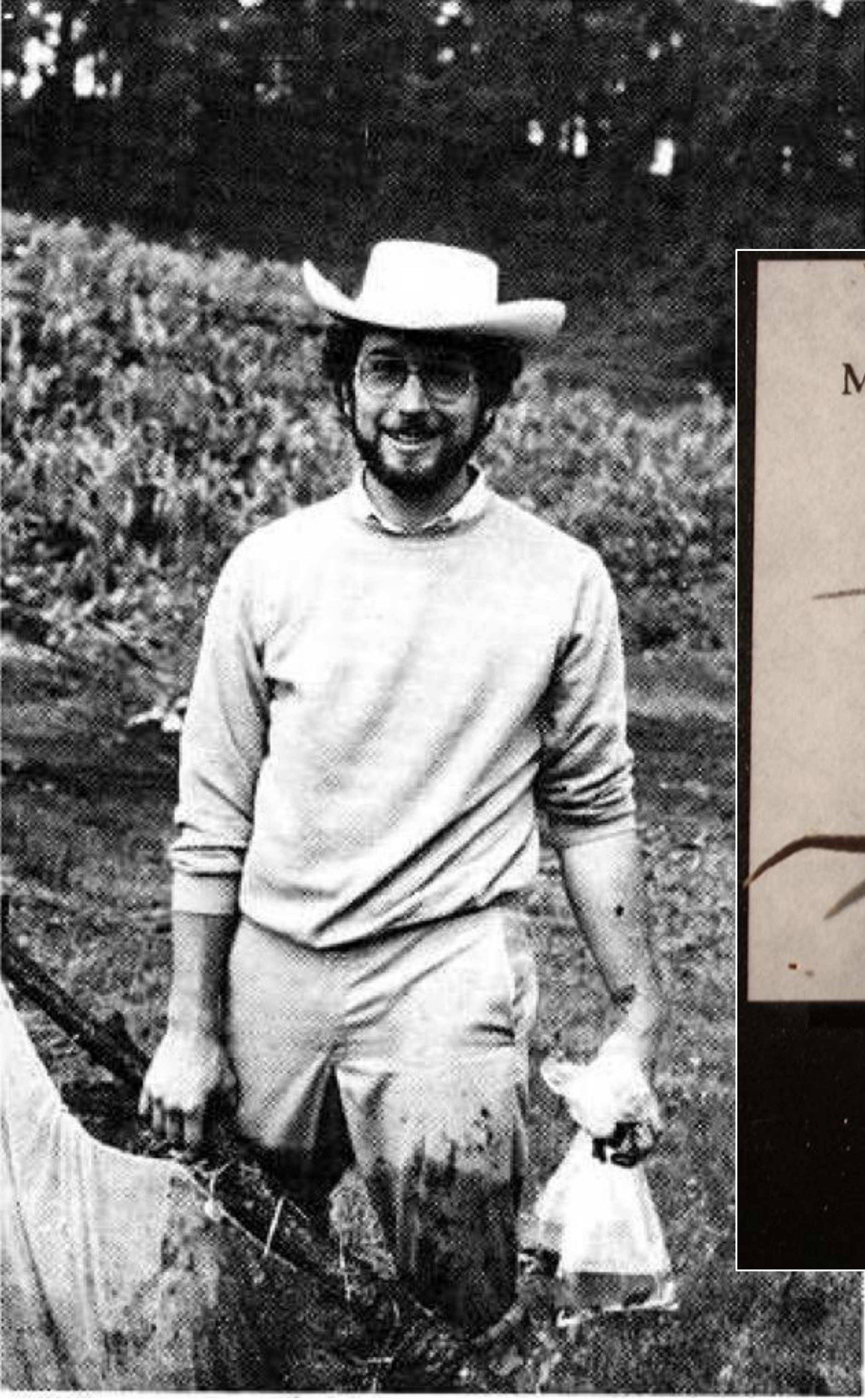
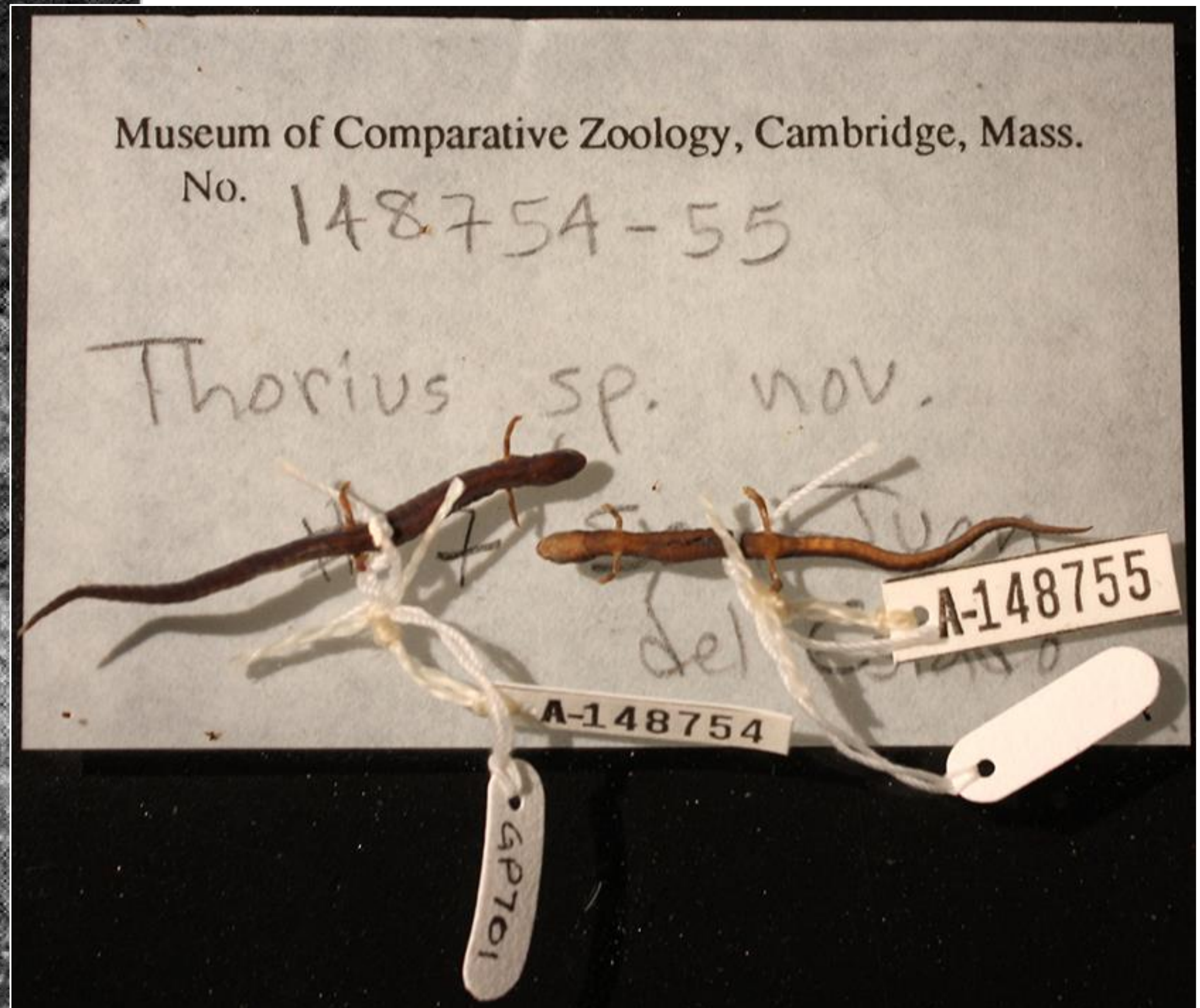
The advent of digital technology and its promise for biodiversity research

James Hanken

Museum of Comparative Zoology
Harvard University

ca. 1974





Museum of Comparative Zoology, Cambridge, Mass.
No. 148754-55
Thorius sp. nov.
A-148755
A-148754
GP701

State of the Art, 1974

-1-

Veracruz (2) Thorius pennatulus narismagnus

118142	Volcan San Martin, 3800'	
118143	Volcan San Martin, S slope, 3575'	
115164	S Sl Volcan San Martin Tuxtla, 3800'	11
121134	SE slope Volcan San Martin, ca. 1100 m.	14
121267	Volcan San Martin, SE slope, ca. 1190 m.	3
121268	Same as above, ca. 1005 m.	
121269	" " ca. 280 m.	2
121270	" " ca. 1000 m.	
121271	" " ca. 1110 m.	8

Veracruz (3)

S-1694	Volcan San Mart
85441	Acultzingo
88833	"
115163	4.7 m SW of Huat

-2-

Oaxaca (5) Thorius sp.

126294	Ixtlan de Juarez, 13.1 mi NE, 9900'	2
126295	Cerro San Felipe, 10,500'	12
126296	Ixtlan de Juarez, 13.8 mi NE, 9800'	19
126297	Oaxaca, 14.1 mi NE and 2.7 mi E, 8900'	7
126845	Cofradia, ca. 8 mi. SW San Vicinte Laohixio, ca. 9000'	5
132095	Llano de los Flores; 2700 m	1
132096-132101	"Cerro Pelon" SW slope, 13 mi. NE of Llano de los Flores (by road); 2700 m	59

Oaxaca (6) Thorius macdougalli

118913	Llano de las Flores, 12 mi. N of Ixtlan de Juarez, 9200'.	8
119705	Llano de las Flores, 2870 m. (S-2502-2505)	183

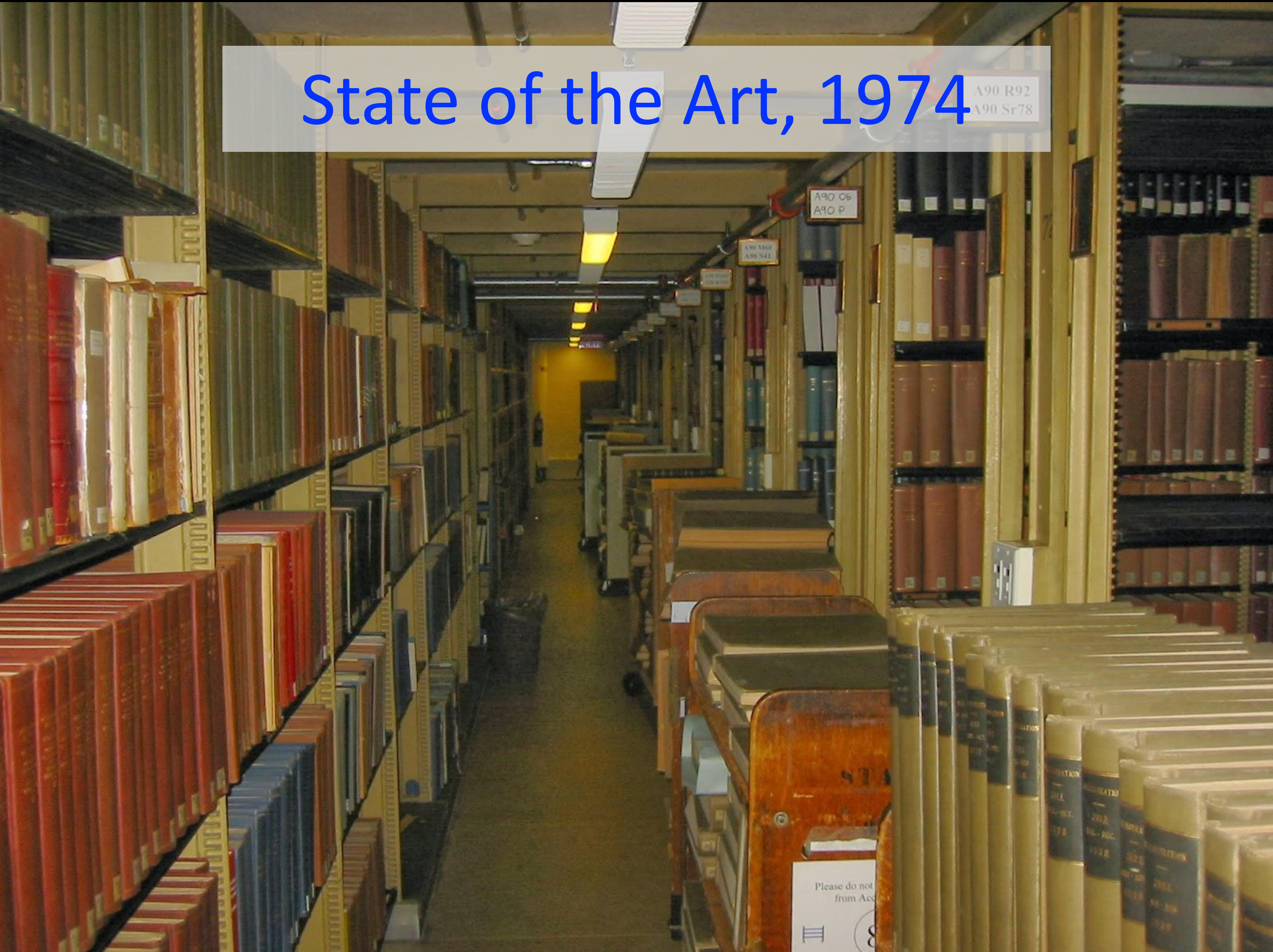
Oaxaca Thorius narisovalis

119702	3.5 mi. S of Ranch el Pinto, 8350'.	5
119703	Rancho Mira Cumbre, 8600'.	2

Oaxaca (7) Thorius pulmonaris

117247	Cerro San Felipe	
119701	3.5 mi. S of Rancho el Pinto, 8350'.	35
121886	ca.10mi. NE of Cuidad Oaxaca	

State of the Art, 1974



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thorius

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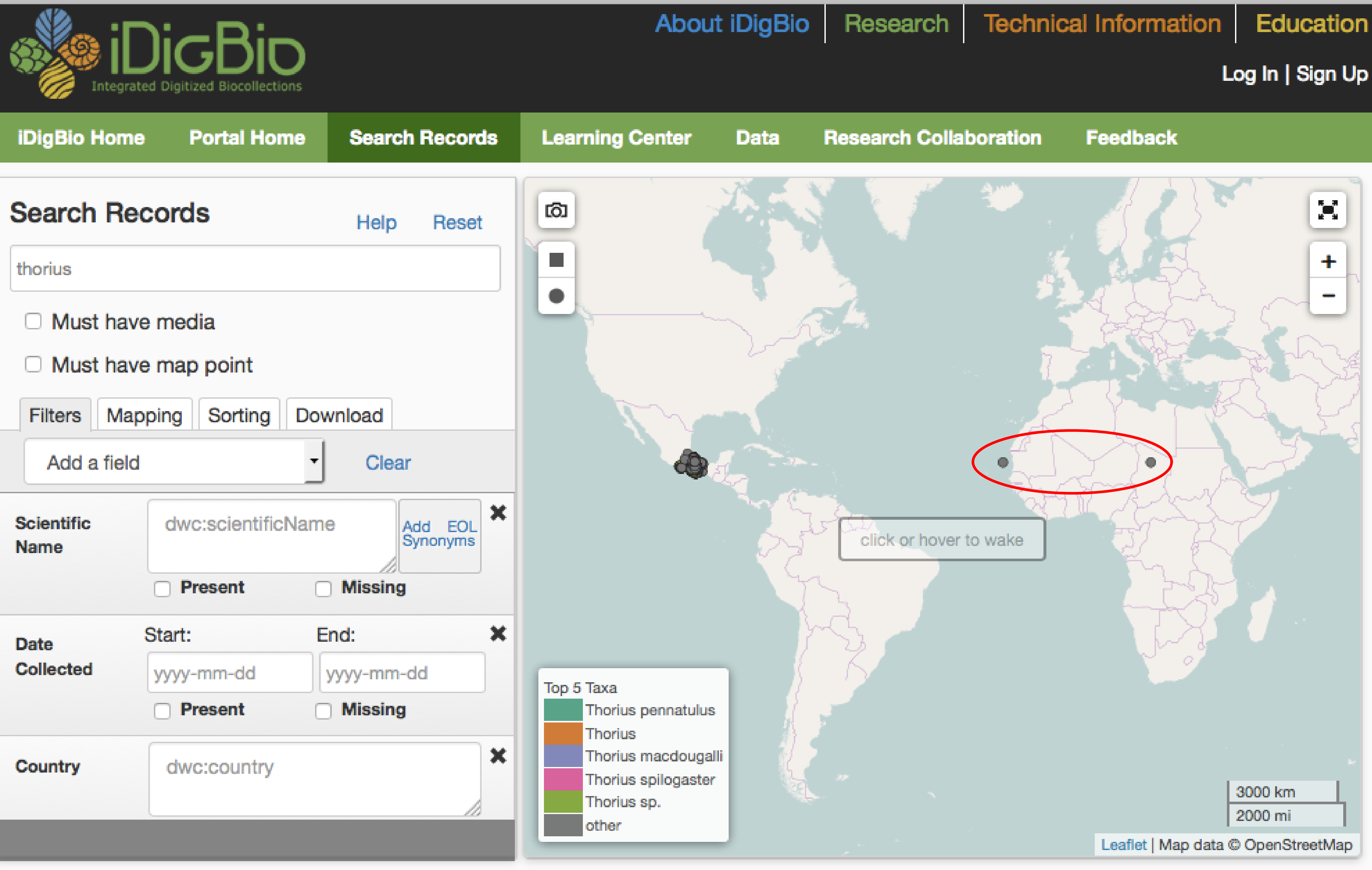
Table | Map

1-100 of 8,845 | Download

Pro tip! Click on a table row to see the full occurrence details.

Identification	Taxonomy	Location	Recorded By	Sex	Date	Map	Media
MCZ Herp A-136428	Amphibia: Thorius longicaudus	Mexico, Oaxaca: 19 km S of Sola de Vega	James F. Lynch, David B. Wake, Theodore J. Papenfuss		1946-11-01		
MCZ Herp A-137376	Amphibia: Thorius boreas	Mexico, Oaxaca: Cerro Pelon, 50 km N Guelatao [VERBATIM ELEVATION:2850...	Gabriela Parra-Olea		1997-10-08		
MCZ Herp A-137378	Amphibia: Thorius macdougalli	Mexico, Oaxaca: 1 km E Cerro Machin	Gabriela Parra-Olea		1999-08-07		
MCZ Herp A-137380	Amphibia: Thorius narisovalis	Mexico, Oaxaca: Cerro San Felipe, 9.3 km W La Cumbre [VERBATIM ELEVATI...	Gabriela Parra-Olea		1999-08-04		
MCZ Herp A-137819	Amphibia: Thorius longicaudus	Mexico, Oaxaca: Mexico Hwy. 131, 19 km S (by road) Sola de Vega	James F. Lynch, David B. Wake, Theodore J. Papenfuss		1974-11-18		
MVZ Amphibian and reptile specimens 106399	Amphibia: Thorius pennatulus	Mexico, Veracruz: S-facing slope of River Canyon, 2 km N Teocelo, on r...	Collector(s): Samuel S. Sweet	undetermined	1972-12-19		
MVZ Amphibian and reptile specimens 106409	Amphibia: Thorius pennatulus	Mexico, Veracruz: Barranca, 2 km N of Teocelo	Collector(s): Theodore J. Papenfuss	undetermined	1972-12-19		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Must have map point
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Sorting
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Clear
Scientific Name
dwc:scientificName
Add EOL Synonyms
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End:
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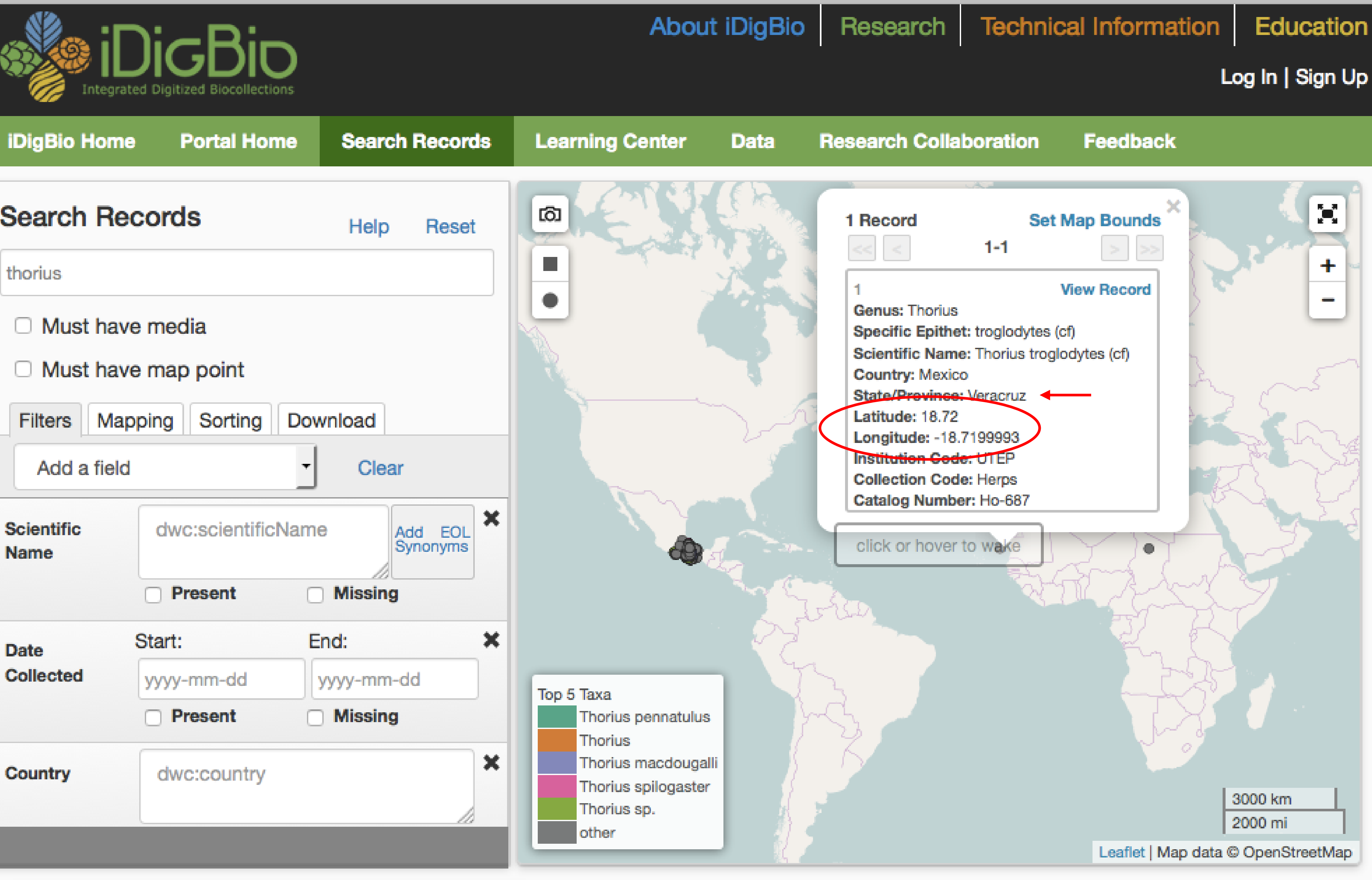
click or hover to wake
Top 5 Taxa
Thorius pennatulus
Thorius
Thorius macdougalli
Thorius spilogaster
Thorius sp.
other
3000 km
2000 mi
Leaflet | Map data © OpenStreetMap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dwc:scientificName
Add EOL Synonyms
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Start:
End:
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Country
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1 Record
Set Map Bounds
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1
View Record
Genus: Thorius
Specific Epithet: troglodytes (cf)
Scientific Name: Thorius troglodytes (cf)
Country: Mexico
State/Province: Veracruz
Latitude: 18.72
Longitude: -18.7199993
Institution Code: UTEP
Collection Code: Herps
Catalog Number: Ho-687
click or hover to wake
Top 5 Taxa
Thorius pennatulus
Thorius
Thorius macdougalli
Thorius spilogaster
Thorius sp.
other
3000 km
2000 mi
Leaflet | Map data © OpenStreetMap

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*Stats as of February 2018

BHL
Biodiversity Heritage Library

Proceedings of the Academy of Natural Sciences of Philadelphia.
A review of the species of Plethodontidae and Desmognathidae
v.21 (1869)

entirely that of the Plethodontidae. This was the less to have been anticipated, as the general characters of the only genus are those of the genus Spelerpes. The history of the metamorphosis is as yet unknown. The only known genus is Mexican.

THORIUS Cope.

Parietal and palatine bones rudimental, represented by cartilage and membrane. Posterior nares therefore not separated from orbit; sphenoidal patches of teeth entirely united; tongue boletoid, free in front. Toes distinct, rudimental, 4—5.

The tarsal bones consist of astragalus, calcaneum, a scaphoid and three minute cuneiform bones. The metatarsals and phalanges are fully ossified, as are the corresponding elements of the fore limbs.

This genus is highly interesting, as indicating the lowest grade of ossific deposit found among the tailed Batrachians, accompanied by characters of full development in other respects. Thus, while the cranium is but imperfectly ossified, and less developed than in a comparatively early larval stage of Amblystoma, the tongue, vertebral column, and extremities have advanced far beyond its larval condition, which is permanent in the latter genus, and the branchial apparatus disappears while the individuals are but little more than half their adult size.

It is represented as yet by but one species, from Mexico, of terrestrial habits.

THORIUS PENNATULUS Cope.

American Naturalist, 1869, 222.

This is a small species, with smooth skin, very weak limbs, and stout tail. The head is scarcely wider than the neck; it is not flattened, the loreal region is rather elevated and distinct, and the muzzle slightly prominent. The upper lip is sometimes truncate, with infranarial angle prominent, sometimes regularly rounded. The nostril is larger than any known salamander, its diameter equalling half that of the pupil.

The vomerine teeth are situated on a transverse, elevated crest, which is a little behind between the inner nares, and though curved backwards, is but little interrupted medially. Each half contains four teeth, perhaps five when complete. The sphenoidal series is large, pyriform, the anterior extremity narrowed and prolonged to opposite the middle of the orbits.

There are thirteen costal folds; three and one-half of their interspaces are [illegible] by the extended hind limb, from its origin. The toes are very

PeerJ

Biology of t
of minute s
Thorius) fr

Gabriela Parra-Olea[1],
Jessica A. Maisano[4], D

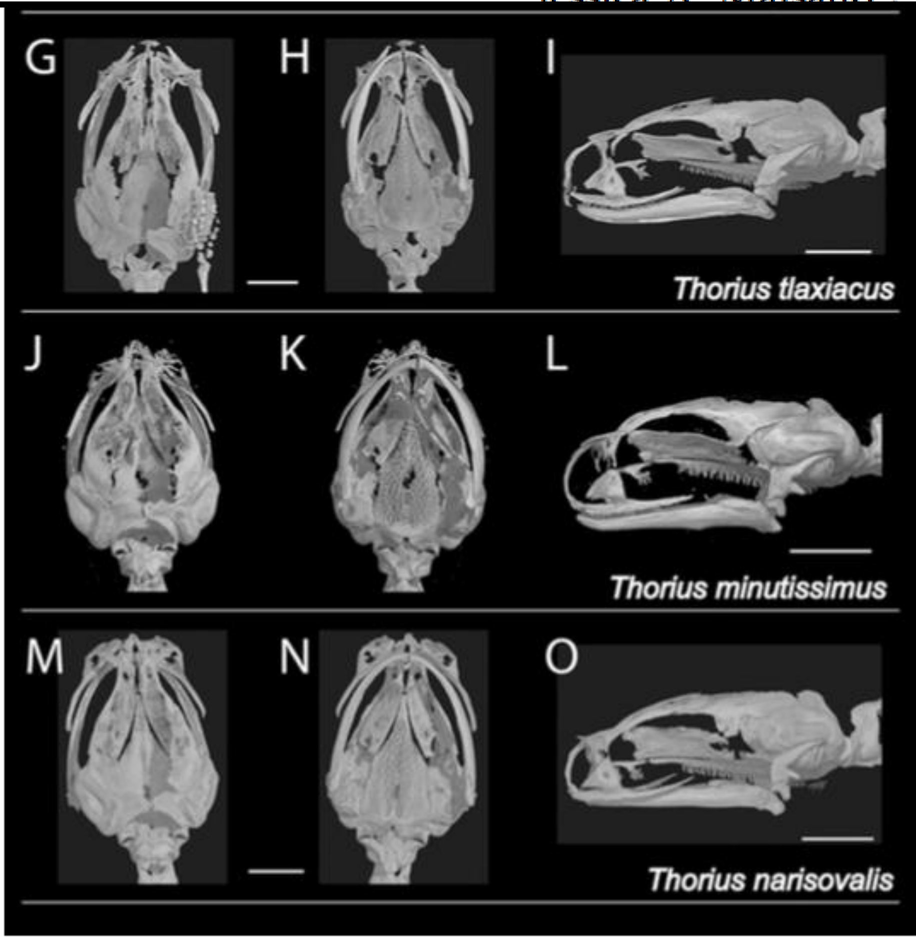


Figure 5 X-ray micro-computed tomography (μCT) scans of adult skulls. (A–C) *Thorius pinicola*, MCZ A-136429, paratype, male; (D–F) *T. longicaudus*, MCZ A-137819, holotype, female; (G–I) *T. tlaxiacus*, MVZ 183447, paratype, male; (J–L) *T. minutissimus*, IBH 23011, female; and (M–O) *T. narisovalis*, MVZ 162257, female. Each skull is shown in dorsal (left), ventral (middle) and left lateral views. The skeleton of the right hand is visible in G. Total length of each skull is only 3–4 mm; scale bar, 1 mm.

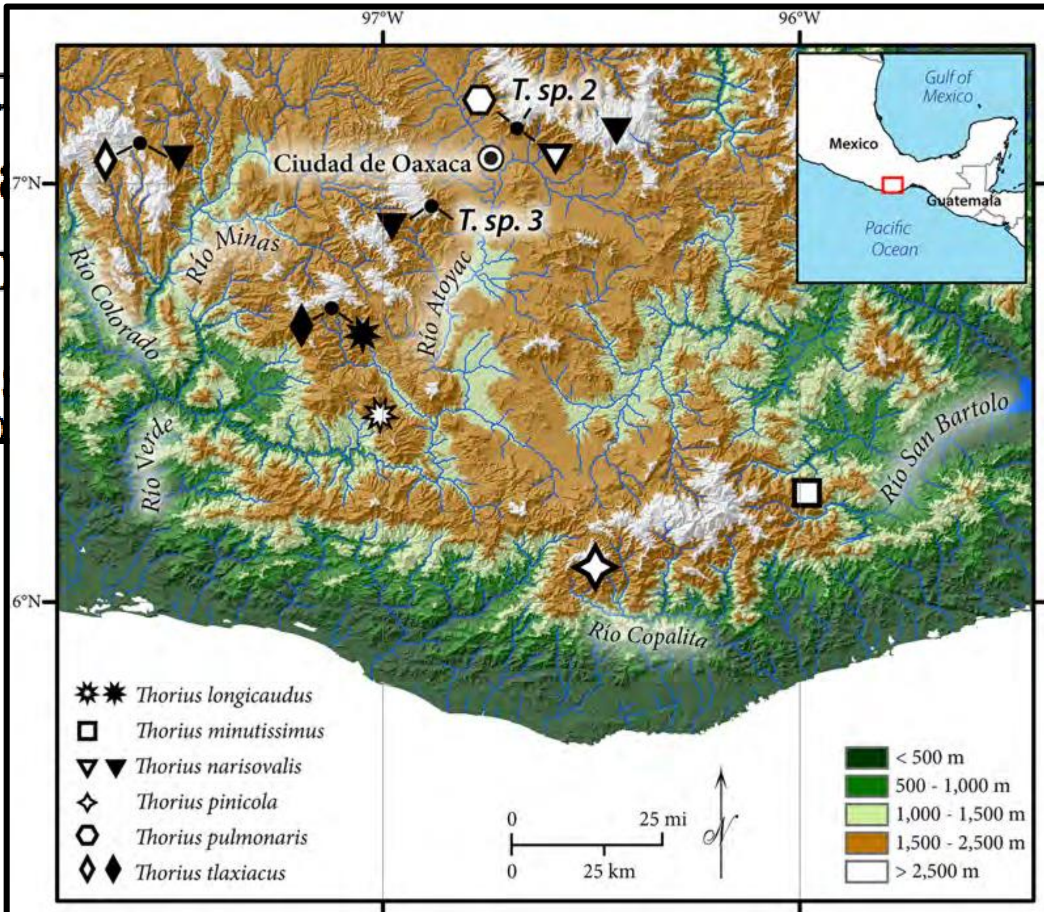


Figure 1 Geographic distribution of *Thorius* in western and southern Oaxaca, Mexico. Type localities of six named species are denoted by open symbols; additional localities are denoted by closed symbols. Known localities of *T.* sp. 2 and *T.* sp. 3, two unnamed Oaxacan species, are also shown (Rovito et al., 2013). Small closed circles denote four localities where two or three species are sympatric or nearly sympatric (from left to right): Heroica Ciudad de Tlaxiaco, San Vicente Lachixio, Zaachila and Cerro San Felipe.

g geographically disjunct populations. Adult
us sp. nov., and *T. tlaxiacus* sp. nov. are larger
tical rather than oval nostrils; *T. pinicola* and
ll three new species occur west of the range of
most distribution of any member of the
ned from each other and from other named
of adult body size, external morphology and
llozymes) and differences in DNA sequences.

What happened, and when?

2012

ORNIS2 PORTAL LAUNCHES

The ORNIS2 portal was launched.

2011

ADBC →

HERPNET2 PORTAL LAUNCHES

The HerpNET2 portal was launched.

2010

FISHNET2 LAUNCHES

The FishNet2 portal was launched.

← VertNet

2004

ORNIS FUNDED

ORNIS was funded by the National Science Foundation (NSF), DBI-0345448, 2004-2010.

2004

FISHNET2 FUNDED

FishNet2 was funded in 2004 by the National Science Foundation (NSF), DBI-0415600, 2004-2010.

2002

HERPNET FUNDED

HerpNET was funded by the National Science Foundation (NSF), DBI-0132303, 2002-2008

2001

MANIS FUNDED

MaNIS was funded by the National Science Foundation (NSF), DBI-0108161, 2001-2006.

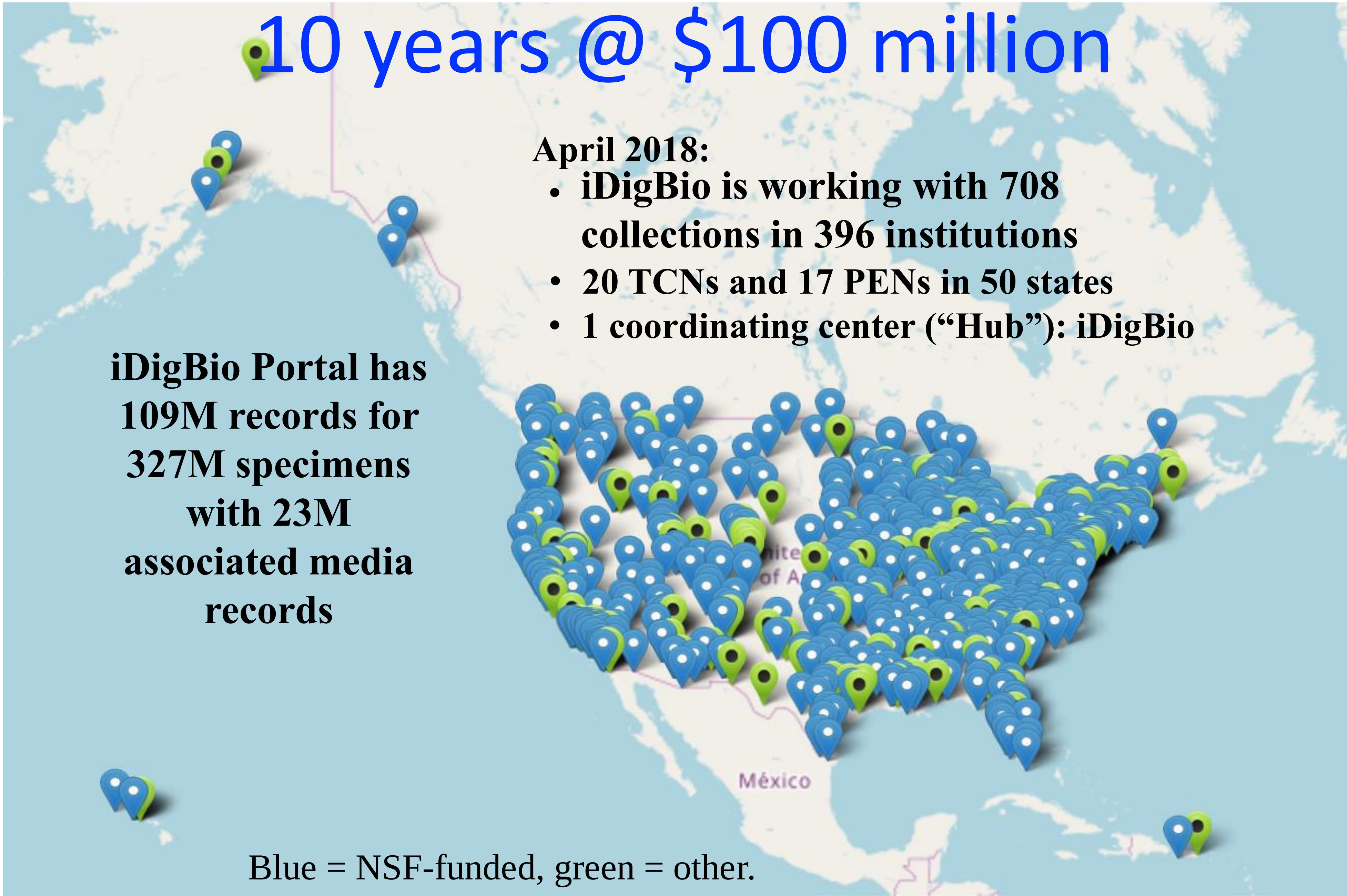
1998

FISHNET FUNDED

FishNet was funded by the National Science Foundation (NSF), DEB-9910159, 1998-2001.

Advancing Digitization of Biodiversity Collections (ADBC)

10 years @ $100 million



April 2018:

- **iDigBio is working with 708 collections in 396 institutions**
- **20 TCNs and 17 PENs in 50 states**
- **1 coordinating center ("Hub"): iDigBio**

iDigBio Portal has 109M records for 327M specimens with 23M associated media records

Blue = NSF-funded, green = other.

Why?

HARNESSING THE POWER of DIGITAL DATA

SCIE…

Report o… to the Committee …

…cience Agencies

…lections

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20502

March 20, 2014

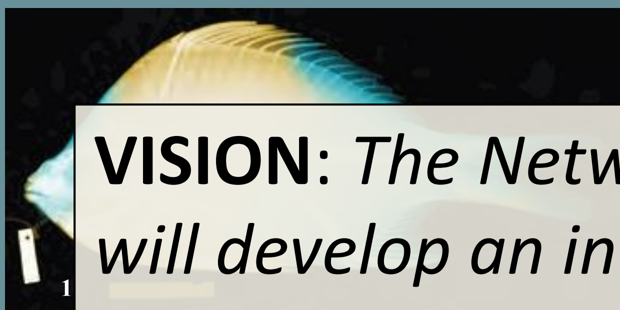
Scientific collections provide an essential base for developing scientific evidence and are an important resource for scientific research, education, and resource management…. Policies and procedures for maintaining, preserving, and developing Federal scientific collections while also increasing access to those collections for appropriate use are, therefore, central to their value.

NSF

National Science Foundation

NIBA Strategic Plan (2010)

The Network Integrated Biocollections Alliance



VISION: *The Network Integrated Biocollections Alliance will develop an inclusive, vibrant, partnership of U.S. biological collections that collectively will document the nation's biodiversity resources and create a dynamic electronic resource that will serve the country's needs in answering critical questions about the environment, human health, biosecurity, commerce, and the biological sciences.*

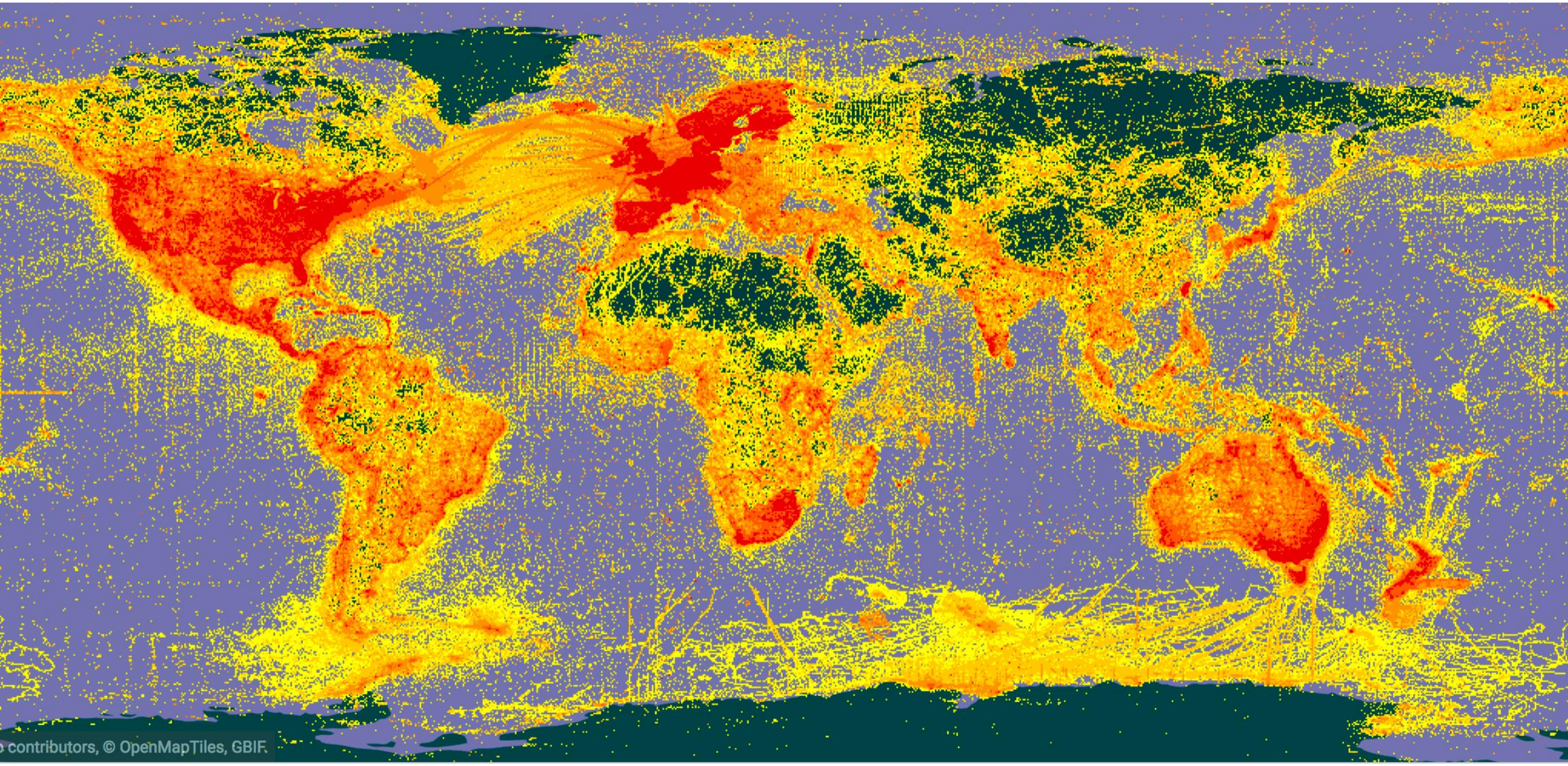
IMPLEMENTATION PLAN FOR THE NETWORK INTEGRATED BIOCOLLECTIONS ALLIANCE

NIBA Implementation Plan (2013)

Digitization is a Global Effort

- Atlas of Living Australia
- CONABIO (Mexico)
- Canadensys (Canada)
- India Biodiversity Portal
- Swedish LifeWatch
- PORBIOTA (Azores, Portugal)
- Edaphobase (Germany)
- Ocean Biographic Information System

Global Biodiversity Information Facility



June 1st 2018: 984,441,947 occurrence records

Data Error is a Serious Problem

CellPress

Current Biology *25*, R1057–R1069, November 16, 2015

Current Biology
Magazine

Correspondence

Widespread mistaken identity in tropical plant collections

specimens had the wrong name prior to a recent taxonomic study. A similar pattern of wrongly named specimens is also shown for Dipterocarps and *Ipomoea* (morning glory). We also examine the number of available plant specimens worldwide. Our data demonstrate that, while the world's collections have more than doubled

(Supplemental Figure S1A). Finally, we documented the increase in the number of tropical herbaria and the accumulation of specimens for several taxa and geographical regions (Supplemental Figure S1B–CI-X).

Figure 1B charts the complete determination history of all names for all specimens of *Aframomum*. Before

"while the world's [plant] collections have more than doubled since 1970, more than 50% of tropical specimens … are likely to be incorrectly named. This finding has serious implications for the uncritical use of specimen data from natural history collections."

analyses [1]. Thus, digitisation of natural history collections is providing unprecedented information to facilitate the study of the natural

over time relative to the current name, as determined in the recent monograph [2]. Additionally, we measured the inconsistency of

specimens of Dipterocarpaceae from nine herbaria, we identified 9,222 collections, each represented by at least two duplicate specimens

New Phytologist

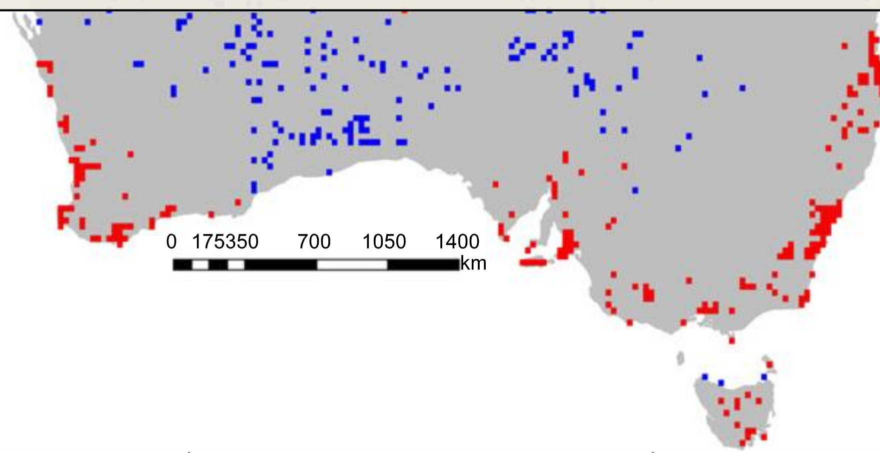
Research

Widespread sampling biases in herbaria revealed from large-scale digitization

- "distance to herbaria explained 45% of the variance in collecting effort in AU, 29% in SA and 12.3% in NE, with a higher density of specimens closer to herbaria."
- There was a significant trend toward collection on weekends (Saturdays and Sundays) in NE … and midweek in SA and AU.

New Phytologist (2017)
doi: 10.1111/nph.14855

Key words: collector bias, geographic bias, herbarium, regional flora, sampling bias, temporal bias, trait bias.



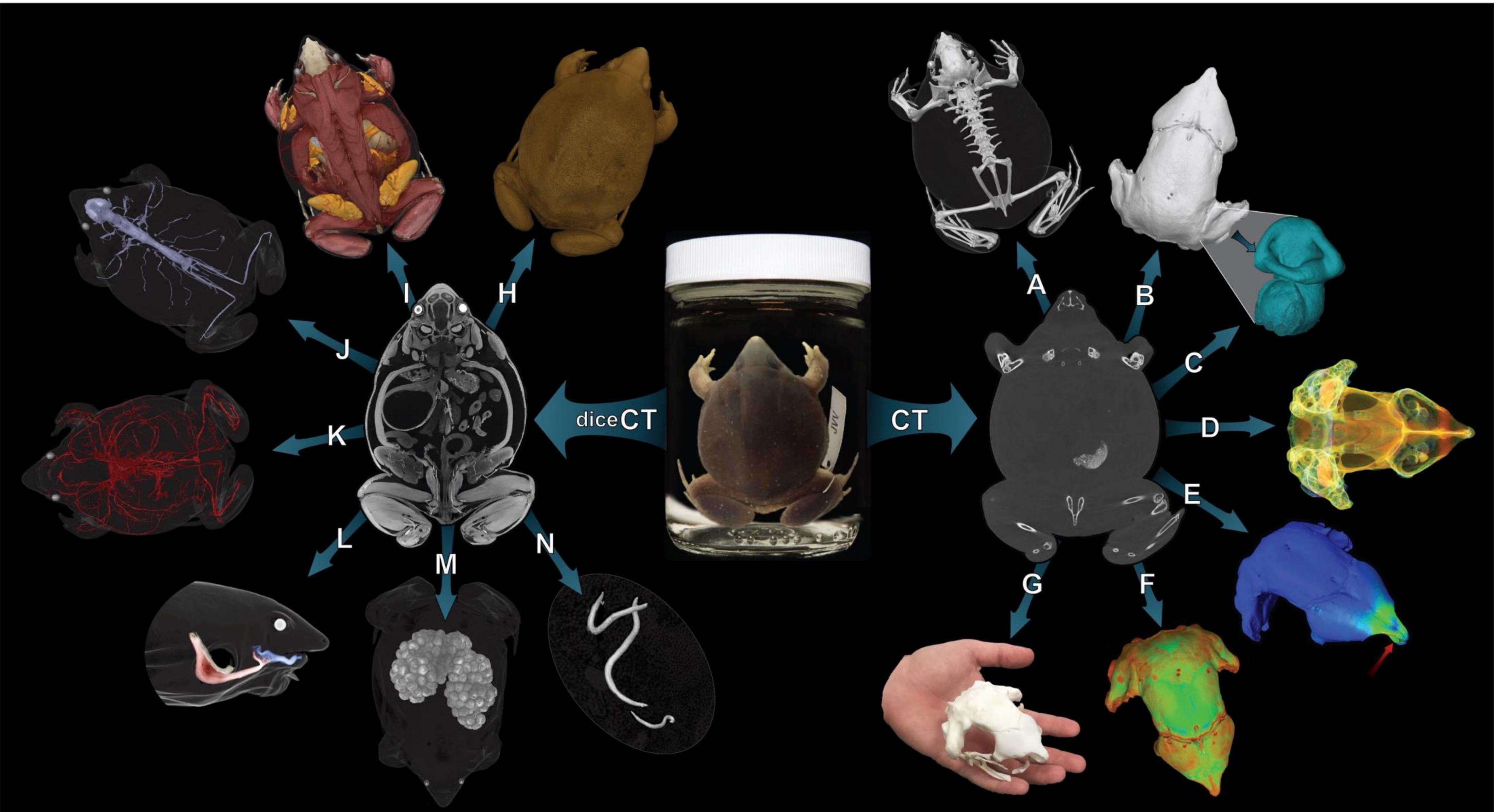
Most Basic Digitization Remains To be Done

- 3–4 billion specimens are housed in natural history collections.
- Core data are online for < 50%.
- Many fewer specimens are georeferenced, imaged.
- Linkages among data types are typically limited and inconsistent.
- Special collections are largely untouched.

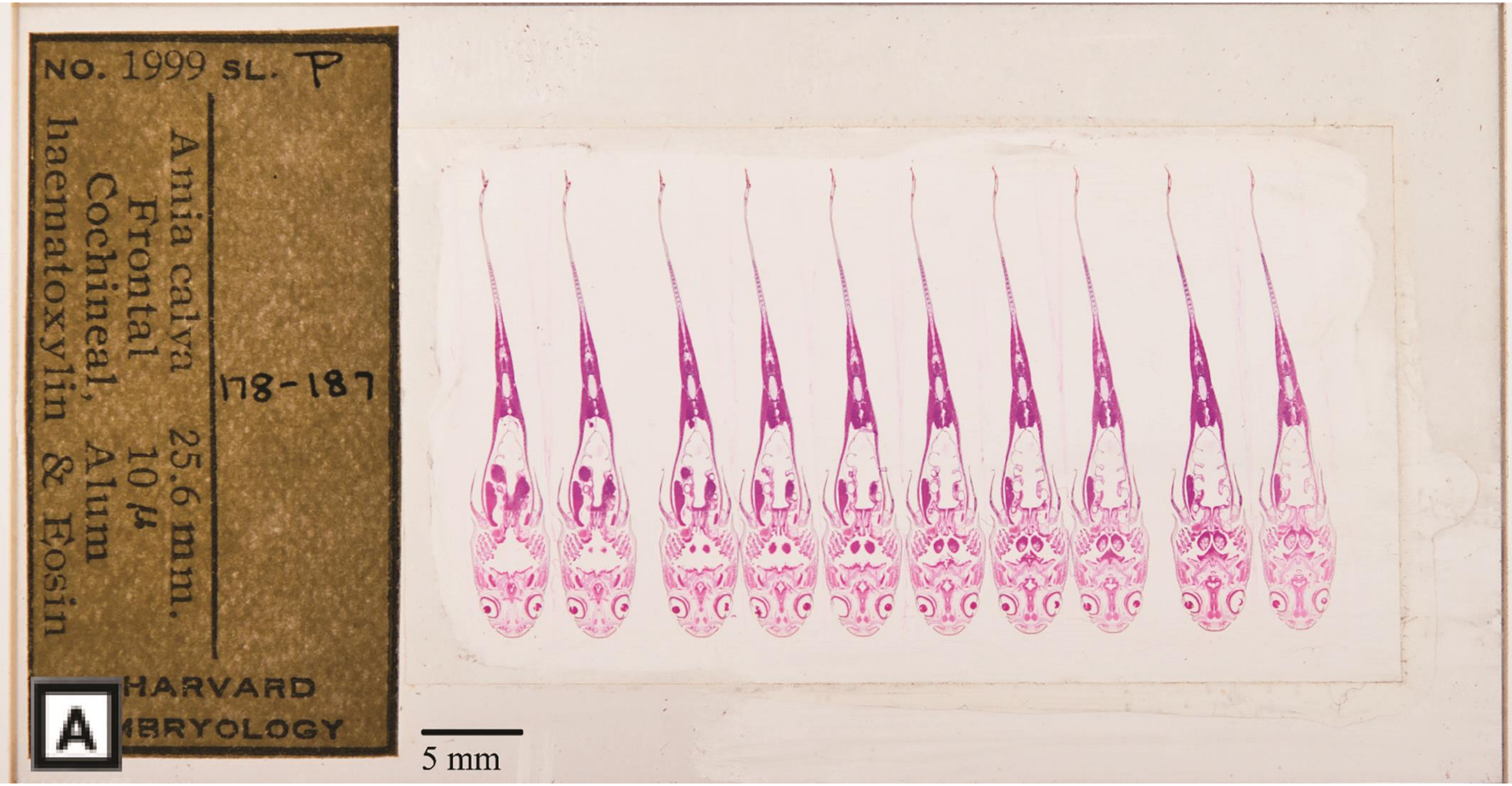
Distributed System of Scientific Collections (DISSCo)

- 114 European museums in 21 countries
- 1.5 billion specimens!
- 2018-2022: Preparatory phase (Innovation and Consolidation programmes), e.g., *European Open Science Cloud Summit,* 11 June 2018
- 2019-2024: Construction phase/programme
- 2024-2025: Deployment phase

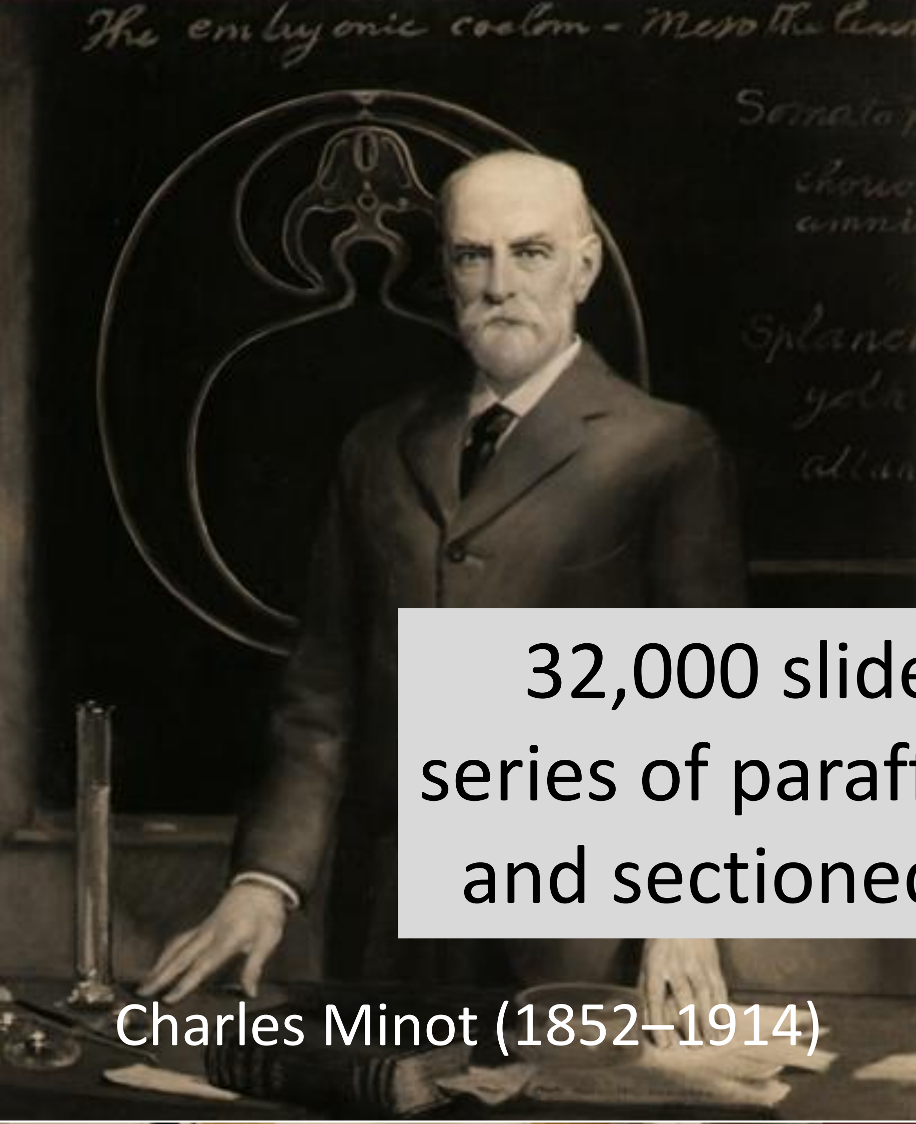
oVert TCN
Microcomputed Tomography (µCT)

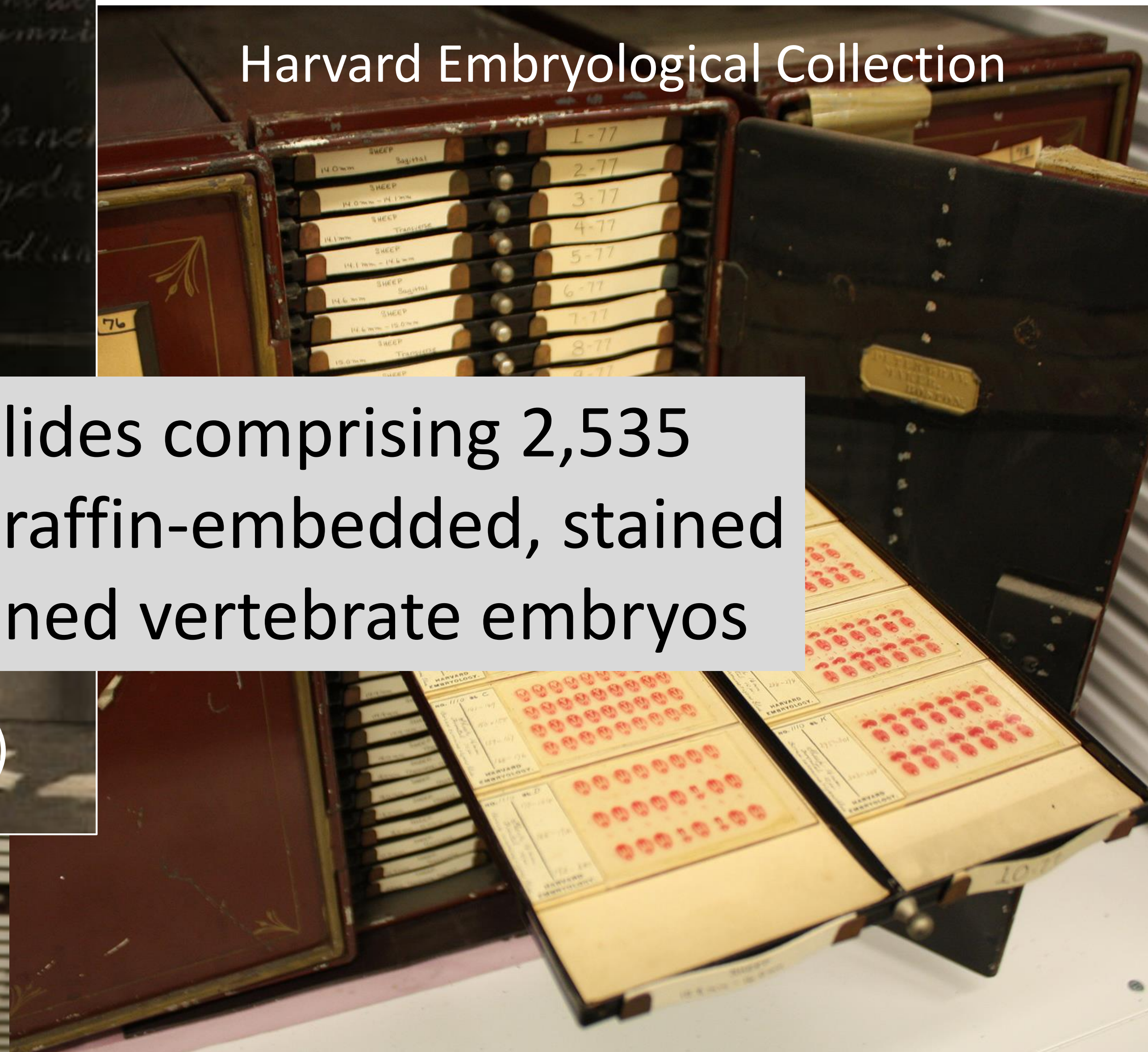


Scanning Microscope Slides



FMNH: ca. 400,000 slides, including 10,000 slides of type specimens.
MCZ: > 32,000 slides of the Harvard Embryological Collection (Charles Minot).
HUH: > 15,000 slides depicting wood anatomy, fungi, diatoms, insect pests, etc.
NMNH: > 2,300 types/paratypes on slides and > 10,000 histological slides just for IZ.





32,000 slides comprising 2,535 series of paraffin-embedded, stained and sectioned vertebrate embryos

BIOLOGY LETTERS

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Research

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Cite this article: Sanger TJ, Gredler ML, Cohn MJ. 2015 Resurrecting embryos of the tuatara, *Sphenodon punctatus*, to resolve vertebrate phallus evolution. *Biol. Lett.* **11**: 20150694. http://dx.doi.org/10.1098/rsbl.2015.0694

Received: 12 August 2015
Accepted: 30 September 2015

Subject Areas:
developmental biology, evolution

Evolutionary developmental biology

Resurrecting embryos of the tuatara, *Sphenodon punctatus*, to resolve vertebrate phallus evolution

Thomas J. Sanger[1], Marissa L. Gredler[2] and Martin J. Cohn[1,2,3]

[1]Department of Molecular Genetics and Microbiology, [2]Department of Biology, and [3]Howard Hughes Medical Institute, University of Florida, PO Box 103610, Gainesville, FL 32610, USA

The breadth of anatomical and functional diversity among amniote external genitalia has led to uncertainty about the evolutionary origins of the phallus. In several lineages, including the tuatara, *Sphenodon punctatus*, adults lack an intromittent phallus, raising the possibility that the amniote ancestor lacked external

BIOLOGICAL REVIEWS

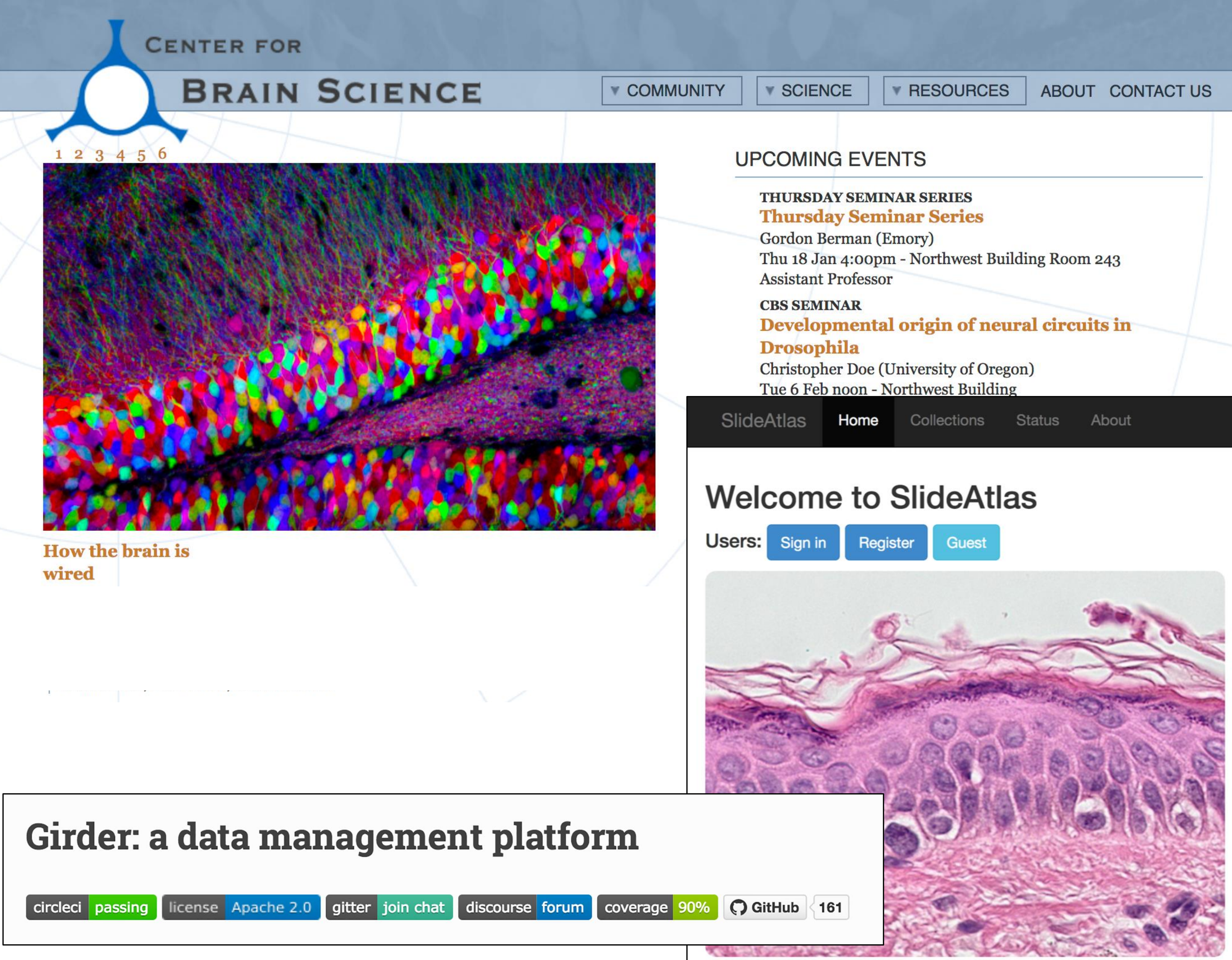
Cambridge Philosophical Society

Biol. Rev. (2015), pp. 000–000.
doi: 10.1111/brv.12187

Fishing for jaws in early vertebrate evolution: a new hypothesis of mandibular confinement

Tetsuto Miyashita*

Department of Biological Sciences, University of Alberta, Edmonton, Alberta T6G 2E9, Canada



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Thu 18 Jan 4:00pm - Northwest Building Room 243
Assistant Professor
CBS SEMINAR
Developmental origin of neural circuits in Drosophila
Christopher Doe (University of Oregon)
Tue 6 Feb noon - Northwest Building
How the brain is wired
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gitter join chat
discourse forum
coverage 90%
GitHub 161

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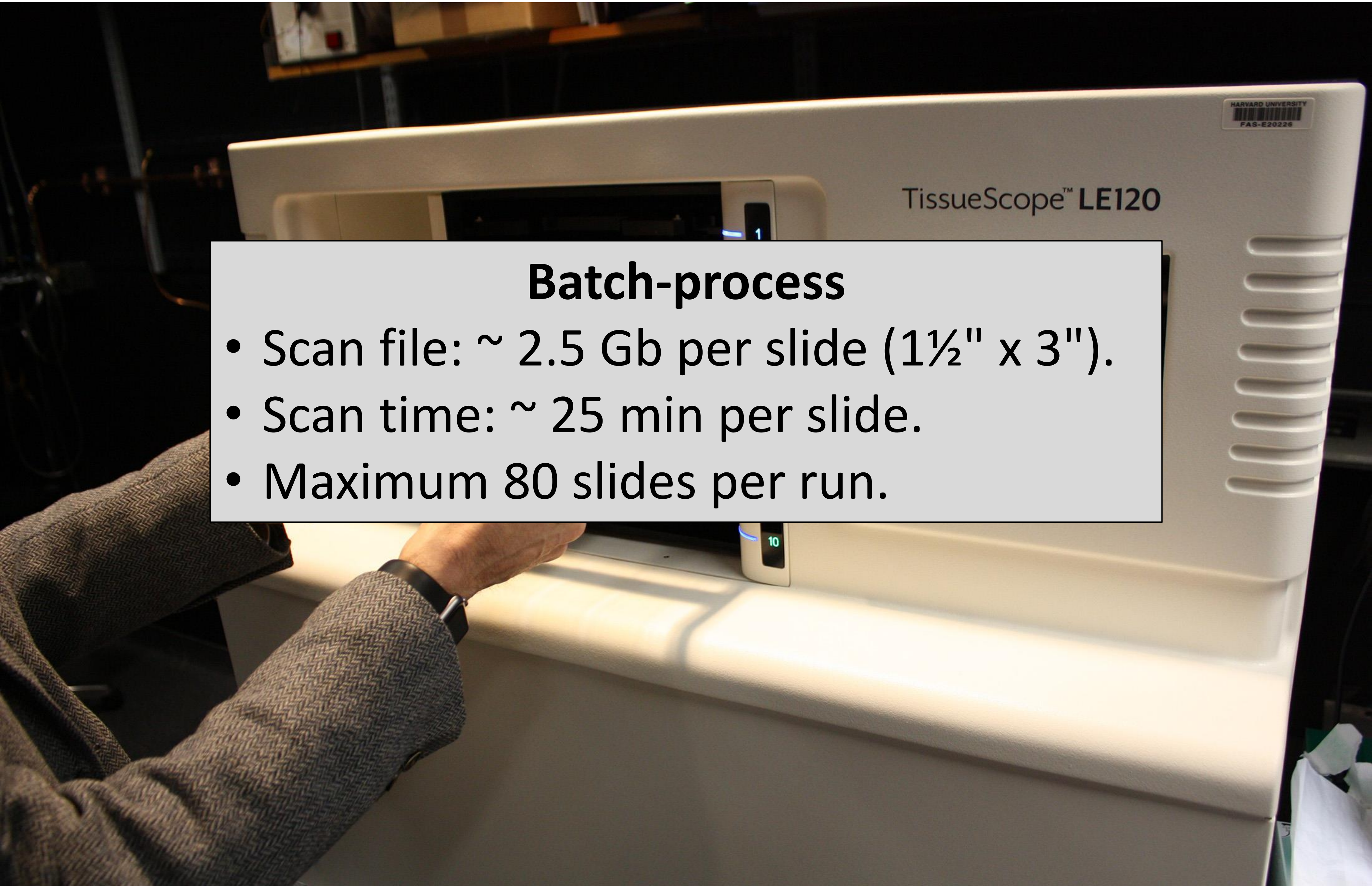

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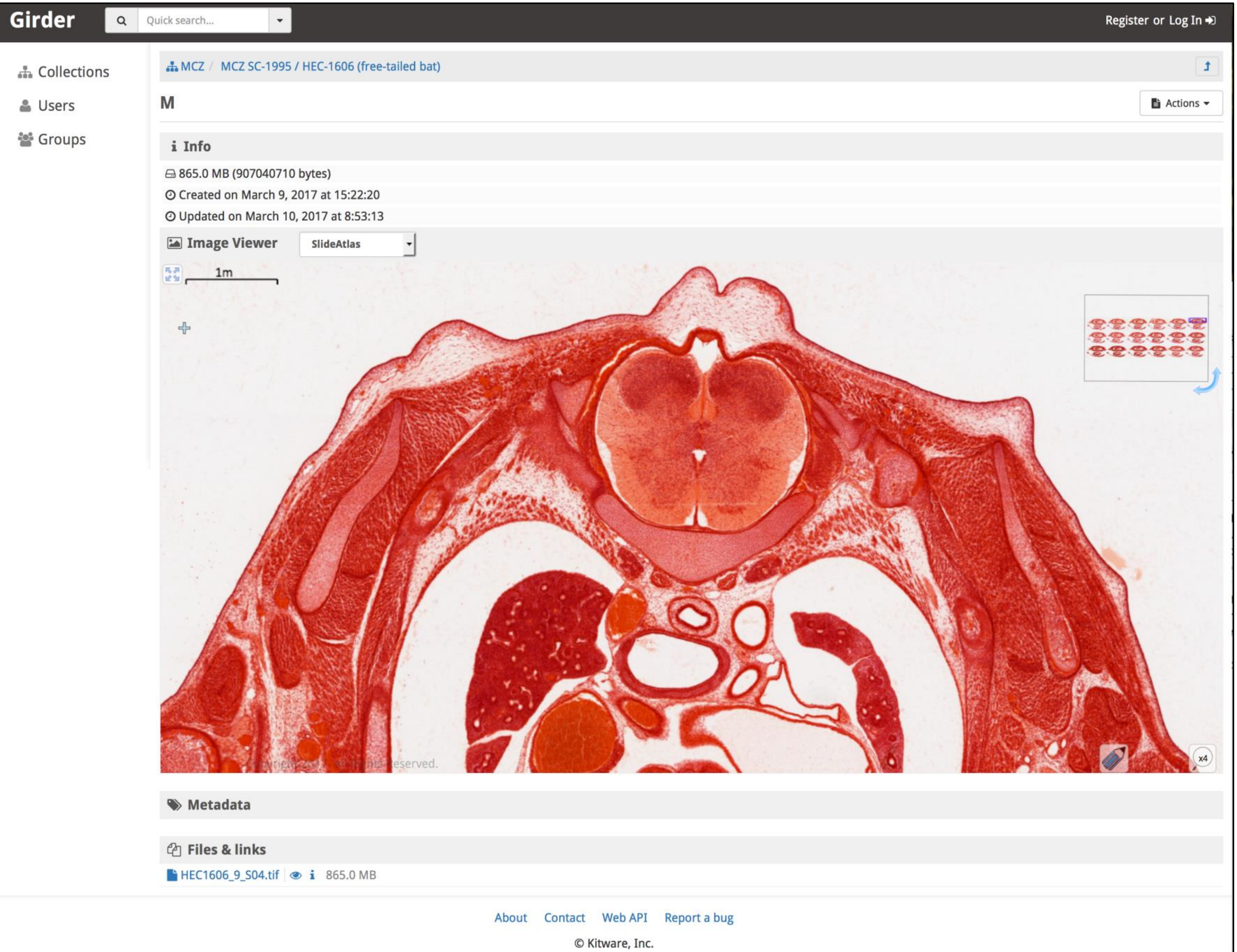
- Scan time: ~ 25 min per slide.
- Maximum 80 slides per run.

Dark Data No More



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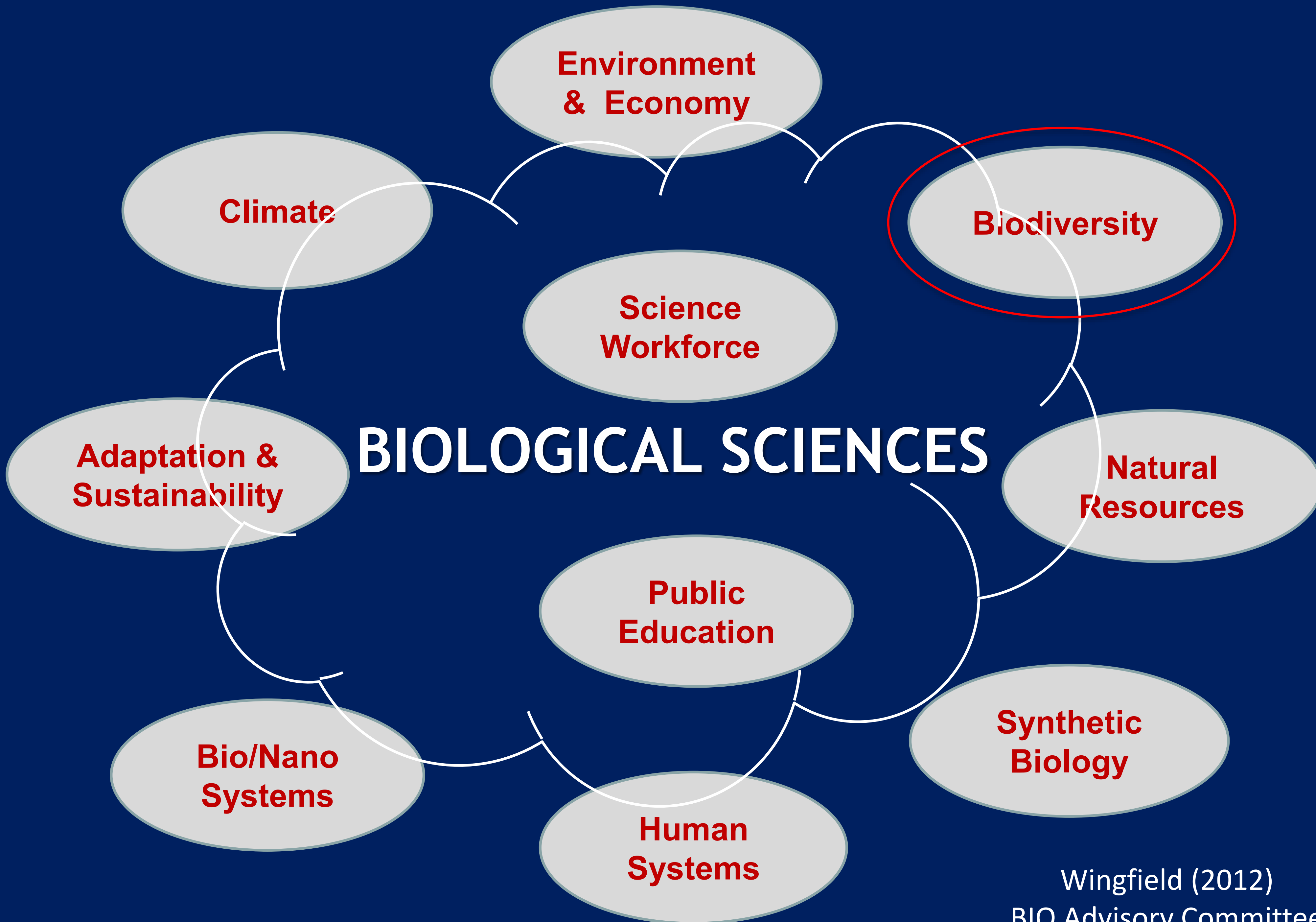
Ultimate Goal:
Linking Research to Collections*

* Wingfield (2012)
BIO Advisory Committee

Protein ⟹ alignment ⟹ phylogenetics ⟹ sequence ⟹ GenBank ⟹ vouchered specimen ⟹ museum

Challenges Facing Humanity in the Next 50 Years



Wingfield (2012)
BIO Advisory Committee

“e-research infrastructure for biodiversity knowledge generation”

PHILOSOPHICAL TRANSACTIONS B

Biodiversity analysis in the digital era

“integration of various taxon-level data types (genome, morphology, distribution and species interactions) within a phylogenetic and environmental framework…. Living in this future will require the adoption of new ways of integrating scientific knowledge into societal decision making.”

rstb.ro

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1600,

Opini

Cite this
Moritz C.
digital era
20150337
http://dx.

Accepted: 2 February 2016

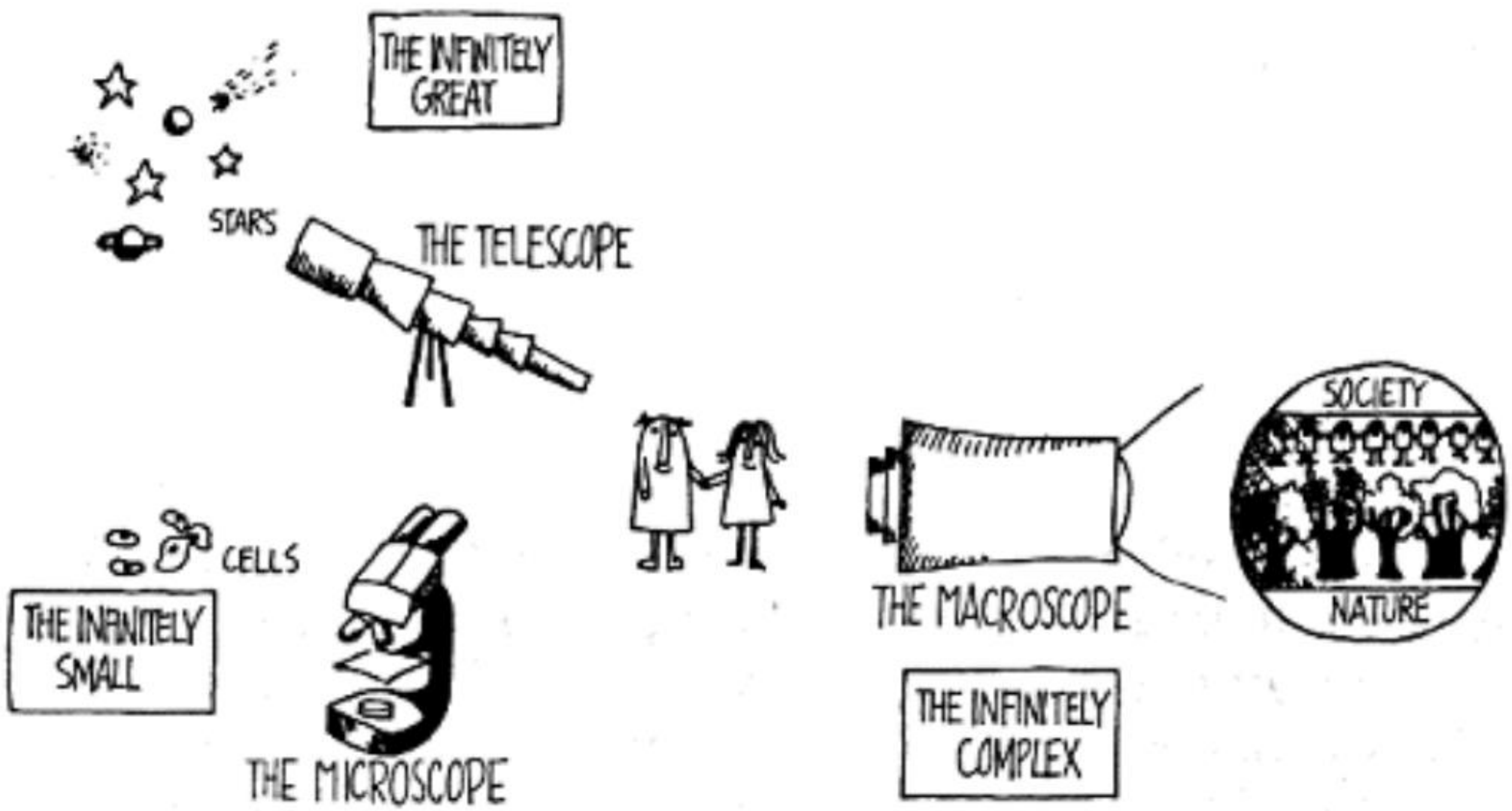
One contribution of 16 to a theme issue ‘From DNA barcodes to biomes’.

Subject Areas:

l look
matics
-level
tions)
g the
data scaling problem in ecology, this integrative framework will provide richer information and fast learning to enable a deeper understanding of biodiversity evolution and dynamics in a rapidly changing world. The Atlas of Living Australia is used as one example of the advantages of progressing towards this future. Living in this future will require the adoption of new ways of integrating scientific knowledge into societal decision making.

This article is part of the themed issue ‘From DNA barcodes to biomes’.

The Macroscope

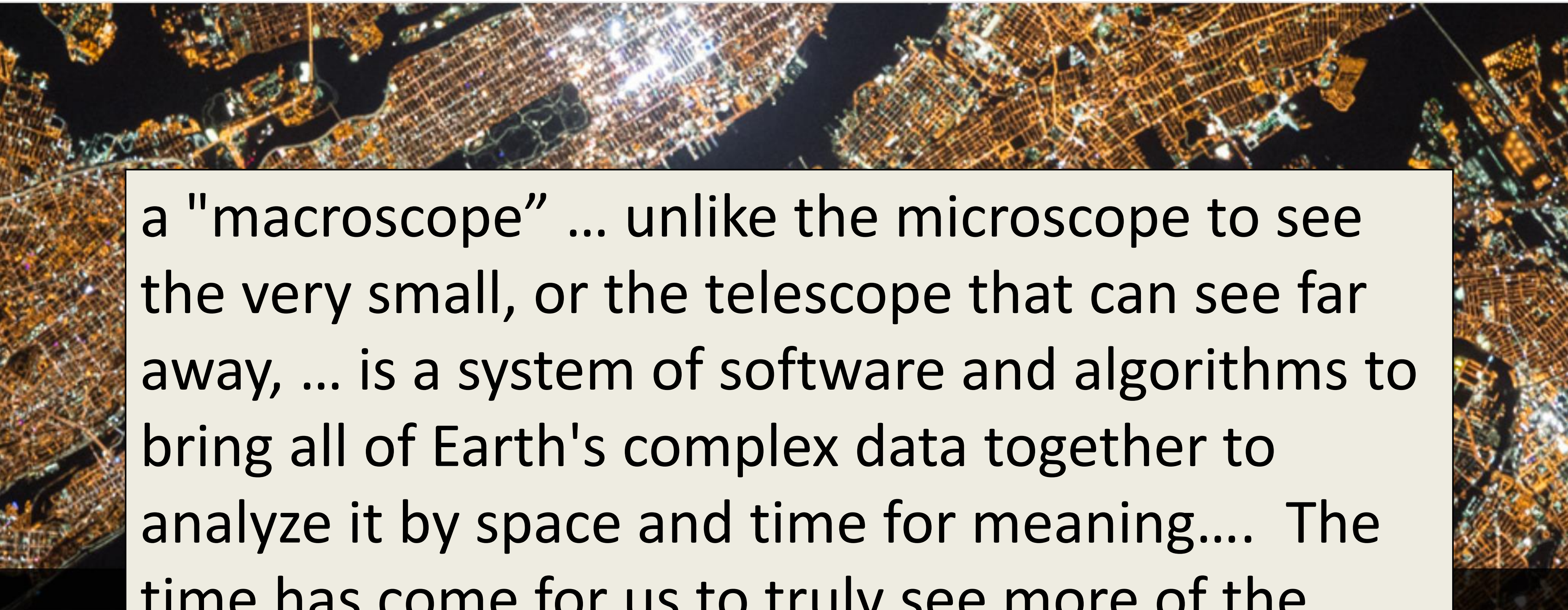


The macroscope can be considered the symbol of a new way of seeing, understanding, and acting.

Joël de Rosnay (1975)

IBM 5 in 5 | Five innovations that will help change our lives within five years

Macroscopes will help us understand Earth's complexity in infinite detail



a "macroscope" … unlike the microscope to see the very small, or the telescope that can see far away, … is a system of software and algorithms to bring all of Earth's complex data together to analyze it by space and time for meaning…. The time has come for us to truly see more of the world thanks to being able to digitize and collect new sources of data from millions of connected objects….

In

org … lex

da… ng.

We call this a "macroscope" – but unlike the microscope to see the very small, or the telescope that can see far away, it is a system of software and algorithms to bring all of Earth's complex data together to analyze it by space and time for meaning.

FLORISTICS

An integrated assessment of the vascular plant species of the Americas

Carme
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“What
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—Alexander von Humboldt (1)

...ernández de Oviedo’s chronicles (2) from 1526 contain the first European accounts

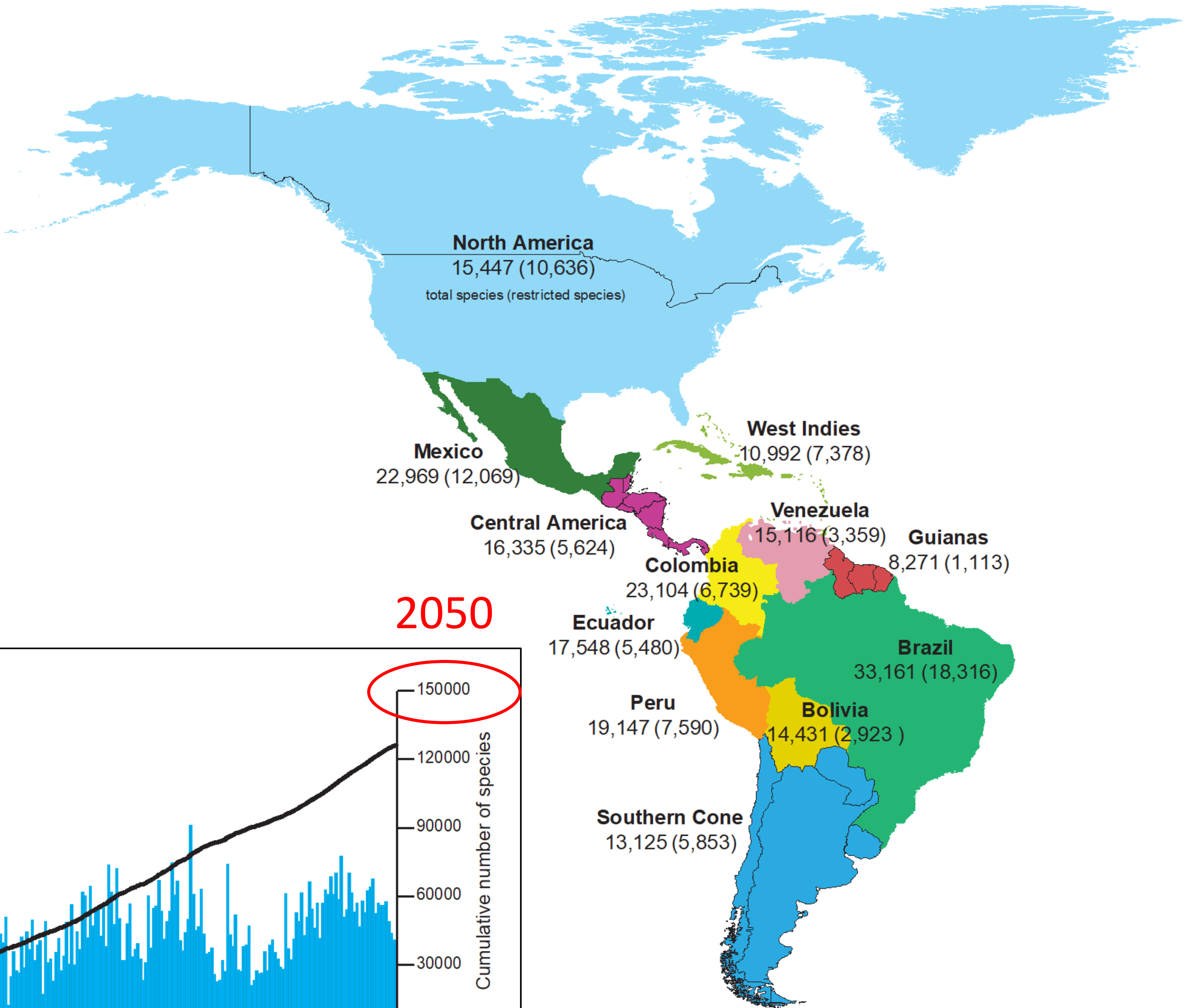
...preparing authoritative checklists often proved more difficult than anticipated, in view of the large amounts of data to be synthesized within them, and some of the projects took a decade or more to complete. Checklists are extensively used

larger than the 77,100 species recorded for Africa (23), which has an area twice its size. Although China has a surface area of similar size to the United States or Canada, its mostly temperate flora consisting of 30,426 species (24) is 97% larger than the flora of the United States and Canada combined.

Within the Americas, Brazil has the most diverse flora, with 33,161 species, followed by Colombia (23,104) and Mexico (22,969) (Fig. 1 and
...idaceae, ...eae with ...ig. S2A); ...(figs. S2 ...laceae is ...Andean ...of those ...bia 15%, ...s also the ...3%) and ...t diverse ...he most- ...te South- ...d Mexico ...in most ...America. ...azil (8%) ...(8%), the ...enezuela
...e family is Rubiaceae (7%), which is well represented in all tropical regions; second in diversity are Orchidaceae and Asteraceae (table S1). Fifty-two families are endemic or near endemic to the Americas, including the nearly endemic Berberidopsidaceae,

We present an integrated assessment of all known native species of vascular plants in the Americas. Twelve regional and national checklists … were merged into a single list. Our publicly searchable checklist includes 124,993 species…, which correspond to 33% of the 383,671 vascular plant species known worldwide.

Ulloa Ulloa et al., Science 358, 1614–1617 (2017)   22 December 2017



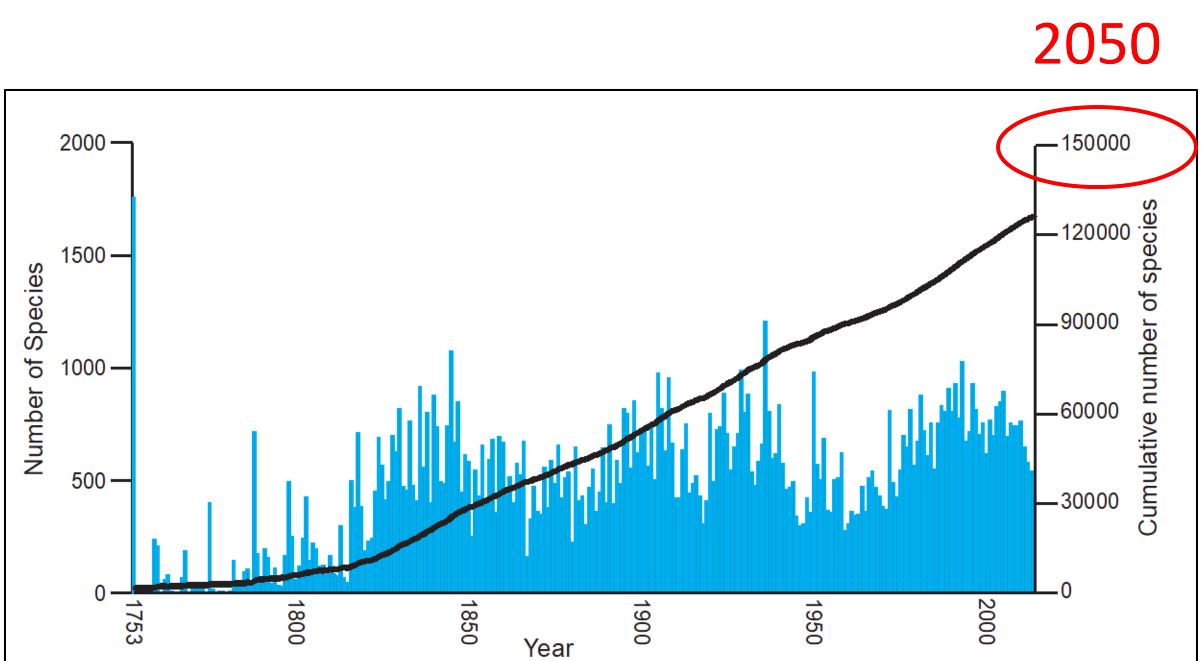


Fig. 4. Species described per year. The number of plant species (basionyms) described per year from 1753 to 2015 for the Americas list (blue bars), and the cumulative number of accepted species (black line).

The biomass distribution on Earth

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A census of the biomass on Earth is key for understanding the structure and dynamics of the biosphere. However, a global, quantitative view of how the biomass of different taxa compare with one another is still lacking. Here, we assemble the overall biomass composition of the biosphere, establishing a census of the

We assemble a census of the biomass of all kingdoms of life. This analysis provides a holistic view of the composition of the biosphere and allows us to observe broad patterns over taxonomic categories, geographic locations, and trophic modes.

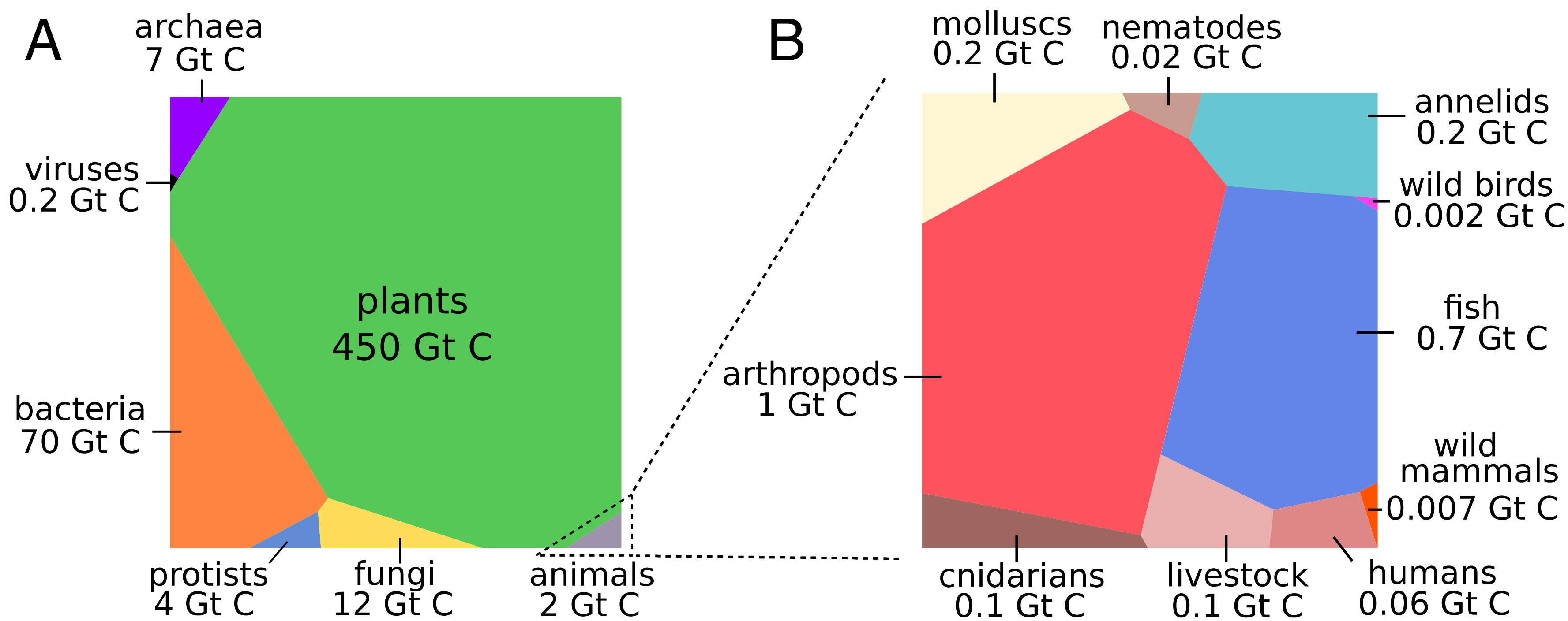
One of the most fundamental efforts in biology is to describe the composition of the living world. Centuries of research have yielded an increasingly detailed picture of the species that inhabit our planet and their respective roles in global ecosystems. In describing a complex system like the biosphere, it is critical to quantify the abundance of individual components of the system (i.e., species, broader taxonomic groups). A quantitative description of the distribution of biomass is essential for taking stock of biosequestered carbon (1) and modeling global biogeochemical cycles (2), as well as for understanding the historical effects and future impacts of human activities.

In the past decade, several major technological and scientific advances have facilitated an improved quantitative account of the biomass on Earth. Next-generation sequencing has enabled a more detailed and cultivation-independent view of the composition of natural communities based on the relative abundance of

Table 1, we report our best estimates for the biomass of each taxon analyzed. We use biomass as a measure of abundance, which allows us to compare taxa whose members are of very different sizes. Biomass is also a useful metric for quantifying stocks of elements sequestered in living organisms. We report biomass using the mass of carbon, as this measure is independent of water content and has been used extensively in the literature (6, 16, 17). Alternative measures for biomass, such as dry weight, are discussed in *Materials and Methods*. For ease of discussion, we report biomass in gigatons of carbon, with 1 Gt C = 10^{15} g of carbon. We supply additional estimates for the number of individuals of different taxa in *SI Appendix*, Table S1.

SYSTEMS BIOLOGY

Global biomass of different forms of life (A) and different animal taxa (B)*



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* "We estimate that the contribution of reptiles and amphibians to the total animal biomass is negligible…."

Building—and Sustaining—the Macroscope Will Require Targeting Diverse User Communities Beyond Natural History & Systematics

- Conservation and land-use planning
- Climate change and invasive species
- Medicine (infectious disease, drug discovery, etc.)
- Agriculture and forestry
- Physiology, developmental biology, ecology, etc.
- Biologically inspired engineering
- K‑12 education