOKININ: AHKs, ABA
STRIGOLACTONE
TRANSCRIPTIONAL REGULATION

INTERACTION WITH MICROBIOTA & TERRESTRIAL STRESSES

COLEOCHAETOPHYCEAE

CHAROPHYCEAE

PHRAGMOPLAST
PLASMODESMATA
APICAL CELL GROWTH
HEXAMERIC CELLULOSE SYNTHASE
BRANCHING
SPECIALISED VEGETATIVE CELLS
CELL-CELL INTERACTION
BIPLASTIDY

PLASMODESMATA

PHRAGMOPLAST
CLEAVAGE FURROW
↑ Z C C ⋯ K C M ↓

2D & 3D
BODY PLAN FORMATION
E — 3D
Z — 1D, 2D
C — 2D, 3D
C — 3D
K — 1D

FILAMENTOUS GROWTH
FRESH WATER

KLEBSORMIDIOPHYCEAE

LATERAL FLAGELLA

CHLOROKYBOPHYCEAE
NON-MOTILE VEGETATIVE PHASE
ADAPTATION TO AERIAL HABITAT

MESOSTIGMATOPHYCEAE

STREPTO PHYTA

RODINIA
~900 Ma

AUXIN TRANSPORT
CYTOKININ
MIKC-TYPE MADS box GENES
DORMANCY
STORAGE PROTEINS

PHYTOCHROME
PRECURSOR OF THE LAND PLANT CELL WALL

CHLOROPHYLL A/B
HIGHLY DEVELOPED CHLOROPLAST GRANA

CHLOROPHYTA
LOSS OF LAND PLANT-LIKE PHOTORESPIRATION

PRASINODERMOPHYTA
LAND PLANT-LIKE PHOTORESPIRATION

GLAUCO-PHYTA

CHLORO-PLASTIDA

RHODO-PHYTA
PROTEORHODOPHYTINA
FLORIDEOPHYCEAE
BANGIOPHYCEAE
CYANIDIALES

ARCHAE-PLASTIDA

ENDOSYMBIOSIS
PLASTID
MITOCHONDRION
PHOTOSYNTHETIC CYANOBACTERIUM
FACULTATIVE AEROBIC α-PROTEO-BACTERIUM

EUKARYOTA
LATE ARCHEAN TO EARLY PROTEROZOIC
2.8-2.2 Ga
SALT WATER

CYANOBACTERIA
OXYGEN EVOLVING COMPLEX
2400-3700

BACTERIA
ARCHAEA
4.0 Ga
HADEAN

COLD — 0°C — HOT

MULTICELLULARITY AMONG EUKARYOTES
- ● ALL MULTICELLULAR
- ● SOME MULTICELLULAR, SOME UNICELLULAR
- ● MOST UNICELLULAR, FEW MULTICELLULAR
- ● ALL UNICELLULAR OR COLONIAL
- ● MOST UNICELLULAR, FEW COLONIAL
- ● ALL UNICELLULAR

LAND PLANTS
STREPTOPHYTE ALGAE
CHLOROPHYTA
RHODOPHYTA
RHIZARIA
CILIATES
DIATOMS
BROWN ALGAE
ACRASIC SLIME MOLDS
EXCAVATES
FUNGI
ANIMALS
CHOANOFLAGELLATES
PLASMODIAL SLIME MOLDS
DICTYOSTELID SLIME MOLDS

GLOBAL BIOMASS BY TAXA

PLANTS	~82.5%
BACTERIA	~13%
FUNGI	~2.2%
ARCHAEA	~1.3%
PROTISTS	
ANIMALS	

2021