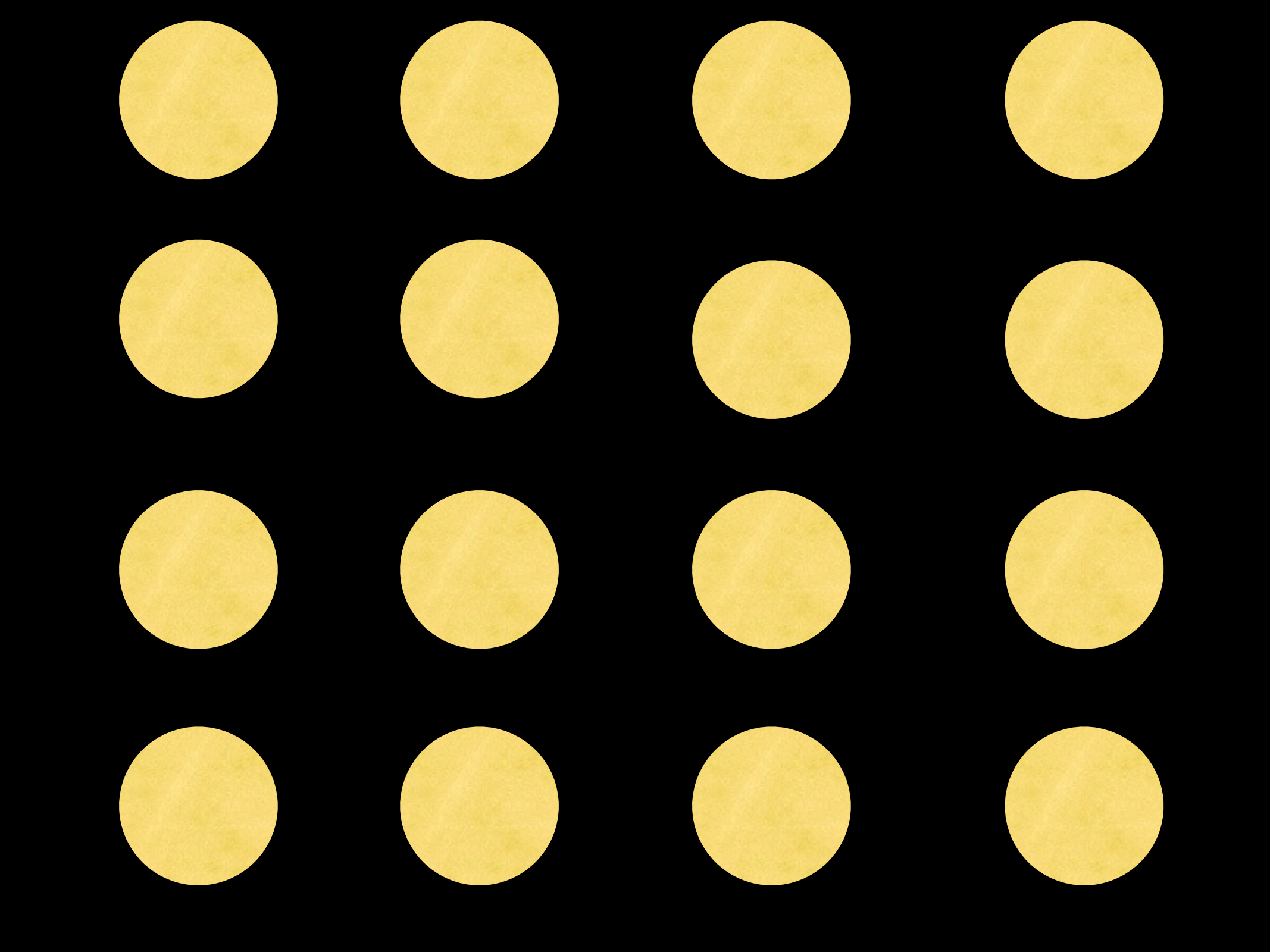
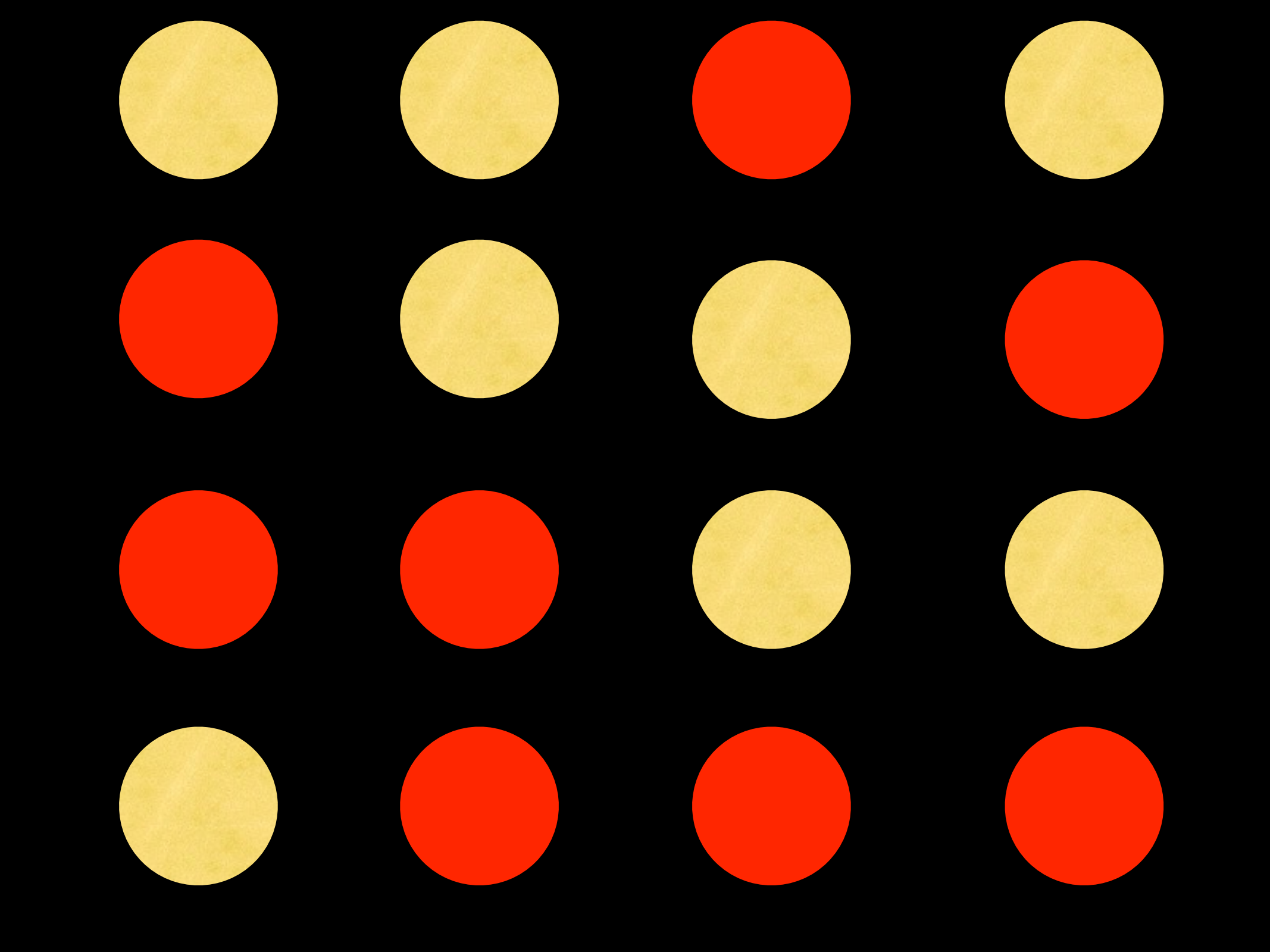
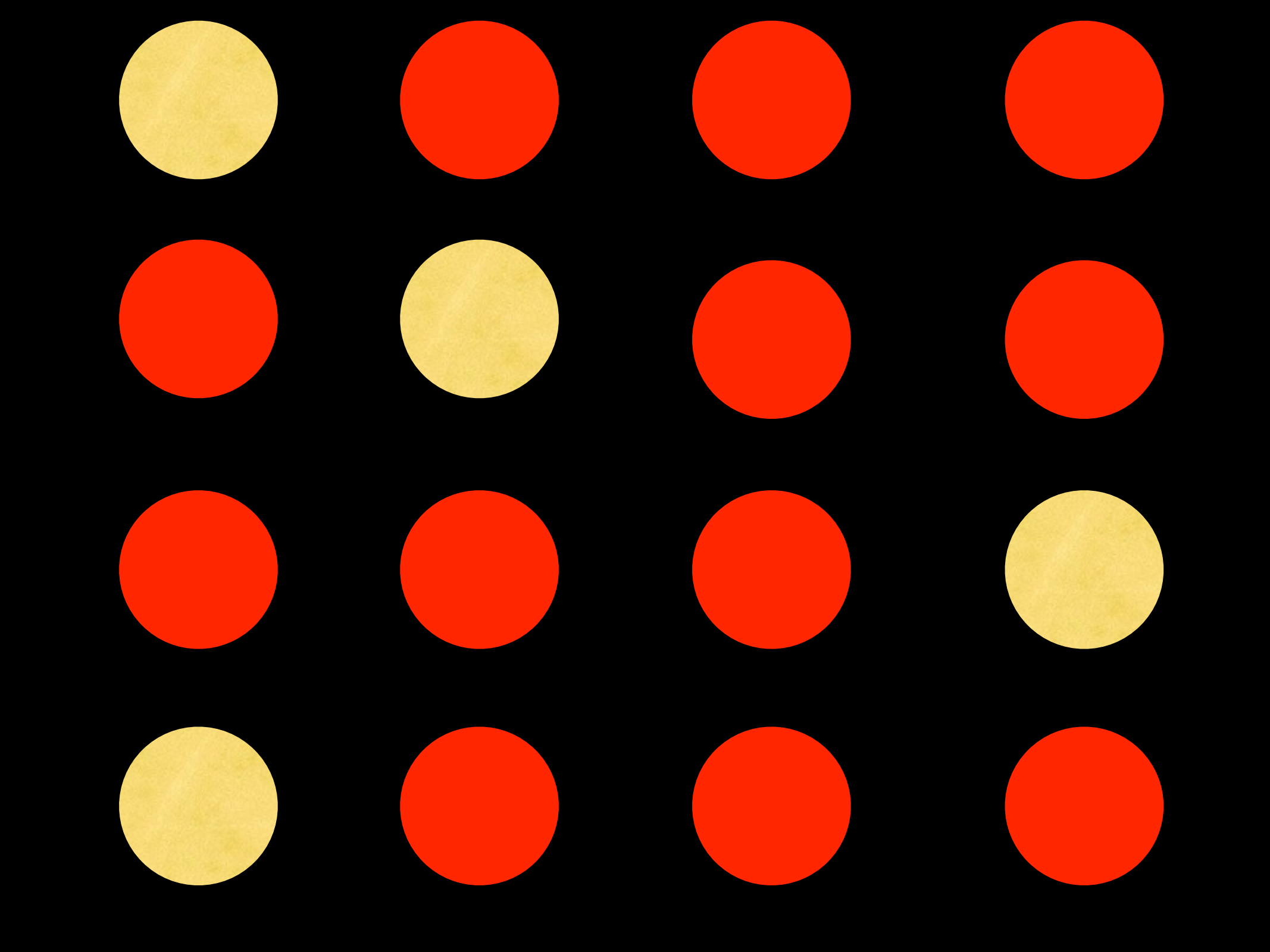
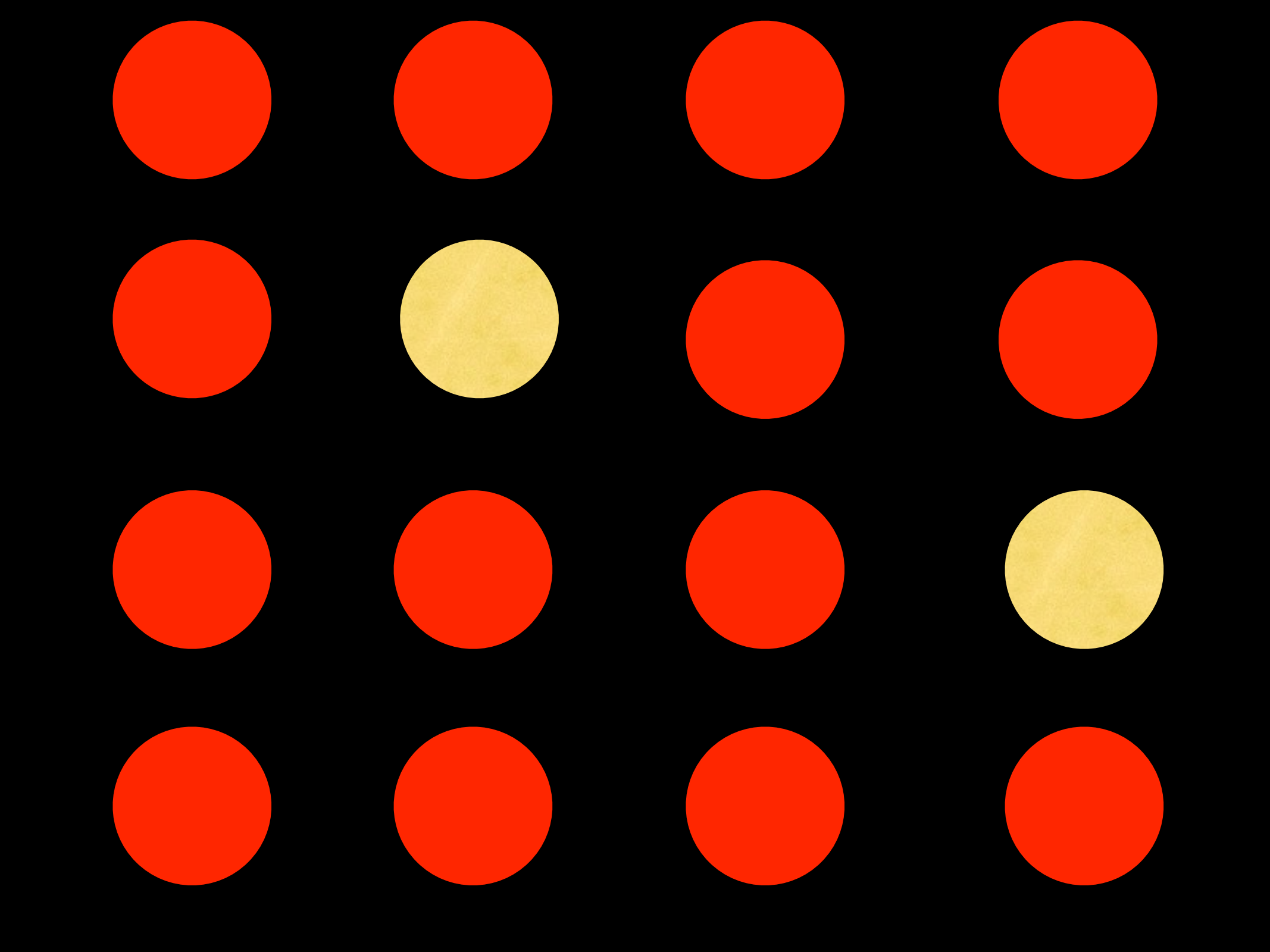
Isotopic Dating

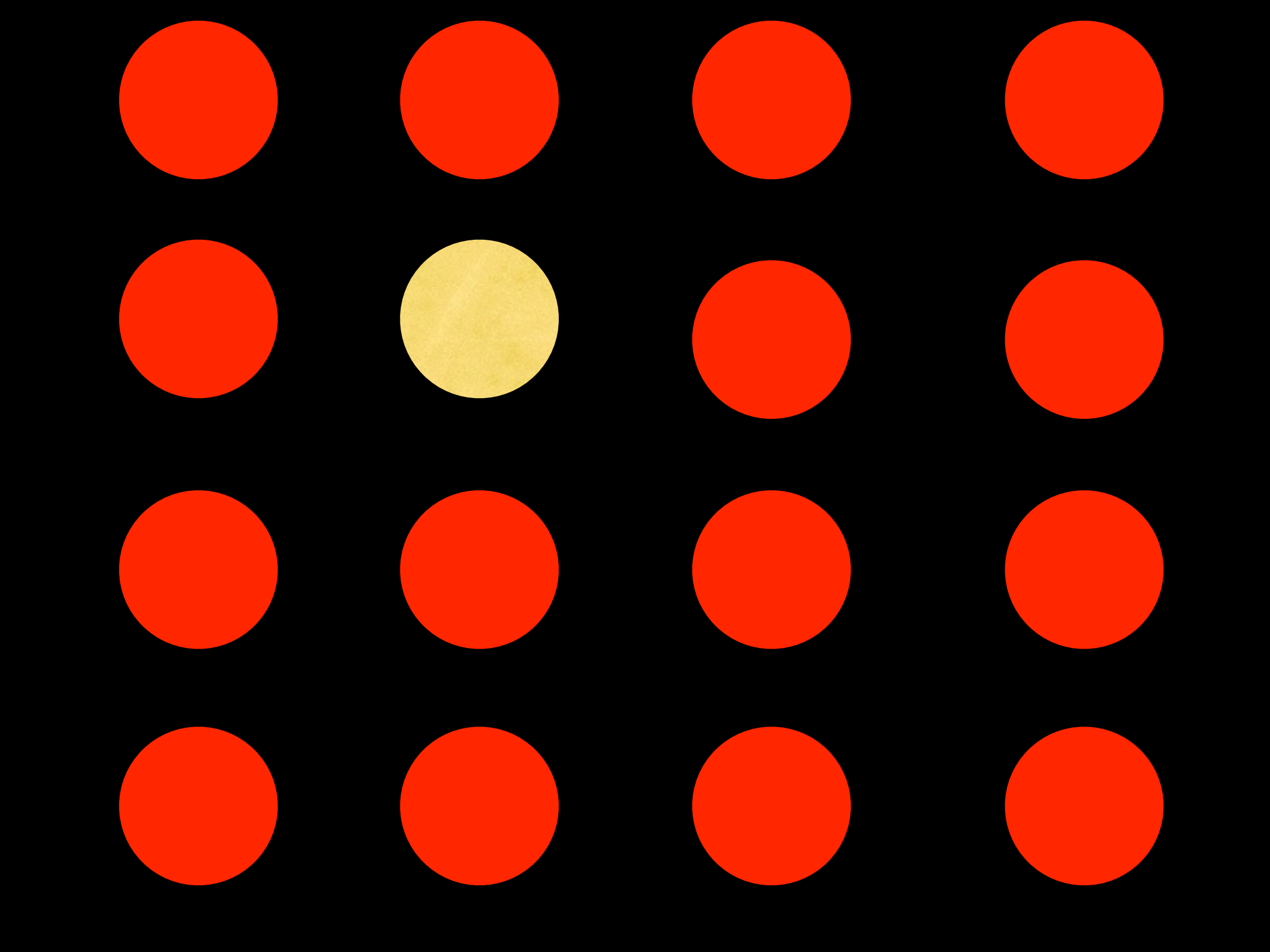
Visualizing radioactive decay one half life at a time











An unweathered rock that contains potassium feldspar is chemically analyzed.

The rock contains 1 atom of radioactive K40 for every 3 atoms of the stable daughter product Ar40 found in the rock.

The half life of the K-Ar decay series is 1.25 billion years.

How old is the rock?

Same problem, but there is one K40 atom for every seven atoms of Ar40. Half life = 1.25 Ga

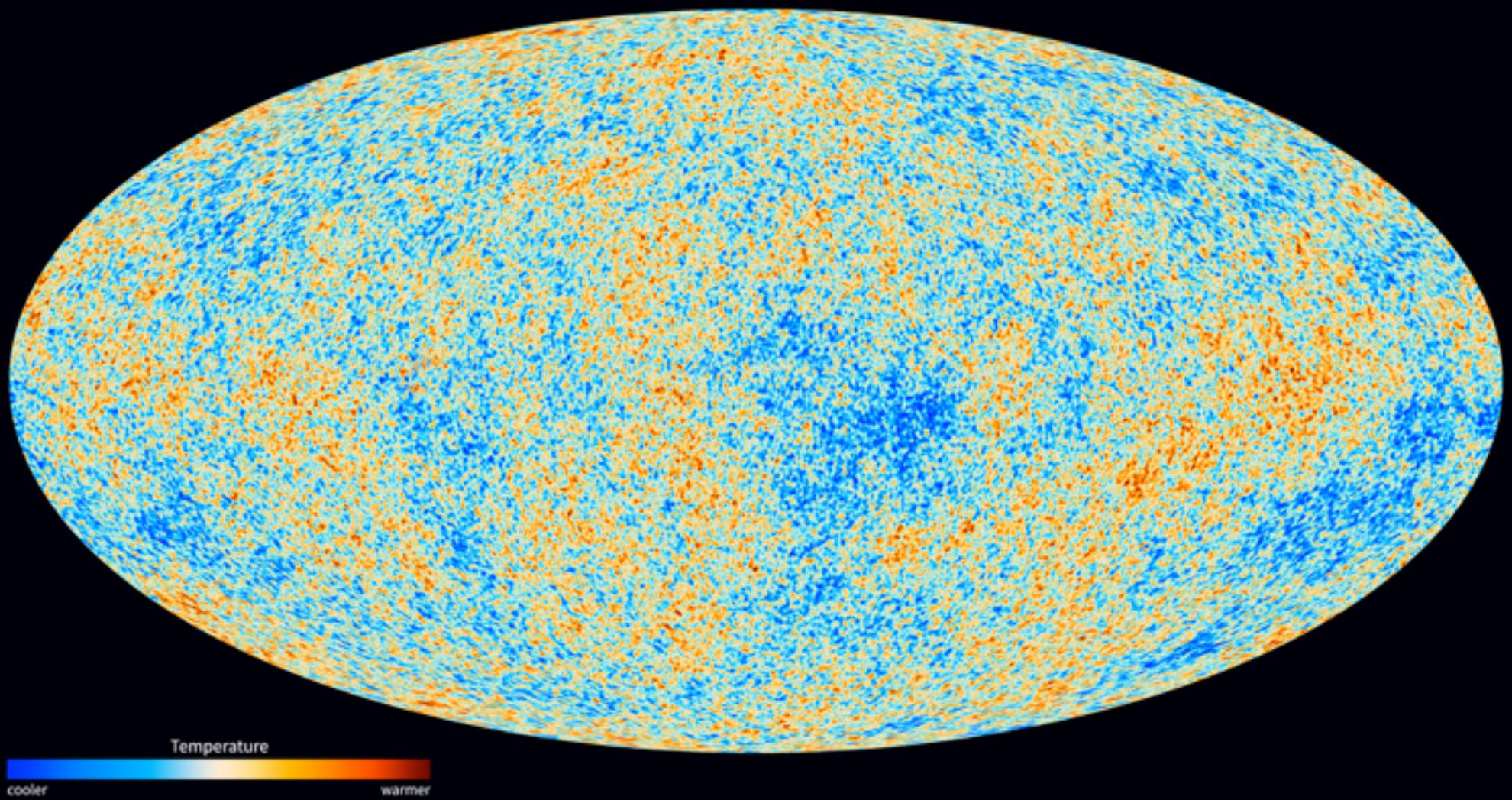
How old is it?

What science currently indicates about the age of various things of interest to us in this course

13.82 billion ± ~50 million years: current best age of the Universe
(time since the beginning of space-time; Big Bang)

Big Bang + 1 second: hydrogen nuclei begin to form

Big Bang + 370,000 years: universe cools to allow protons to capture electrons, and space became transparent to light



The oldest light in the universe, emitted 370,000 years after the Big Bang and detected by the ESA's Planck space telescope.

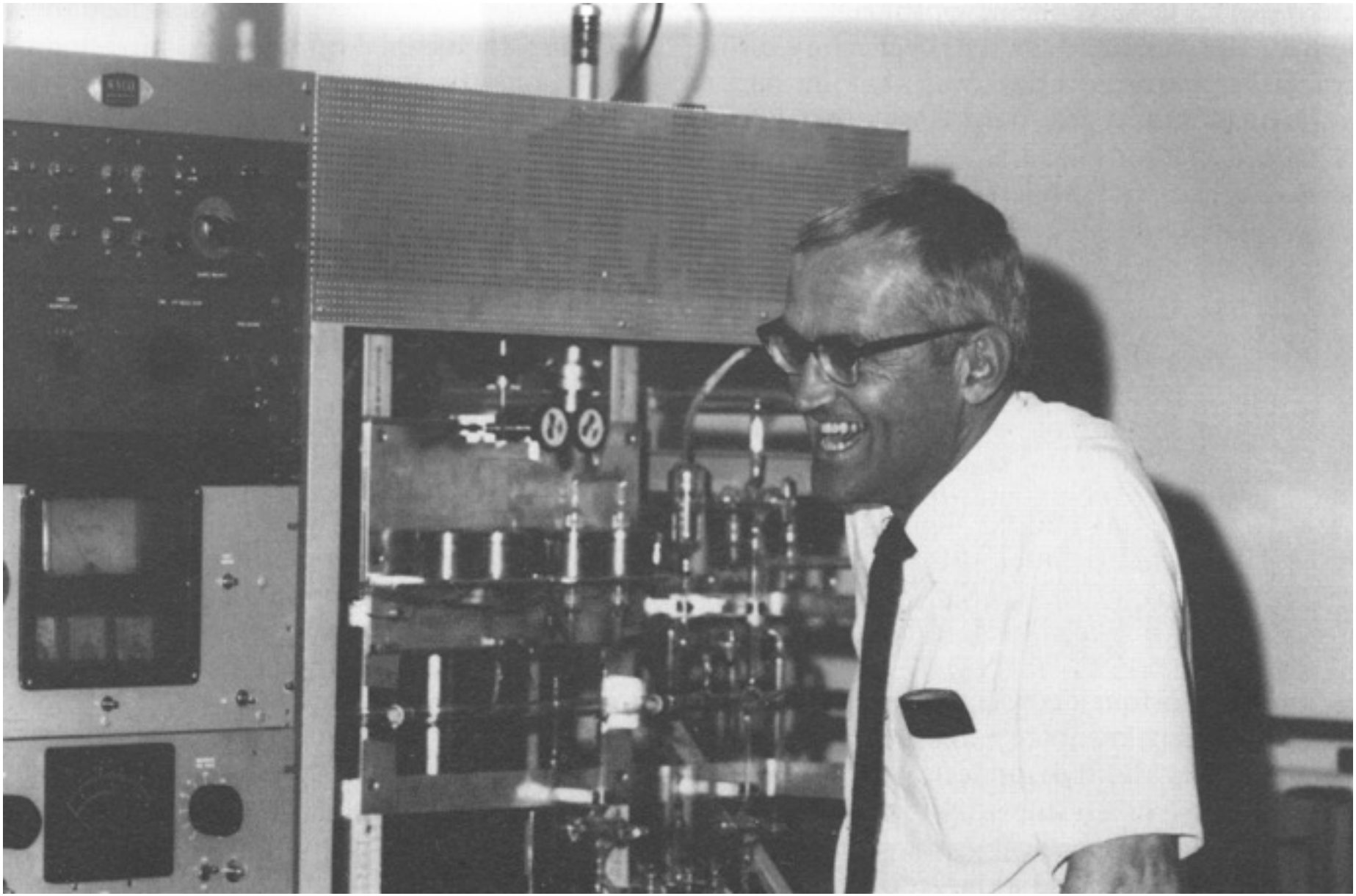
~13.4 billion years ago: the first stars begin to form

Between ~13.4 billion and ~4.6 billion years ago: heavier atoms created by nucleosynthesis in stars, spread through space by supernova explosion

4.566 billion years ago: Solar nebula cools, allowing solid matter to condense

G.B. Dalrymple, 2001, The age of the Earth in the twentieth century -- a problem (mostly) solved: Geological Society, London, Special Publication 190, p. 205-221.

4.54 billion ± 50 million years:
current best age of the Earth



Claire Patterson, who in 1956 used Arthur Holmes method (as modified by Harrison Brown) to date Earth at 4,550±70 million years.

4.51/4.54 (?) billion years: formation of the Moon

G.B. Dalrymple, 2001, The age of the Earth in the twentieth century -- a problem (mostly) solved: Geological Society, London, Special Publication 190, p. 205-221.

3.8 billion years: oldest (reasonable) chemical evidence of life on Earth (still not a consensus)

“Evolution” means change over time.

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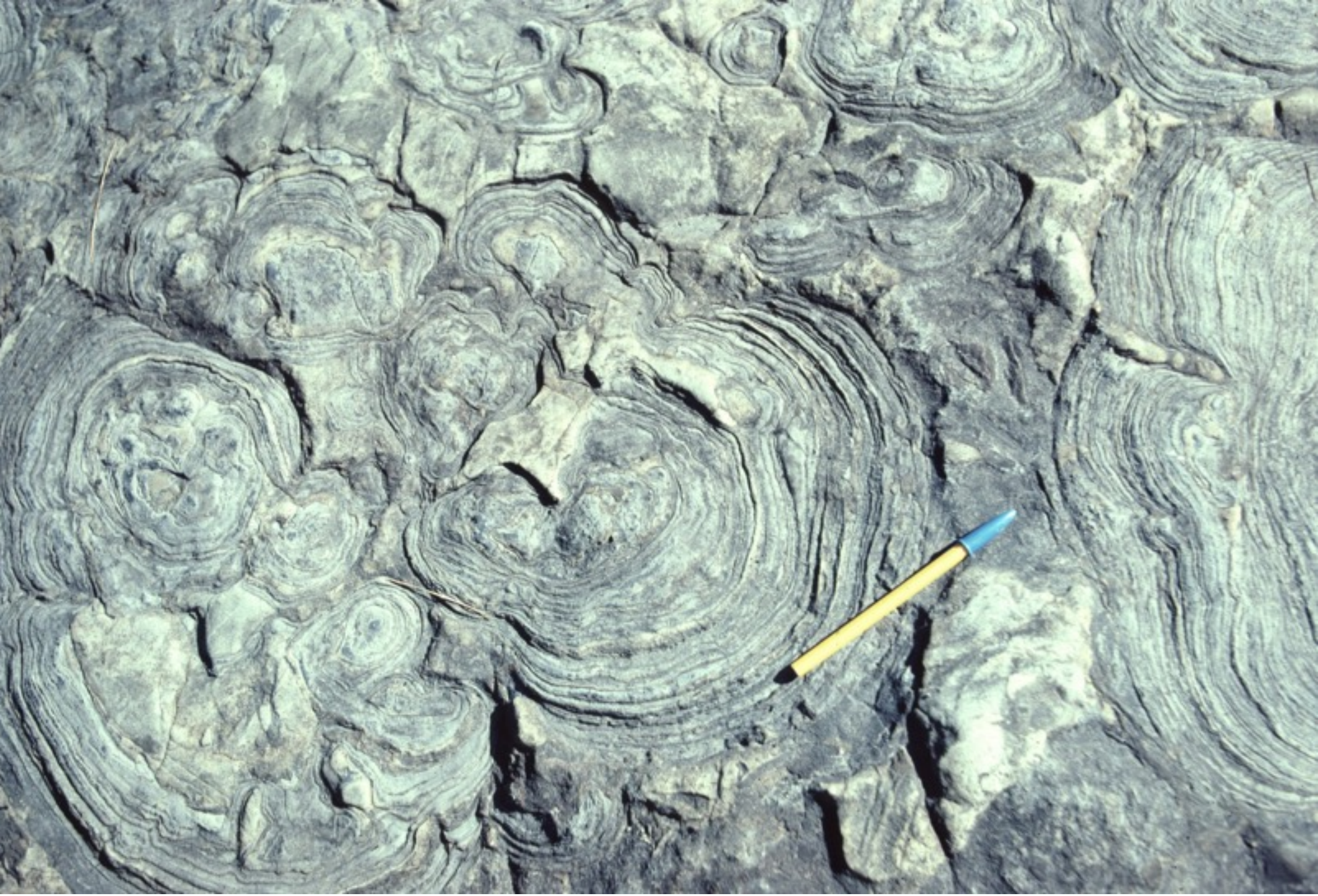
Change happens.

"Evolution" means change over time.

Change happens.

Biological evolution is observed in the lab and in the fossil record.

~3.5 billion years: oldest fossil cyanobacteria



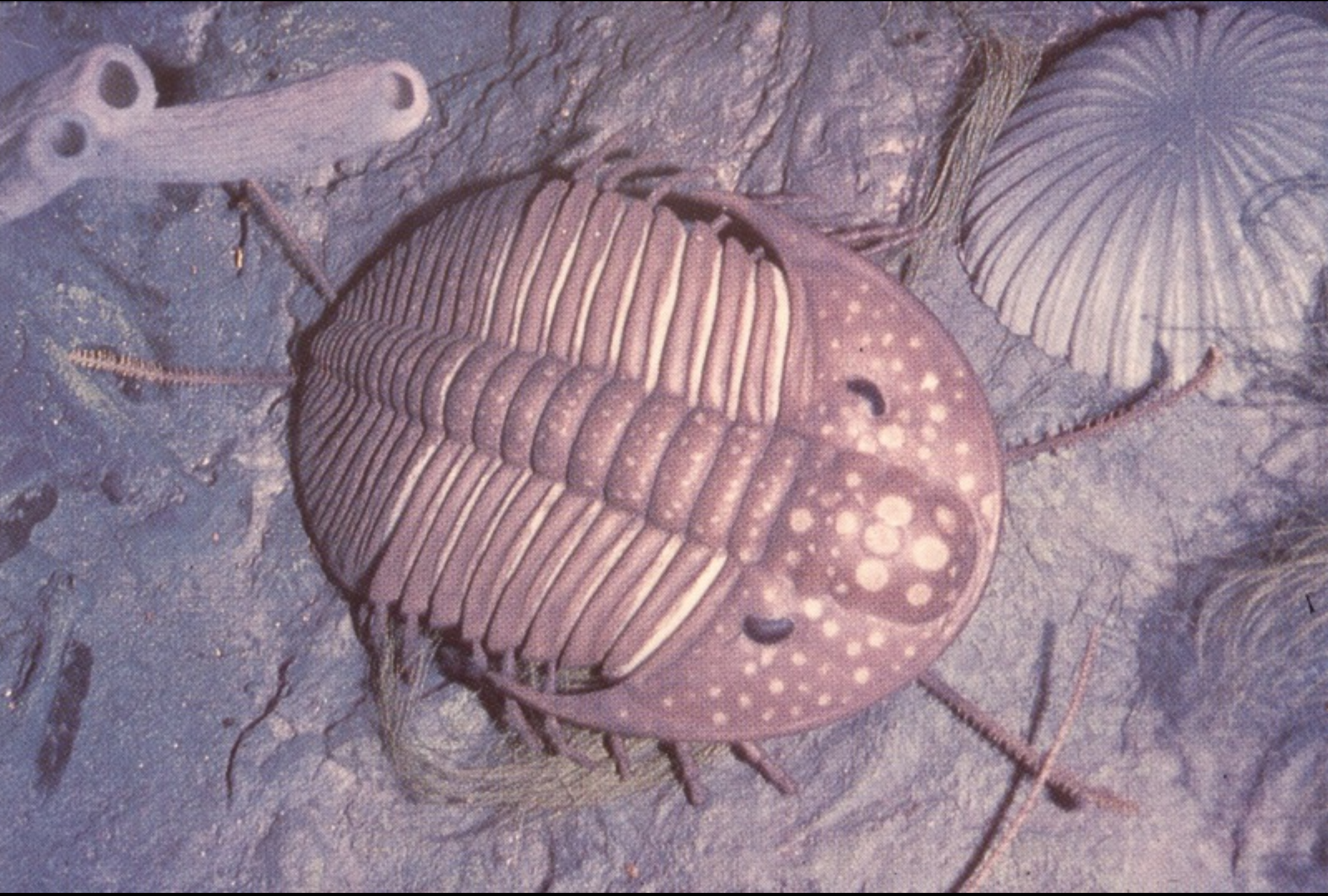
Algal stromatolites, from at least 2 Ga to the present.

~2 billion years: unambiguous fossil bacteria, from the Gunflint Chert of Canada

1.8 billion years:
oldest unambiguous
eukariotic organisms (algal
protists called *acritarchs*) with
cellular nuclei and
chromosomes with DNA

The fossil record includes some species that are no longer alive.

The fossil record indicates that new species have originated through changes in pre-existing species



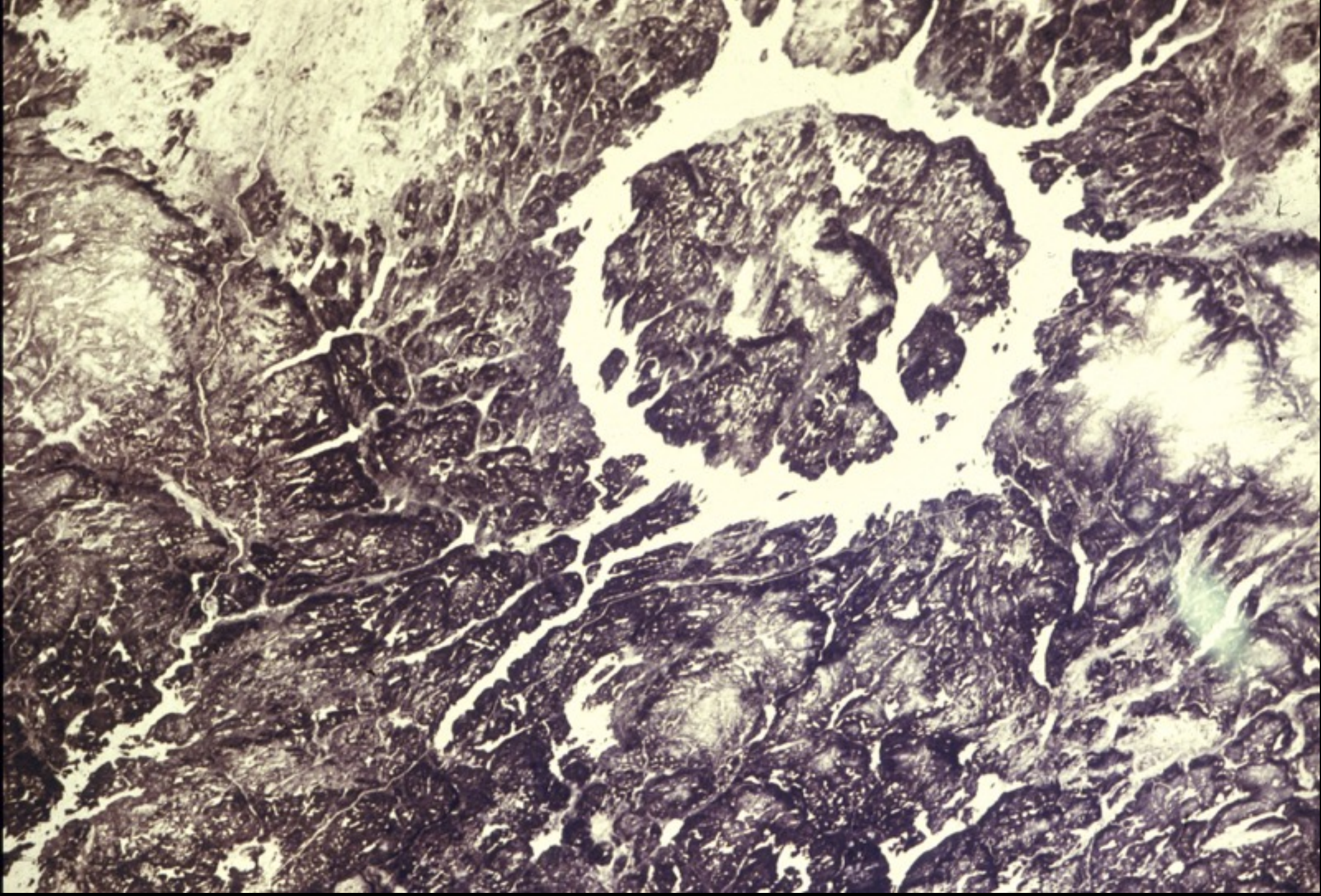
Artist's model of a trilobite; from ~542 Ma to ~245 Ma.

400 million year old cephalopod in Silurian dolomite

Theropod footprint from Glen Rose, Texas


VIRGINIA

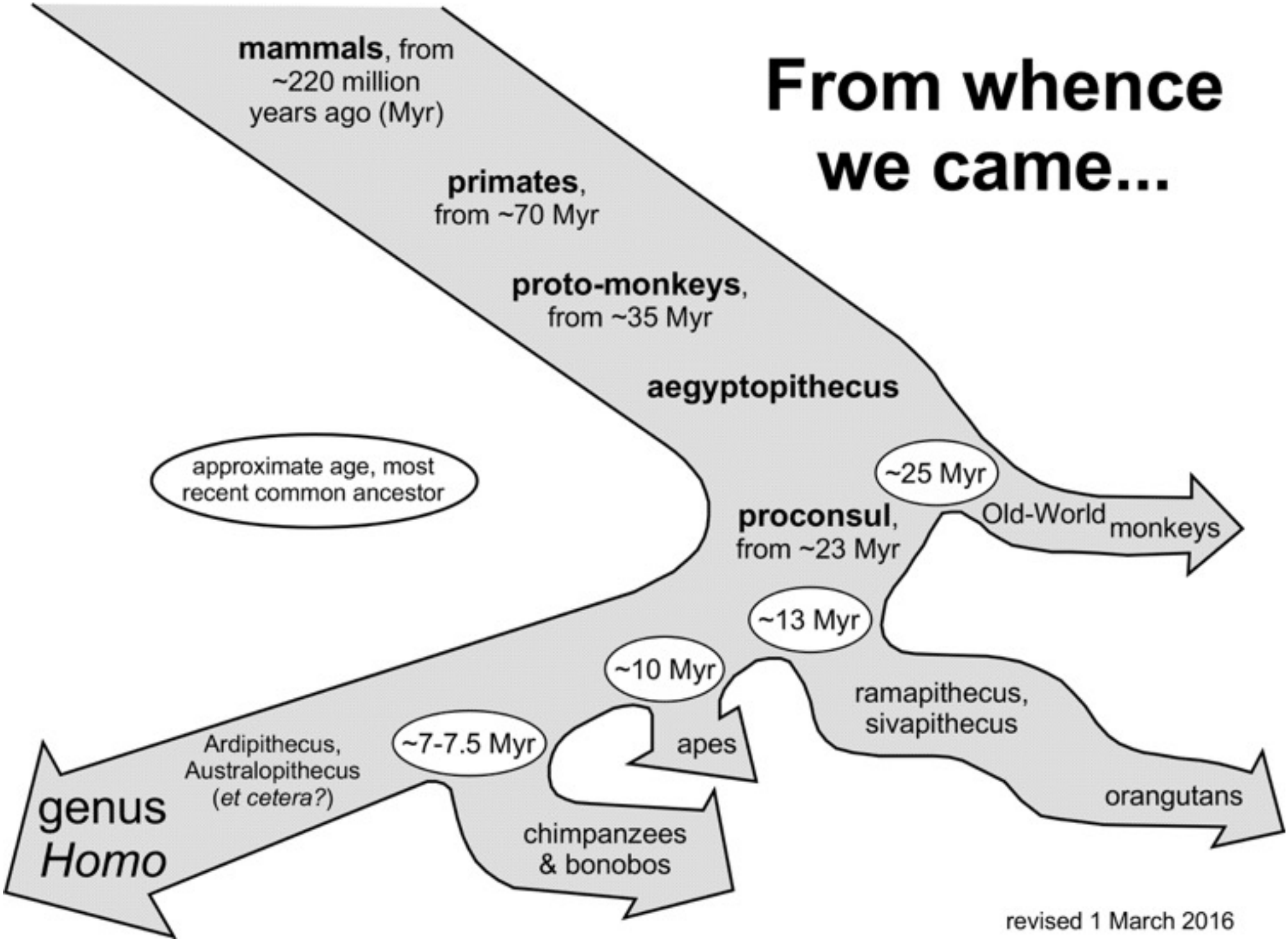
Fossils at Dinosaur National Monument, ~150 Ma



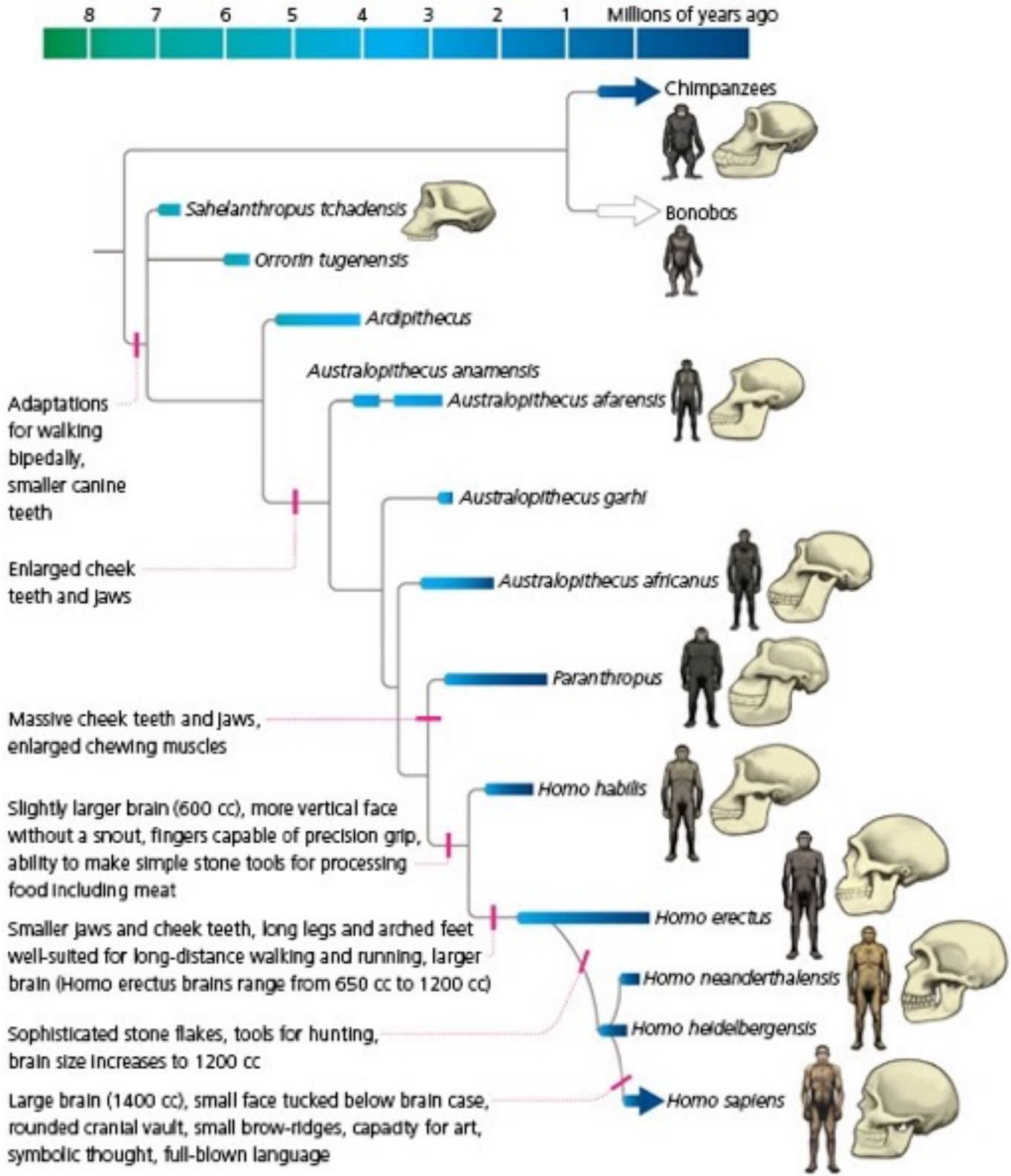
Manicouagan impact crater, Canada, ~200 Ma

Cretaceous-Tertiary boundary layer at Trinidad, Colorado

Summary of the fossil record relating specifically to humans


From whence we came...
mammals, from ~220 million years ago (Myr)
primates, from ~70 Myr
proto-monkeys, from ~35 Myr
aegyptopithecus
approximate age, most recent common ancestor
~25 Myr
Old-World monkeys
proconsul, from ~23 Myr
~13 Myr
~10 Myr
ramapithecus, sivapithecus
apes
~7-7.5 Myr
Ardipithecus, Australopithecus (et cetera?)
orangutans
genus Homo
chimpanzees & bonobos
revised 1 March 2016

- Oldest mammal fossils: ~220 Ma
- Oldest primate fossils: ~70 Ma


8
7
6
5
4
3
2
1
Millions of years ago
Chimpanzees
Bonobos
Sahelanthropus tchadensis
Orrorin tugenensis
Ardipithecus
Australopithecus anamensis
Australopithecus afarensis
Adaptations for walking bipedally, smaller canine teeth
Australopithecus garhi
Enlarged cheek teeth and jaws
Australopithecus africanus
Paranthropus
Massive cheek teeth and jaws, enlarged chewing muscles
Homo habilis
Slightly larger brain (600 cc), more vertical face without a snout, fingers capable of precision grip, ability to make simple stone tools for processing food including meat
Homo erectus
Smaller jaws and cheek teeth, long legs and arched feet well-suited for long-distance walking and running, larger brain (Homo erectus brains range from 650 cc to 1200 cc)
Homo neanderthalensis
Homo heidelbergensis
Sophisticated stone flakes, tools for hunting, brain size increases to 1200 cc
Homo sapiens
Large brain (1400 cc), small face tucked below brain case, rounded cranial vault, small brow-ridges, capacity for art, symbolic thought, full-blown language

Homo habilis evolved from earlier forms ~2.5 Ma. Habilis had a significantly larger brain (600-800 cc), was an omnivore, and made Oldowan tools.

Homo ergaster evolved from earlier forms ~2 Ma. Ergaster had a larger brain (800 cc), had a human-like skeleton including an external nose, and made Acheulean tools.

Homo erectus evolved from earlier forms ~2 Ma. Erectus migrated throughout Africa and to Asia and Europe

Homo heidelbergensis originated in Africa. Some individuals migrated into Asia ~300-400 ka, and from them arose *Homo neanderthalensis* and the newly discovered Denisovians.

Homo sapiens is thought to have evolved from *Homo heidelbergensis* in Africa by ~200 ka.

The earliest known *Homo sapiens* fossils are ~195,000 years old, from the Kibish River area of southern Ethiopia.

Ian McDougall et al., 2005, Stratigraphic placement and age of modern Humans from Kibish, Ethiopia: Nature, v. 433, p. 733-736.

Fossil remnants of *Homo sapiens* date from ~200 ka

- Kibish River, southern Ethiopia: ~195±5 ka by 40Ar/39Ar dating of volcanic ash
- Jebel Qafzeh, Israel: 92-120 ka by thermoluminescence, ESR, uranium series
- Jebel Irhoud, Morocco: 87-190 ka by ESR
- Skhul, Israel: 81-119 ka by ESR, TR
- Singa, Sudan: =/>133 ka by ESR, uranium series

C.B. Stringer, 2001, Dating the origin of modern humans: Geological Society, London, Special Publication 190, p. 265-274
Ian McDougall et al., 2005, Stratigraphic placement and age of modern Humans from Kibish, Ethiopia: Nature, v. 433, p. 733-736.

May 2010: An international research team announced in the journal *Science* that it has sequenced the 3 billion letters of the neanderthal genome.

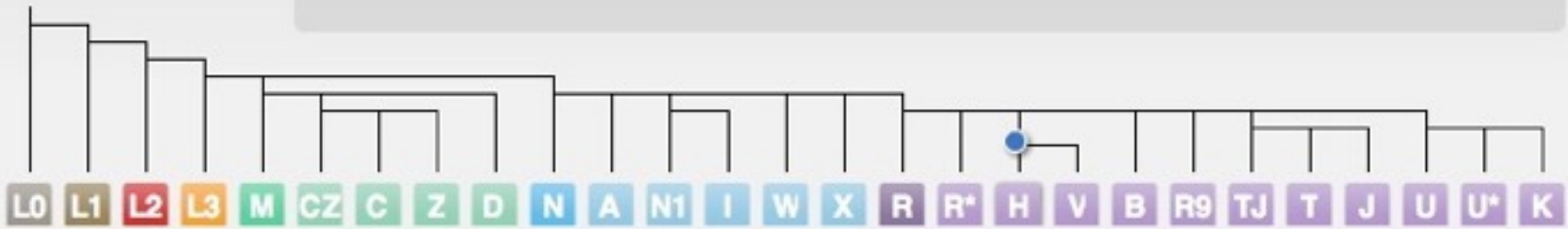
The initial analysis suggests that up to 2% of the DNA in the genome of present-day humans outside of Africa originated in Neanderthals or in Neanderthals' ancestors.

Gallerus Oratory, Dingle Peninsula, Ireland
6th century

The Human Family Tree

The Human Family Tree airing on August 30, at 9 PM EST retraces the deepest branches of the human species to reveal interconnected stories hidden in our genes. Click on a participant from the show to see how you are related.

H - This is your haplogroup.



YOUR MITOCHONDRIAL HVR I SEQUENCE

16189C, 16291T, 16519C

ATTCTAATTTAAACTATTCTCTGTTCTTTCATGGGGAAGCAGATTTGGGTACCA
CCCAAGTATTGACTCACCCATCAACAACCGCTATGTATTTCGTACATTACTGCC
AGCCACCATGAATATTGTACGGTACCATAAATACTTGACCACCTGTAGTACATA
AAAACCCAATCCACATCAAAACCCCCCCCCCCATGCTTACAAGCAAGTACAGCAA
TCAACCCTCAACTATCACACATCAACTGCAACTCCAAAGCCACCCCTCACCCA
CTAGGATACCAACAAACCTACTCACCCTTAACAGTACATAGTACATAAAGCCAT
TTACCGTACATAGCACATTACAGTCAAATCCCTTCTCGTCCCCATGGATGACCC
CCCTCAGATAGGGGTCCCTTGACCACCATCCTCCGTGAAATCAATATCCCGCA
CAAGAGTGCTACTCTCCTCGCTCCGGGCCCATAACACTTGGGGGTAGCTAAAG
TGAACTGTATCCGACATCTGGTTCCTACTTCAGGGCCATAAAGCCTAAATAGCC
CACACGTTCCCCTTAAATAAGACATCACGATG

Key C Sub. (transition) C Sub. (transversion) C Insertions _ Deletions

◉ Your sequence ○ CRS ○ mtDNA diagram ○ SNPs

YOUR RESULTS

PARTICIPANT ID: FWU6GGBS4K

Type mtDNA

Haplogroup
H

How to Interpret Your Results

At left is displayed the sequence of your mitochondrial genome that was analyzed in the laboratory. Your sequence is compared against the Cambridge Reference Sequence (CRS), which is the standard mitochondrial sequence initially determined by researchers at Cambridge, UK. The differences between your DNA and the CRS are highlighted, and these data allow researchers to reconstruct the migratory paths of your genetic lineage. Substitution (transition): a nucleotide base mutation in

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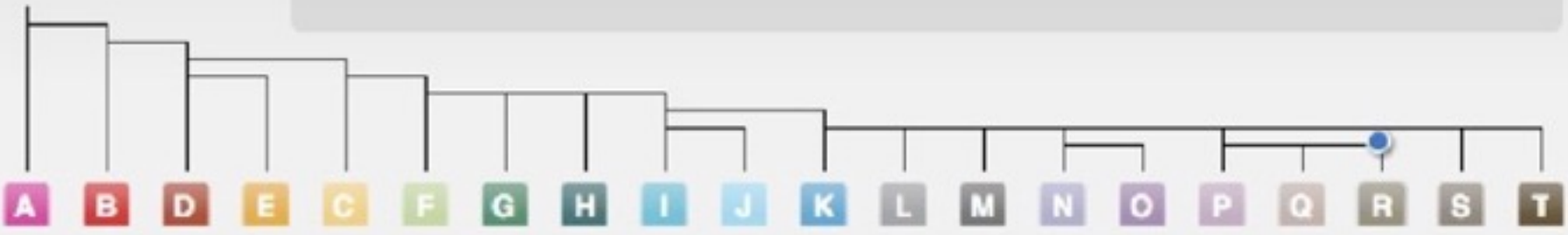

Dating human migration using mtDNA and Y chromosomes

https://www3.nationalgeographic.com/genographic

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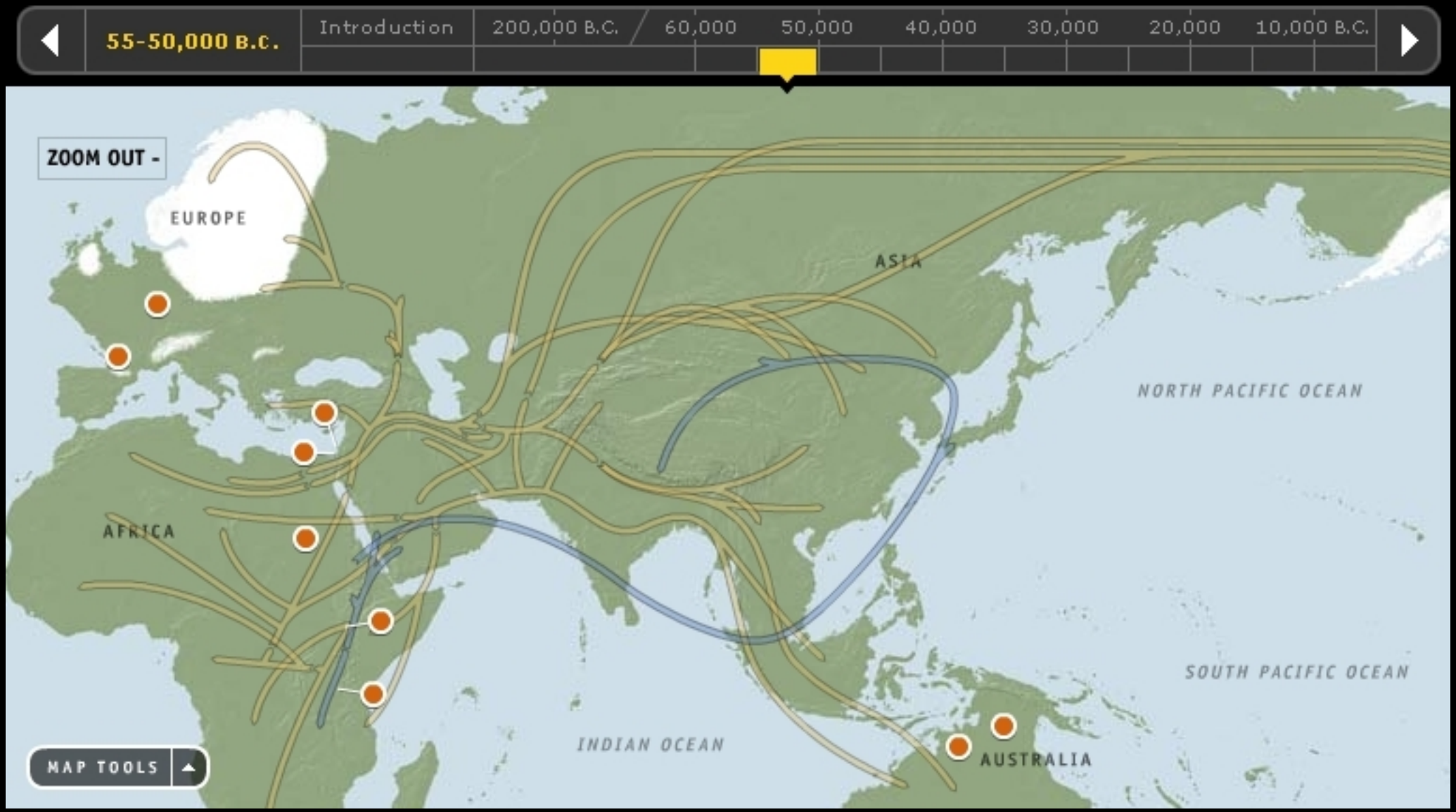

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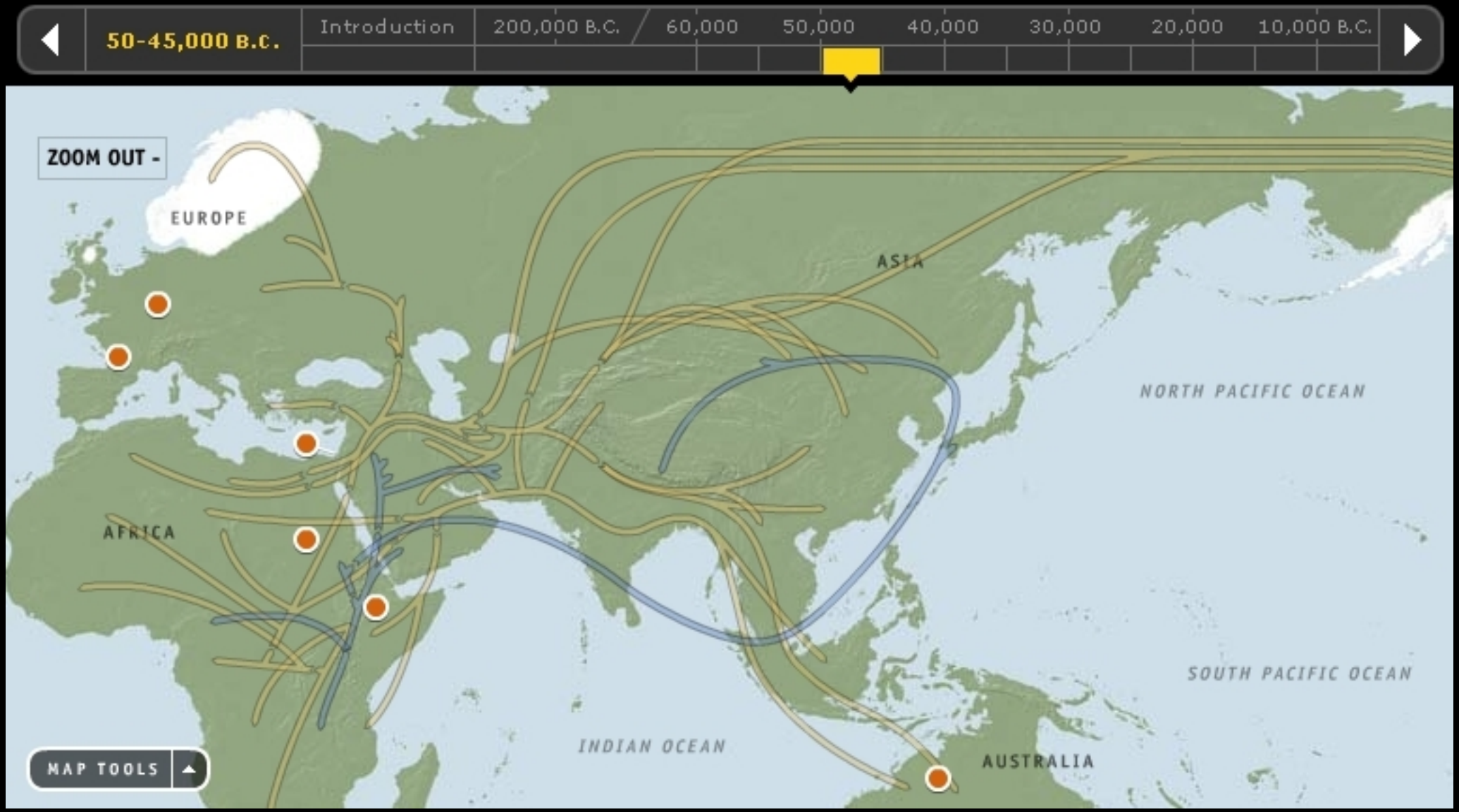

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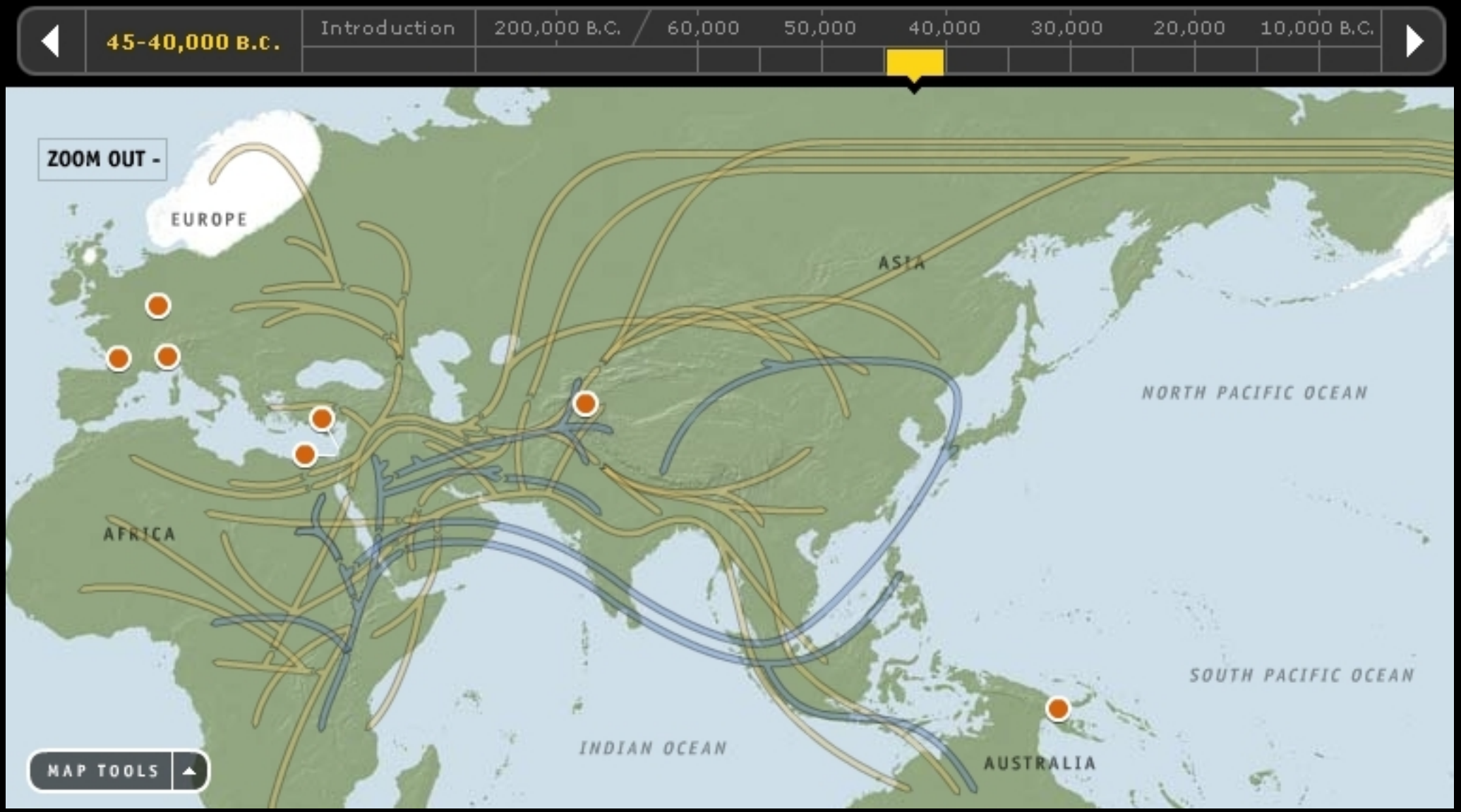

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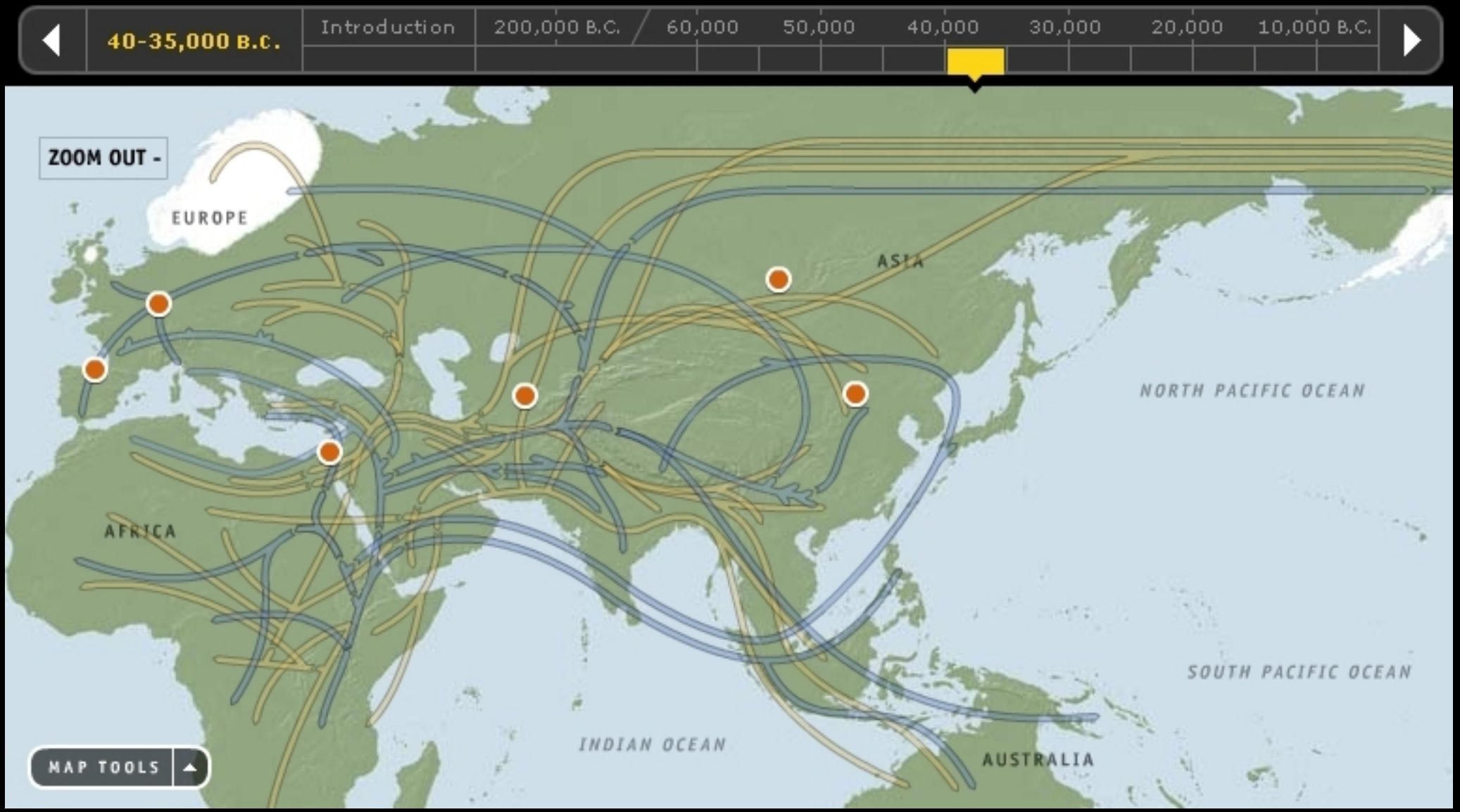

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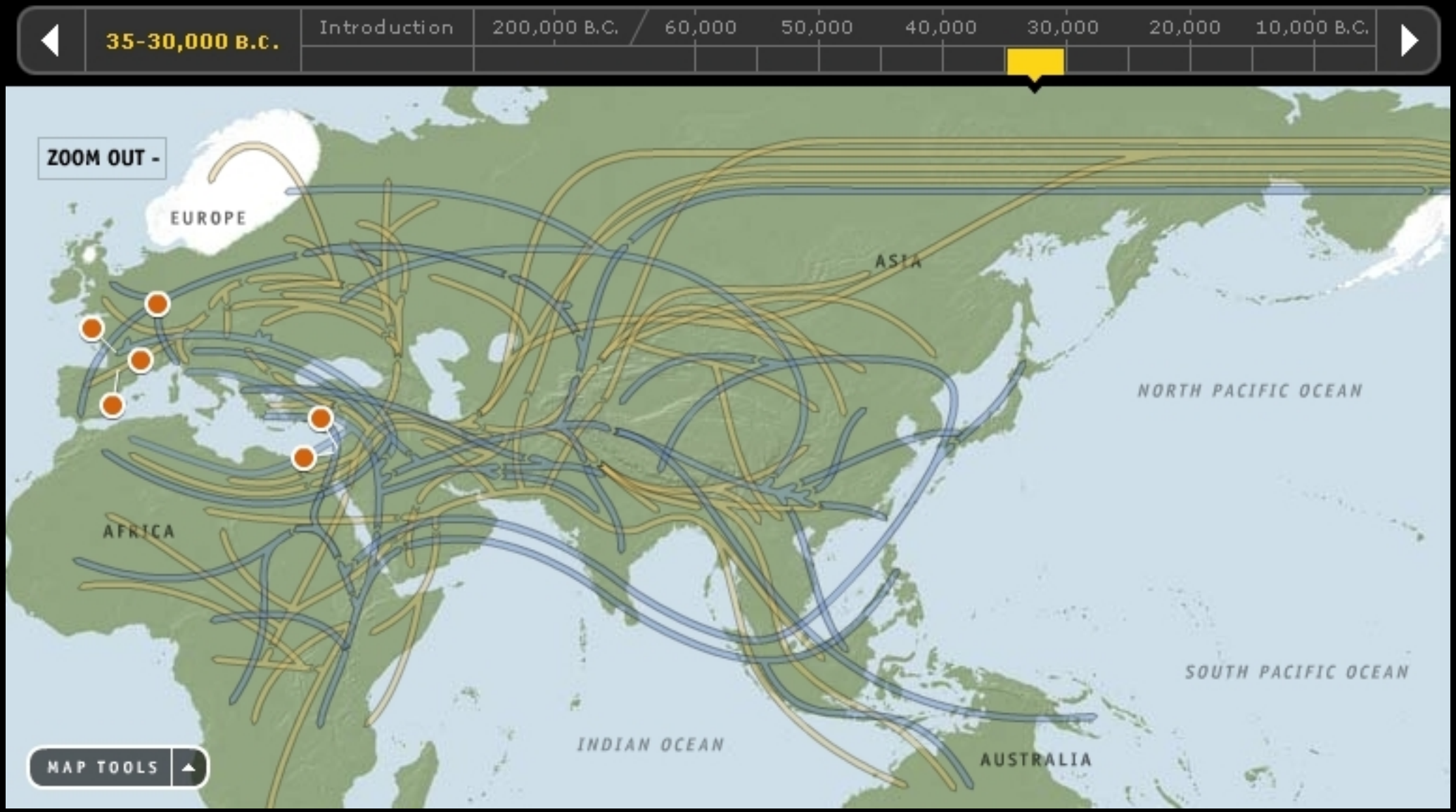

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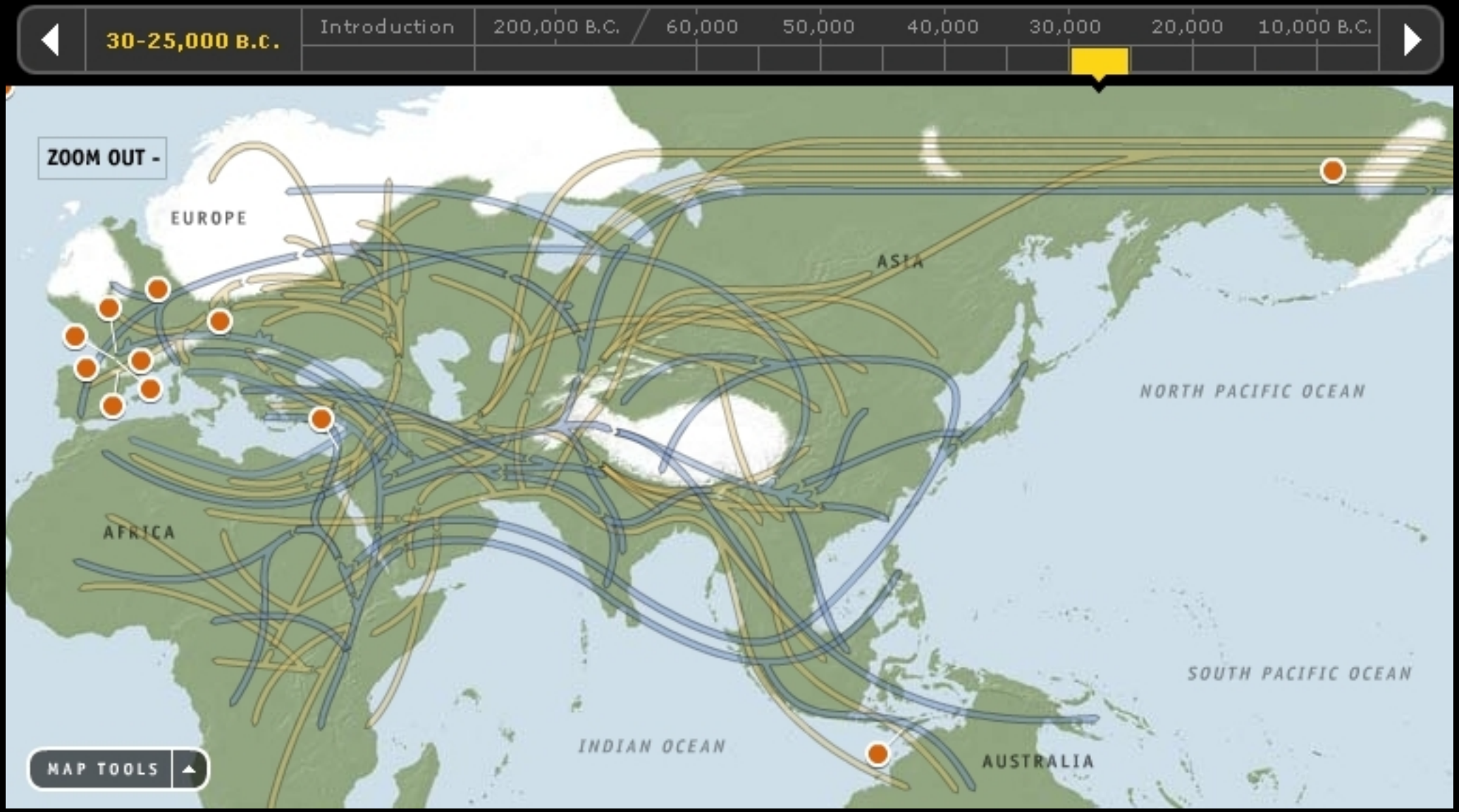
Dating human migration using mtDNA and Y chromosomes



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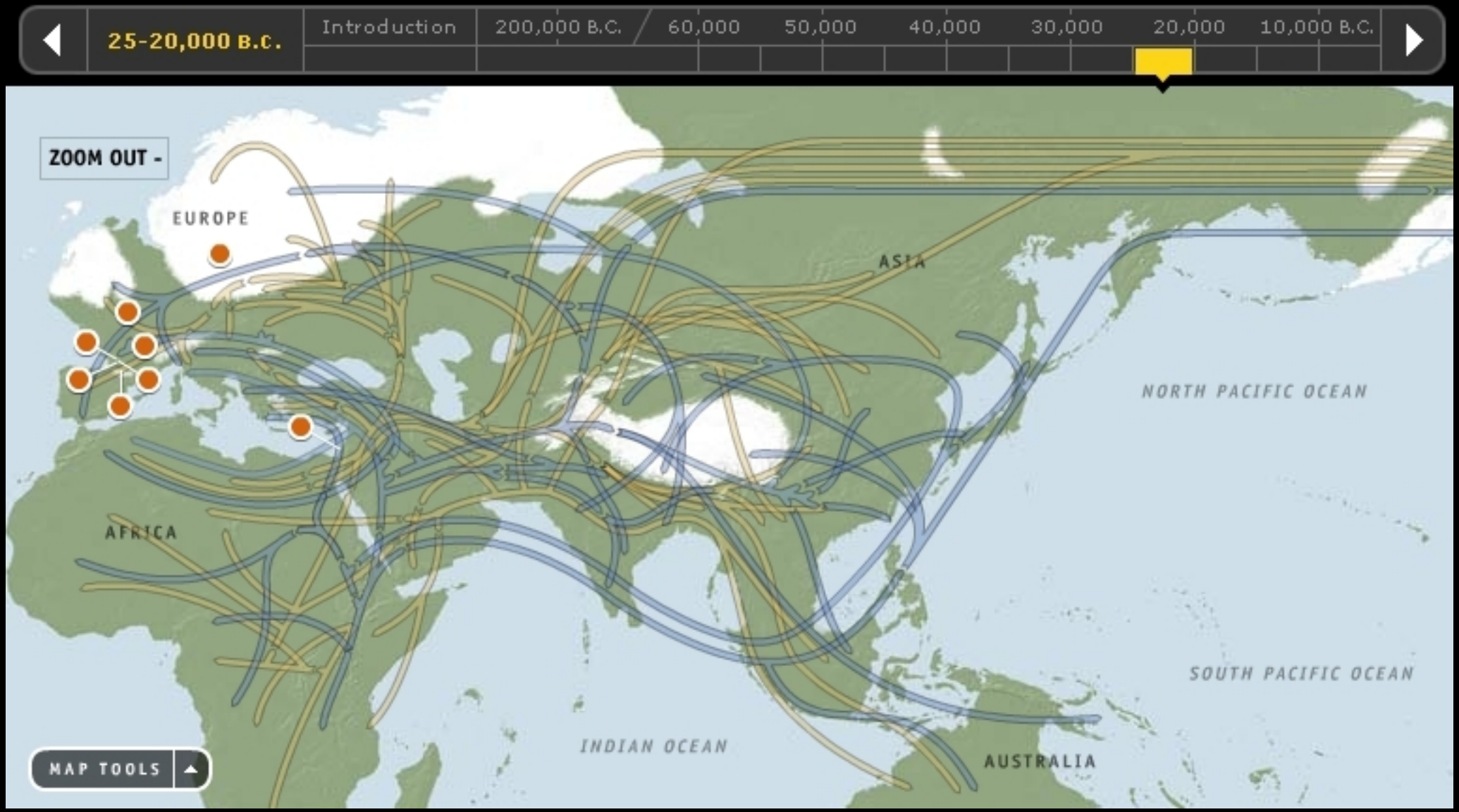

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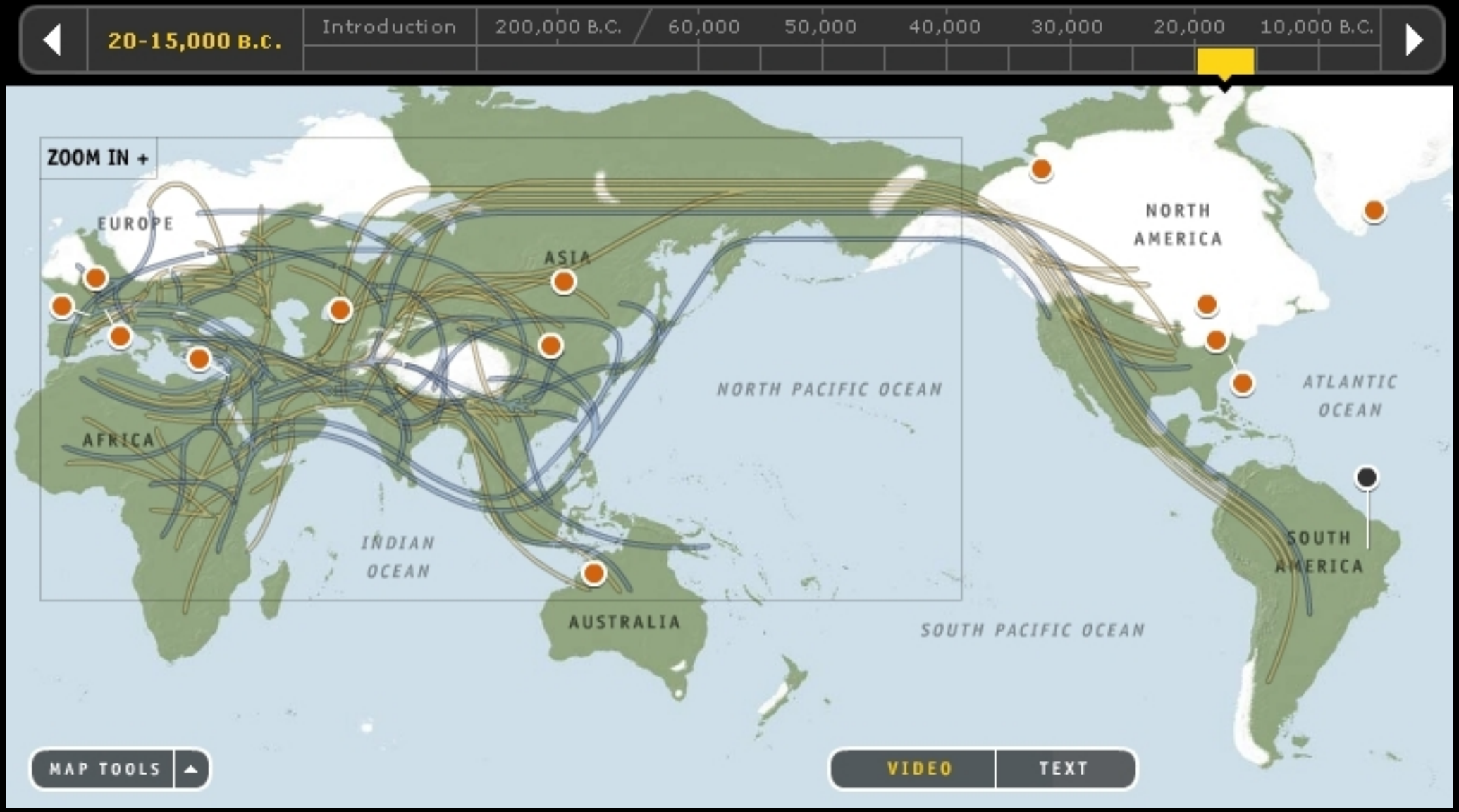

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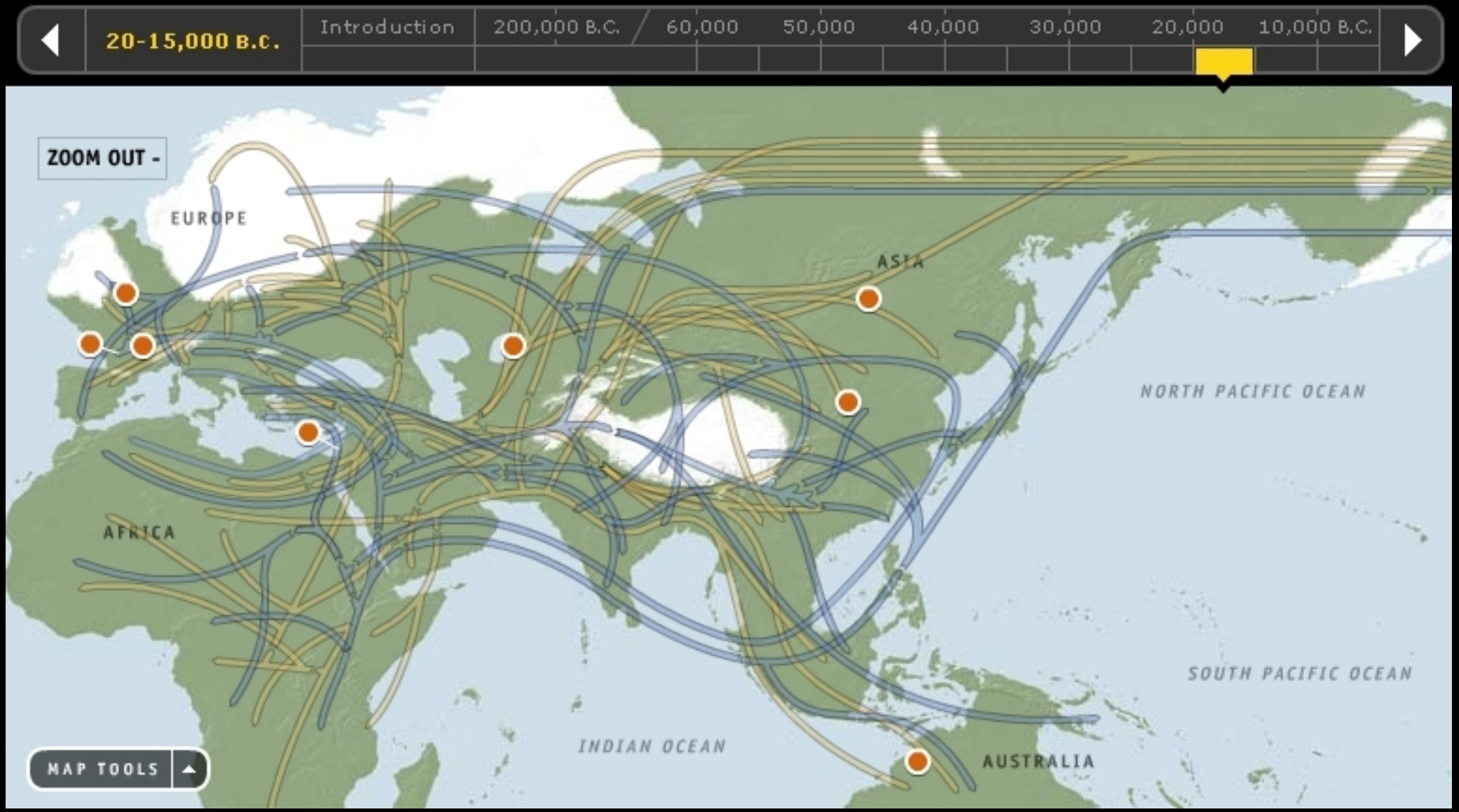

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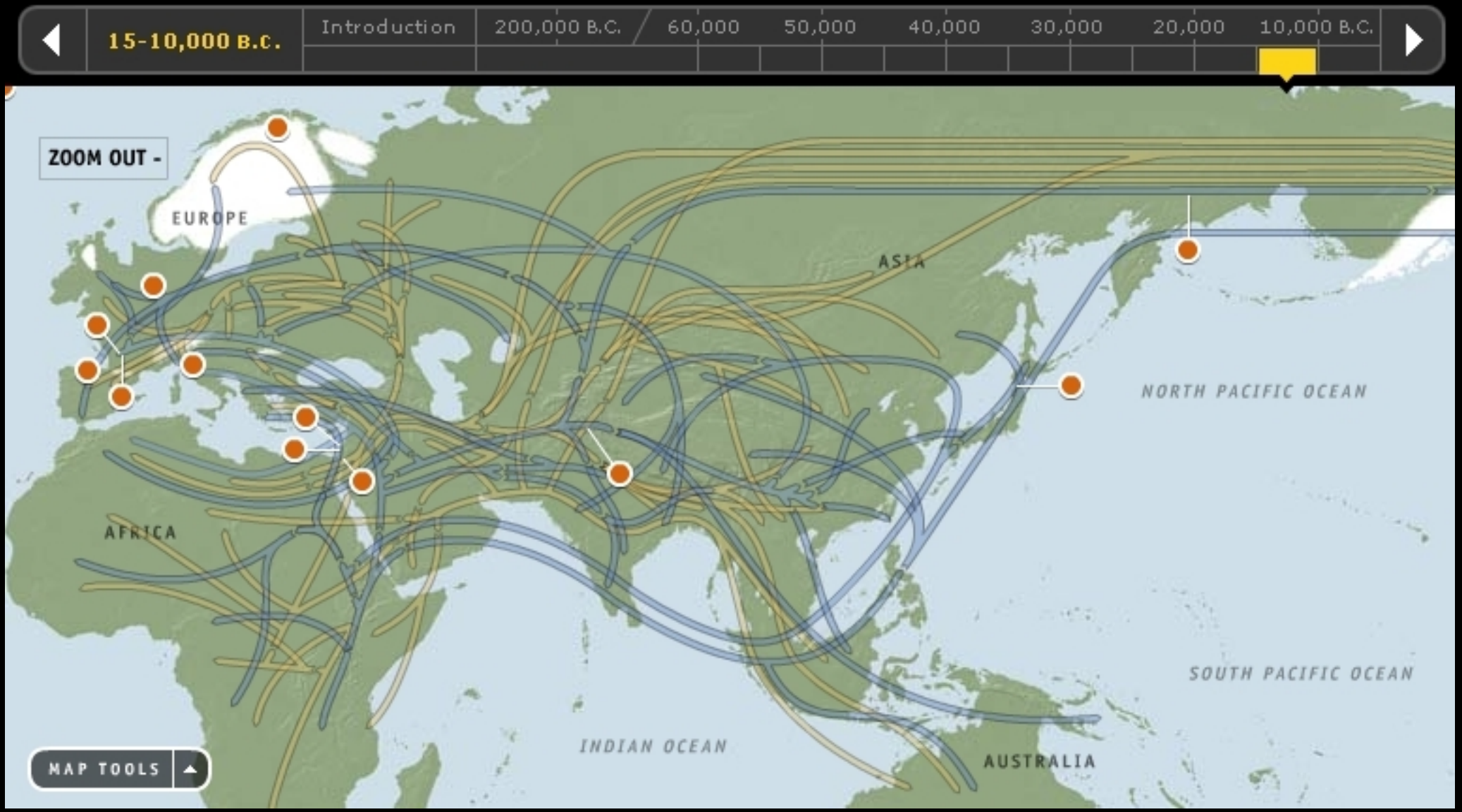
Dating human migration using mtDNA and Y chromosomes



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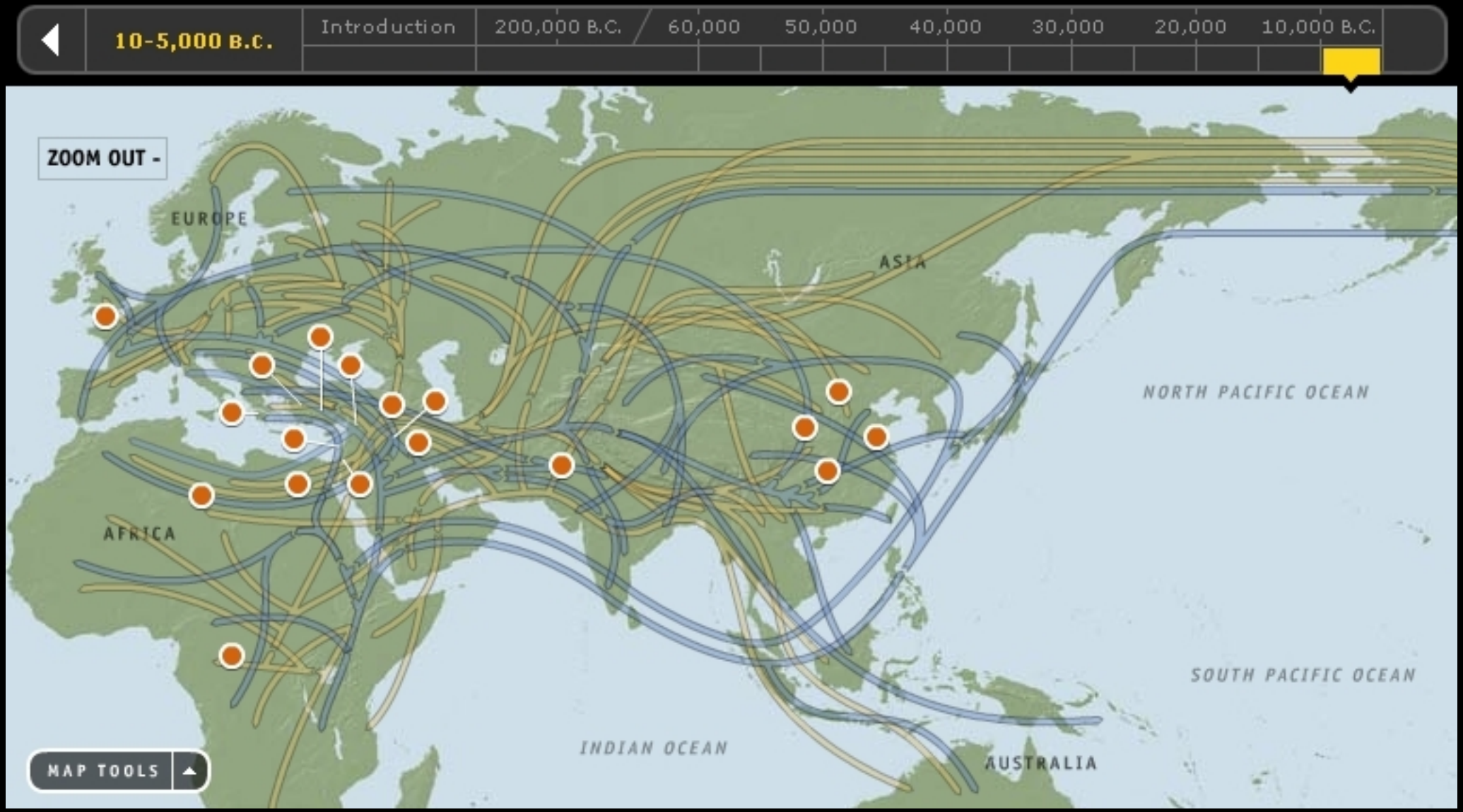

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