

Persistent Hardware Descriptors: persistent identification of instrument instances and hardware configurations

Caterina Strambio-De-Castillia



Anita Bandrowsky



James Chambers



David Grunwald



Nate Herzog



Josh Moore



Judith Lacoste



Adrian Zai

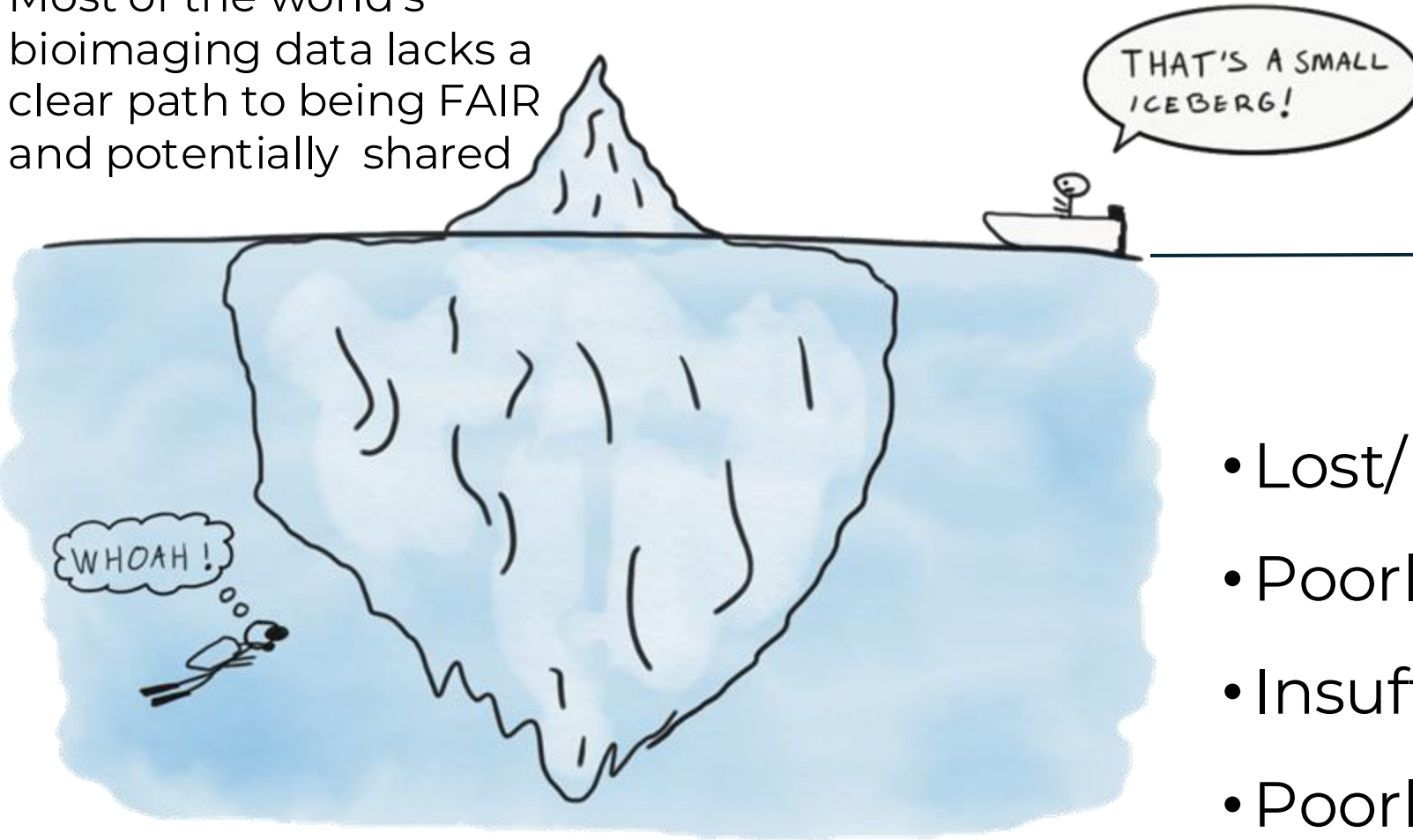
Most of the world's bioimage data is not FAIR and is not ready to be shared

Most of the world's bioimaging data lacks a clear path to being FAIR and potentially shared

**Available FAIR
bioimage data...**

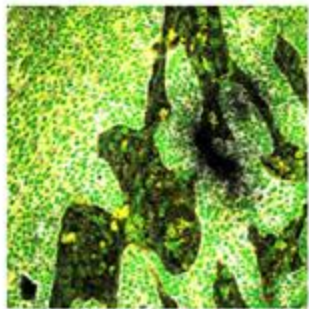
... hidden treasure

- Lost/Misplaced/Fragmented
- Poorly annotated
- Insufficient metadata
- Poorly managed

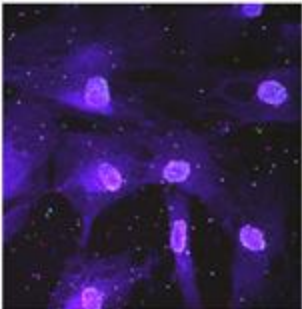


Bioimages: complex data and metadata

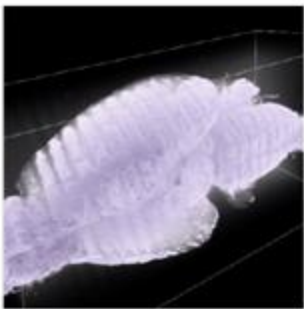
Diversity in imaging applications/modalities



Multiplexed



Spatial tx

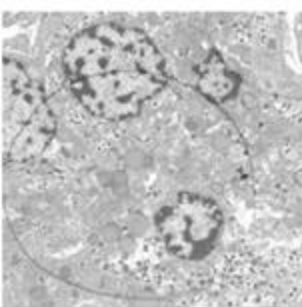


Light-sheet

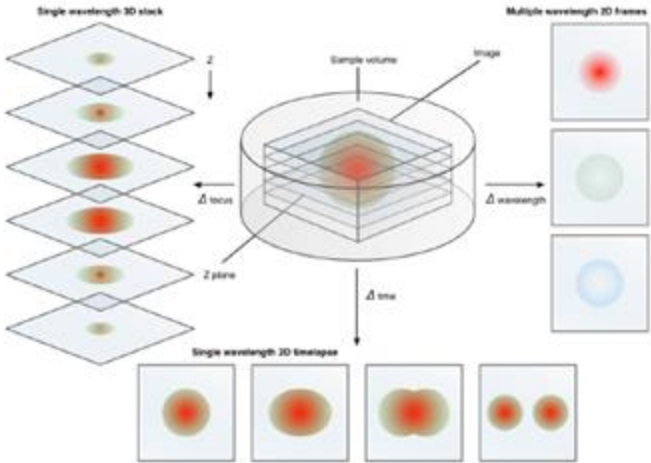
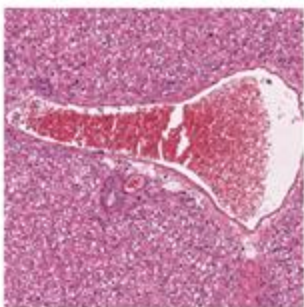
Infrared



Scanning EM



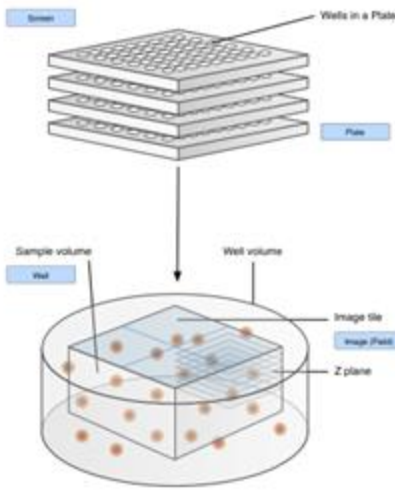
Digital pathology



5D Images

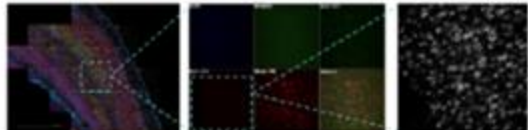
3D, multi-color, movies, or any combination

<https://ome-model.readthedocs.io/>



High-content Screen

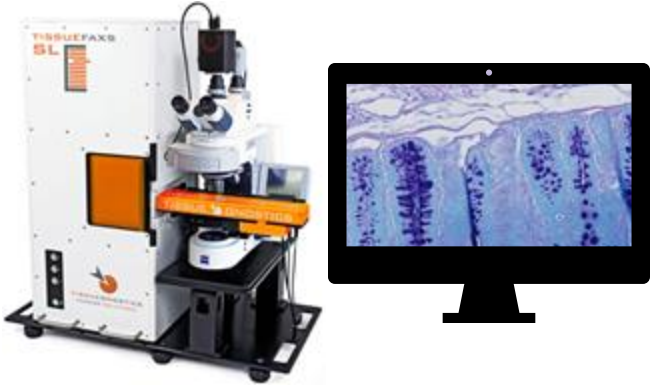
Complex Acquisitions



Single-cell tissue

Microscopy Core Facilities

Full-service core-facilities



- Digital pathology (brightfield and fluorescence slide scans)
- Spatial omics
- Multiplexed FISH/RNA Scope

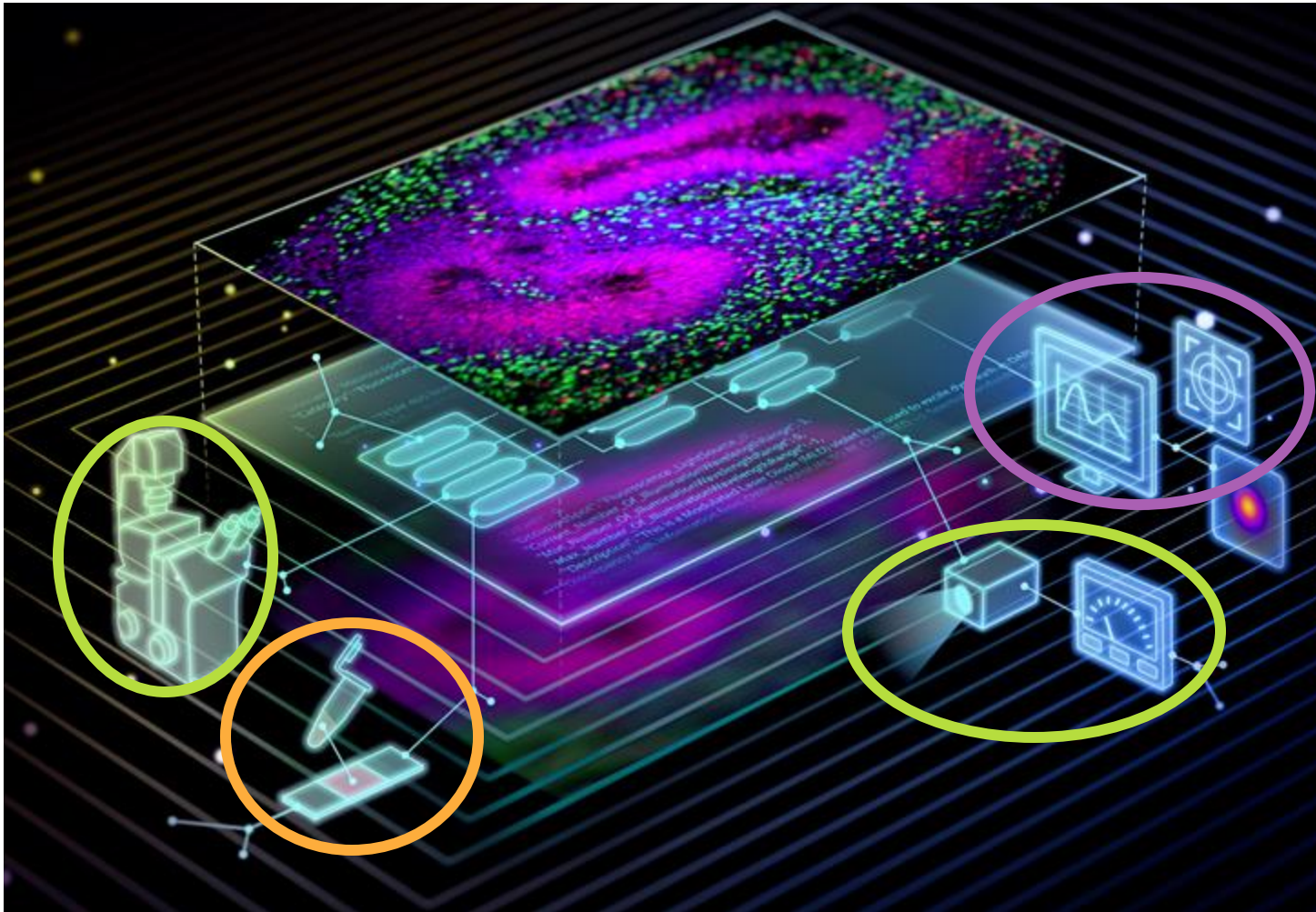
Researchers using microscopes at core-facilities and in individual labs



- Widefield microscopy
- Confocal microscopy
- Super-resolution microscopy
- Live-cell imaging

- Multiple production sites
- Diverse samples + experimental conditions
- Thousands of diverse microscopes with multiple parts
- Multiple modalities
- >150 file formats
- TB, PB,
- Multiple analysis software
- Need to integrate with other data-types

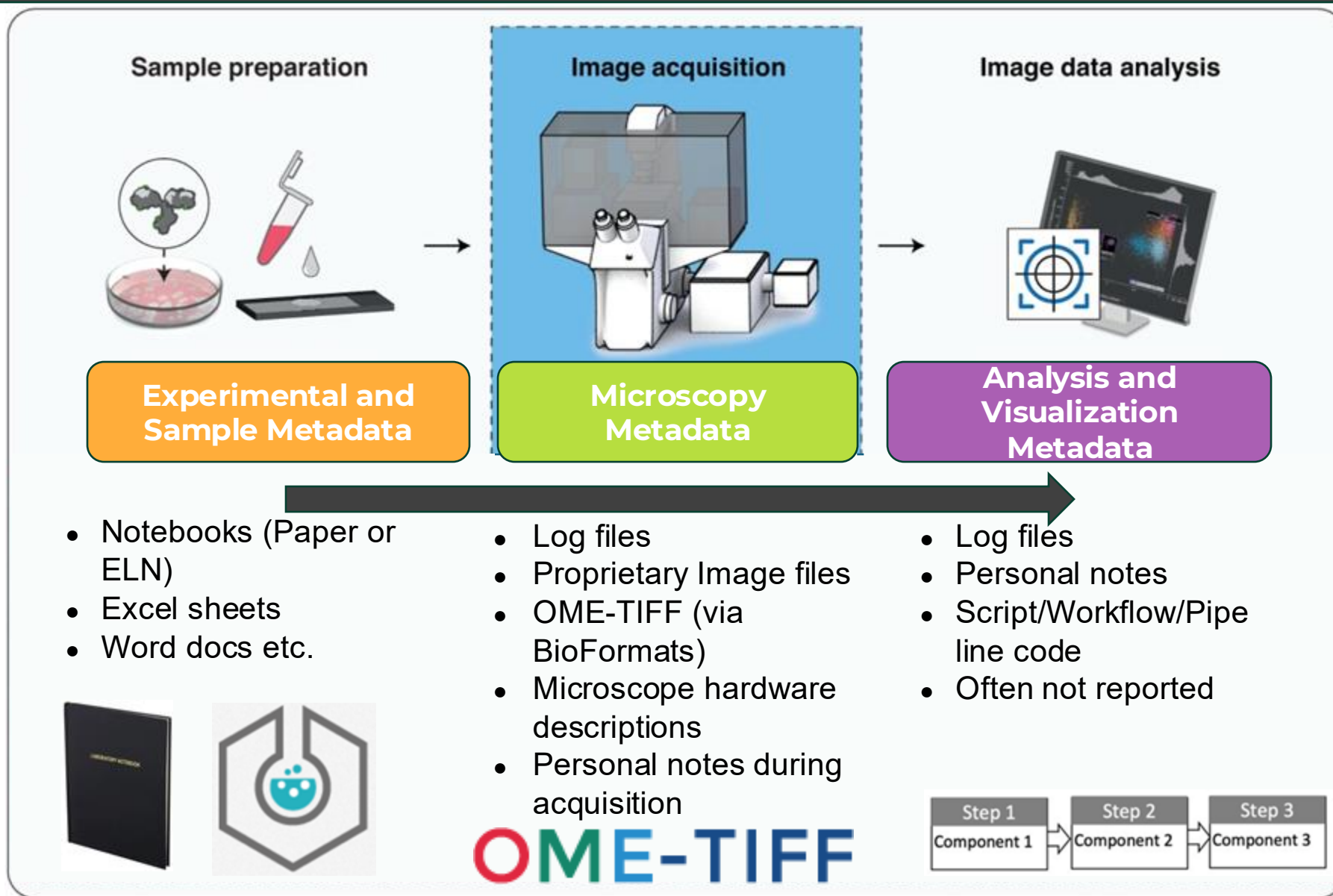
Biolmage Metadata



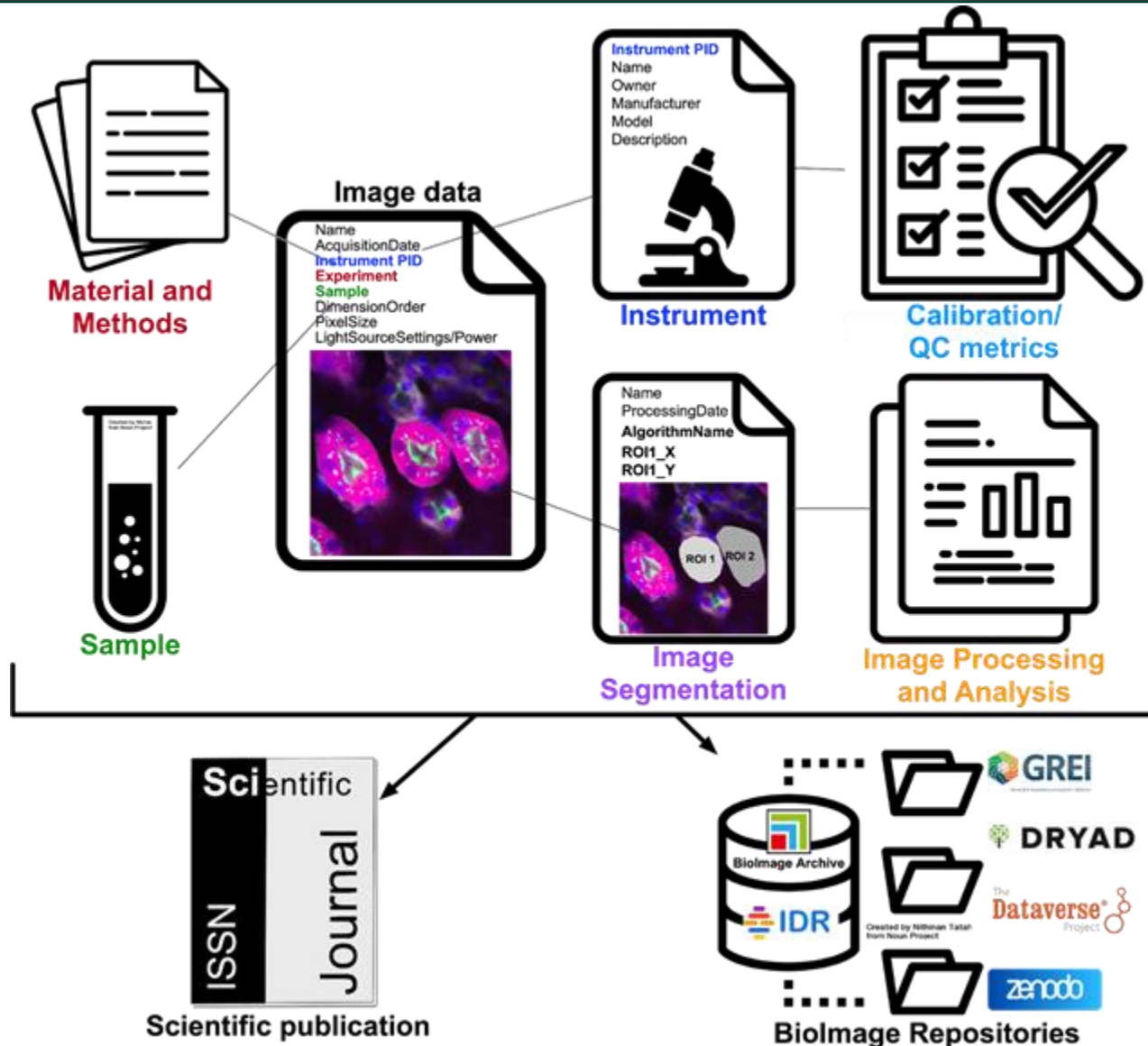
All information that is needed to interpret, evaluate the quality reproduce and share microscopy images

- Sample preparation
- Image Acquisition
 - Hardware configuration
 - Acquisition setting
 - Quality Control
- Image data processing and analysis

Fragmentation is the enemy

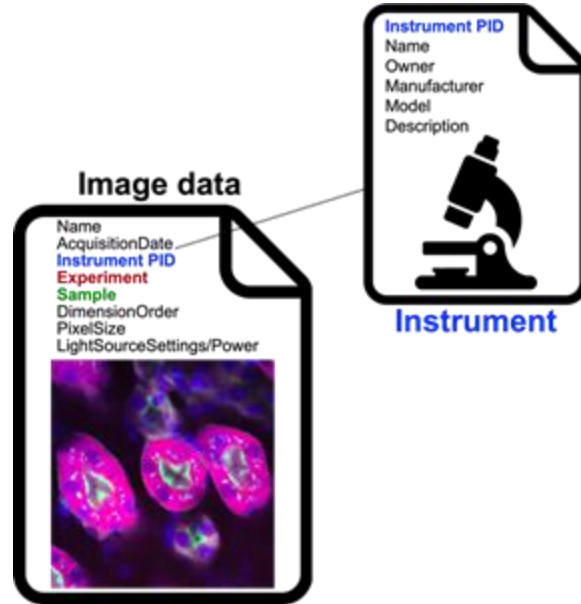


Where is bioimage metadata?



PIDs can help maintain links between different essential information

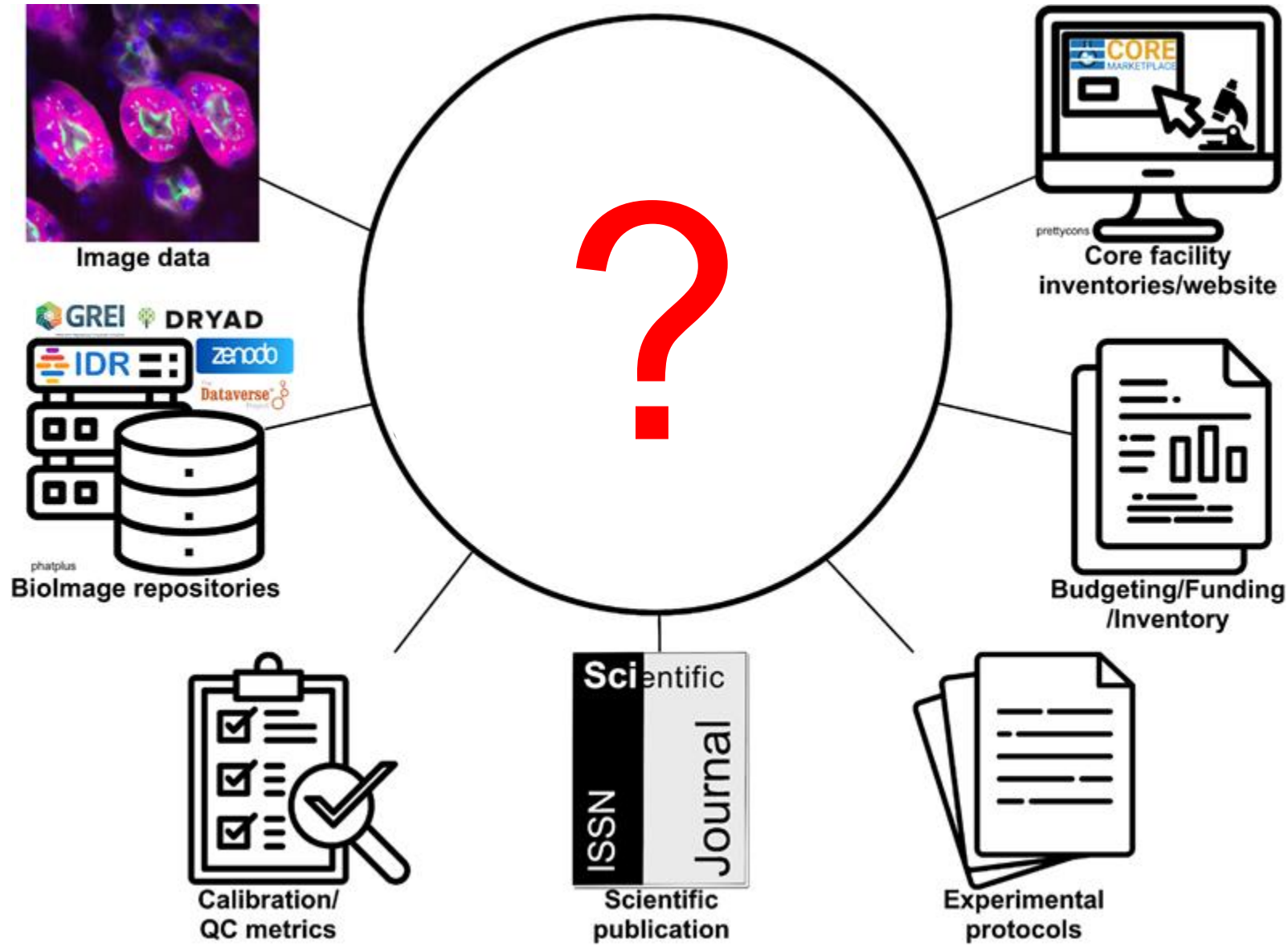
Persistent Hardware Descriptors help making data FAIR



Linked PIDs for

- **Instrument instance**
- **Instrument model**
- **Hardware configuration**

Labs and Core Facilities have different overlapping needs for the Instrument Data Management





BioImaging North America (BINA)



Mission: Engaging bioimaging scientists across North America by creating an inclusive and supportive community to share, advance and succeed together.



Events and Newsletter each month!

> 2000 MEMBERS

8 Working Groups: **Builders**, **Communications**, **Corporate Partners**, **Diversity, Equity & Inclusion**, **Early Career**, **Image Informatics**, **Quality Control & Data Management**, **Training & Education**



www.BioImagingNorthAmerica.org/join



contact@bioimagingna.org


















[@BioimagingNA](https://twitter.com/BioimagingNA)





Quality Control & Data Management Working Group

 <p>Caterina Strambio De Castillia > <i>Chair</i> UMass Chan Medical School</p>	 <p>Claire Brown > <i>Board Liaison</i> McGill University</p>	 <p>Adán Guerrero > <i>Member</i> Universidad Nacional Autónoma de México, Cuernavaca</p>	 <p>Michael Halter > <i>Member</i> National Institute of Standards and Technology (NIST)</p>	 <p>Arturo Pimentel > <i>Member</i> Universidad Nacional Autónoma de México</p>	 <p>Damir Sudar > <i>Member</i> Oregon Health Science University</p>
 <p>Eduardo Brito Alarcón > <i>Member</i> Universidad Nacional Autónoma de México, Cuernavaca</p>	 <p>James Chambers > <i>Member</i> University of Massachusetts, Amherst</p>	 <p>Judith Lacoste > <i>Member</i> MIA Cellavie Inc.</p>	 <p>Caroline Miller > <i>Member</i> Histology, Imaging, and Image Analysis Consultant</p>	 <p>Kurt Weiss > <i>Member</i> University of Wisconsin-Madison</p>	
 <p>Alex Corbett > <i>Member</i> University of Exeter</p>	 <p>Nathalie Gaudreault > <i>Member</i> Allen Institute for Cell Science</p>	 <p>Glyn Nelson > <i>Member</i> Newcastle University</p>	 <p>Roland Nitschke > <i>Member</i> University of Freiburg</p>		

- Quantitative assessment and calibration of microscope performance,
- Rigorous record-keeping of data generation and processing conditions
- Connection of imaging dataset with machine-readable metadata describing its “provenance.”



BINA belongs to a network of international organizations spanning the globe



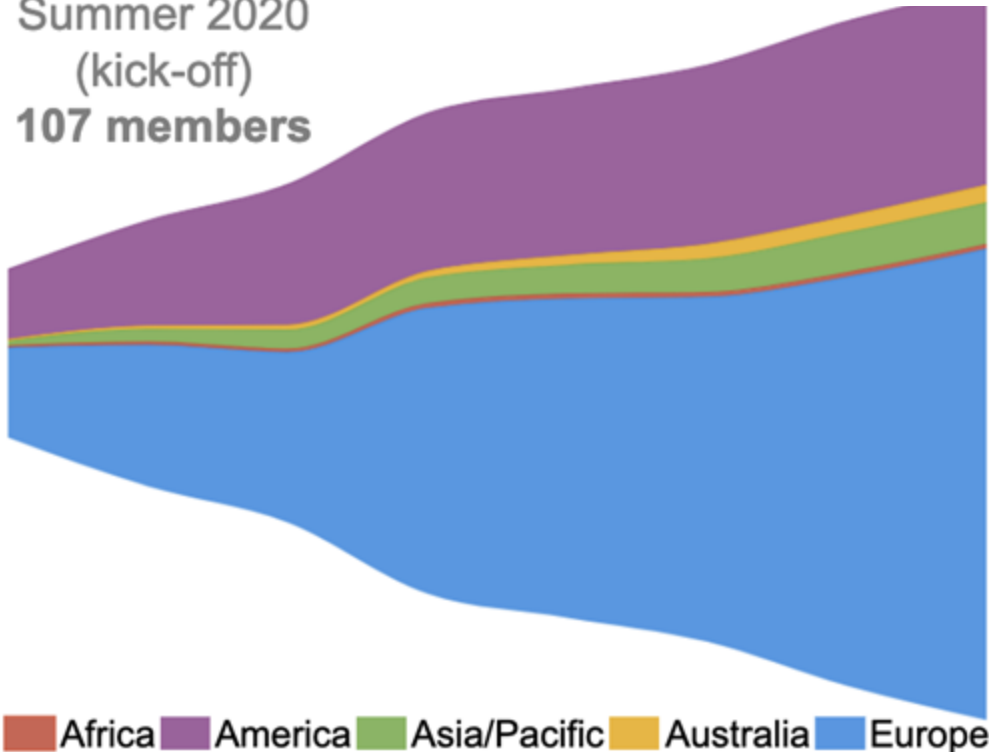
QUAREP-LiMi: industry and academia to promote quality, reproducibility and sharing-value



Membership growth

2025
> 600 members

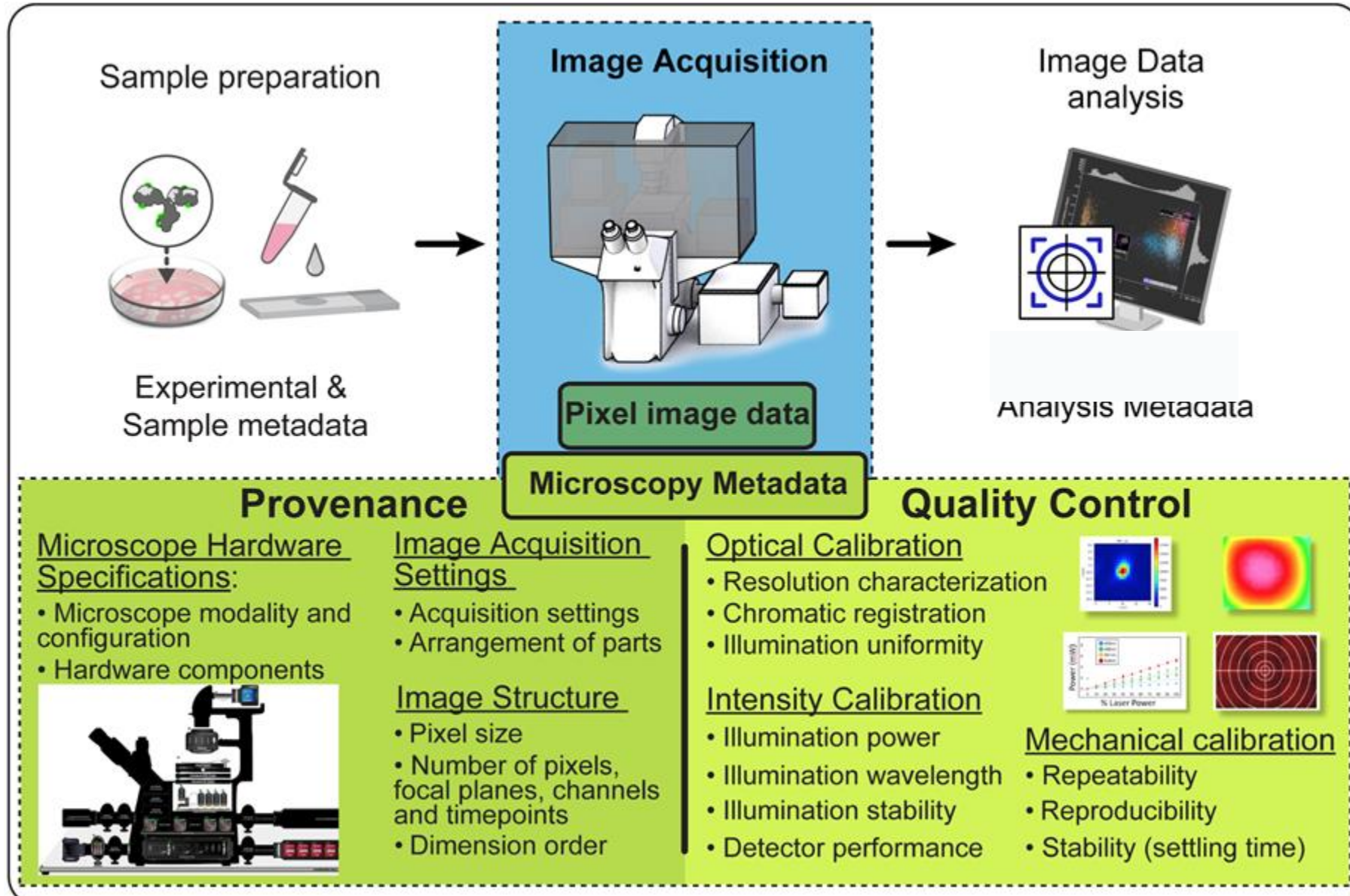
Summer 2020
(kick-off)
107 members



Membership composition



Image Acquisition Metadata



Community standards: Microscopy Metadata Specifications to expand the OME-data model



Comment

3 Dec 2021

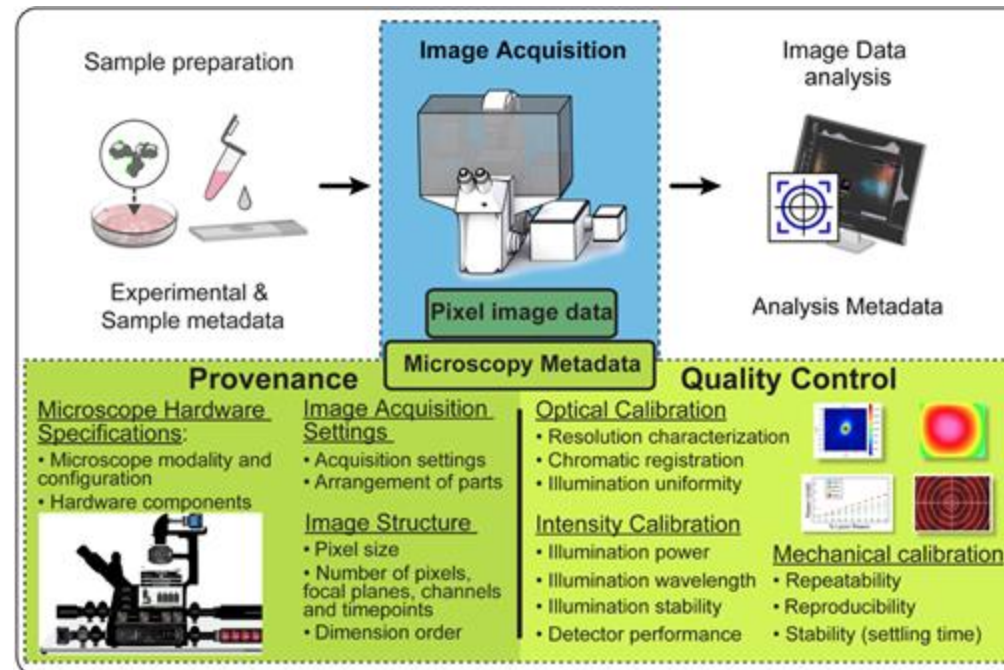
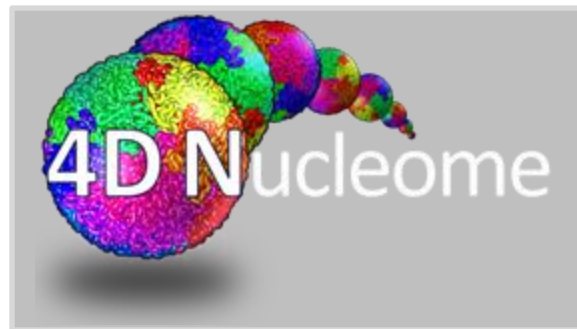
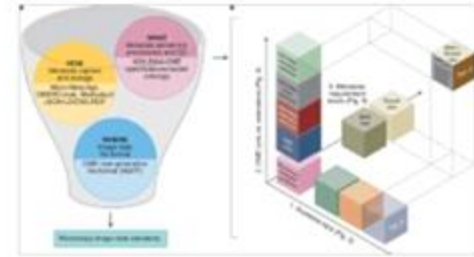
[Nature Methods](#)



Towards community-driven metadata standards for light microscopy: tiered specifications extending the OME model

Rigorous record-keeping and quality control are required to ensure the quality, reproducibility and value of imaging data. The 4DN Initiative and BINA here propose light Microscopy Metadata Specifications that extend the OME Data Model, scale with experimental intent and complexity, and make it possible for scientists to create comprehensive records of imaging experiments.

Mathias Hammer, Maximiliaan Huisman ... Caterina Strambio-De-Castillia



Hammer et al. (2021) *Nat Methods*;
<https://doi.org/10.1038/s41592-021-01327-9>



Community standards: Microscopy Metadata Specifications to expand the OME-data model



Comment

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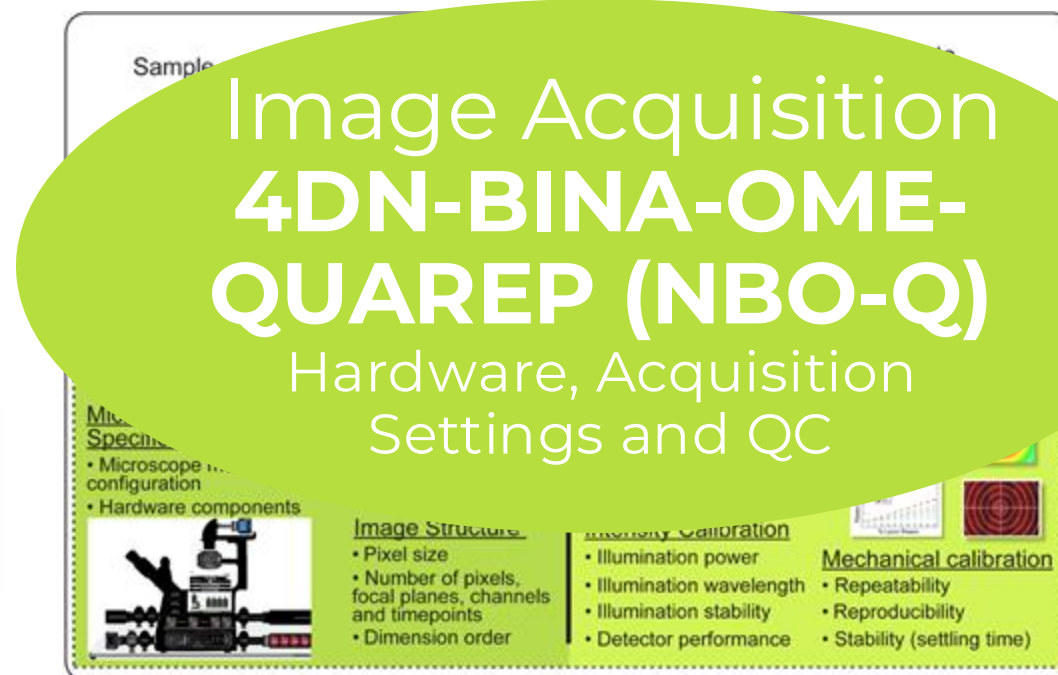
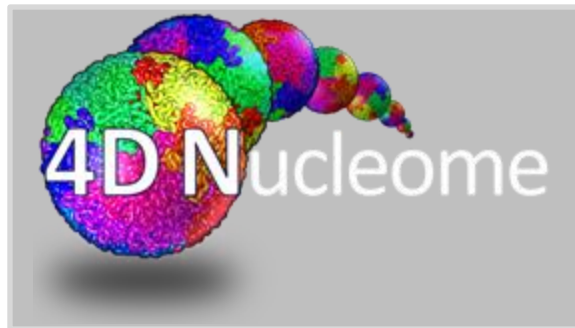
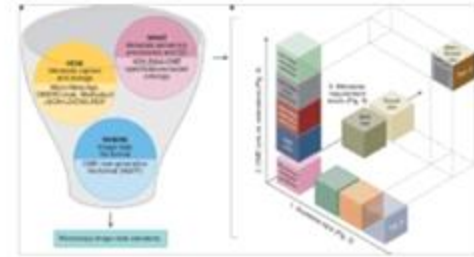
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QUAREP-LiMi

Hammer et al. (2021) *Nat Methods*;
<https://doi.org/10.1038/s41592-021-01327-9>



Community tools: Micro-Meta App can be used to capture NBO-Q Image Acquisition metadata



Brief Communication

Open Access

3 Dec 2021

[Nature Methods](#)



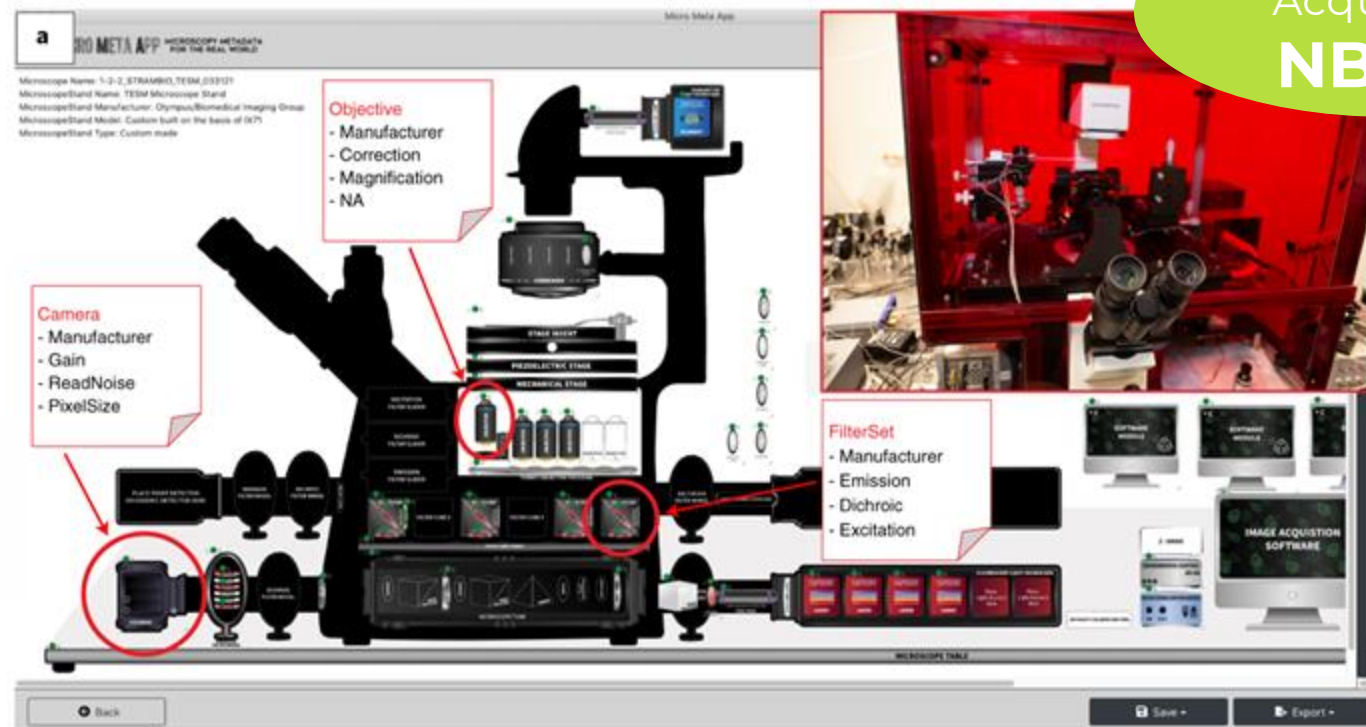
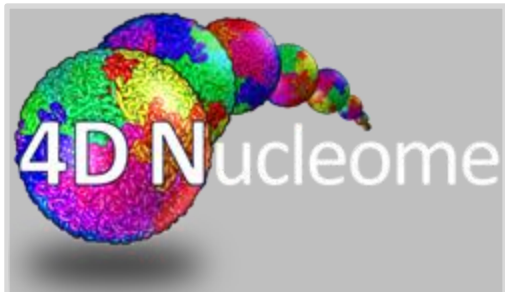
Micro-Meta App: an interactive tool for collecting microscopy metadata based on community specifications

Micro-Meta App is an intuitive, highly interoperable, open-source software tool designed to facilitate the extraction and collection of relevant microscopy metadata as specified by recent community guidelines.

Alessandro Rigano, Shannon Ehmsen ... Caterina Strambio-De-Castillia



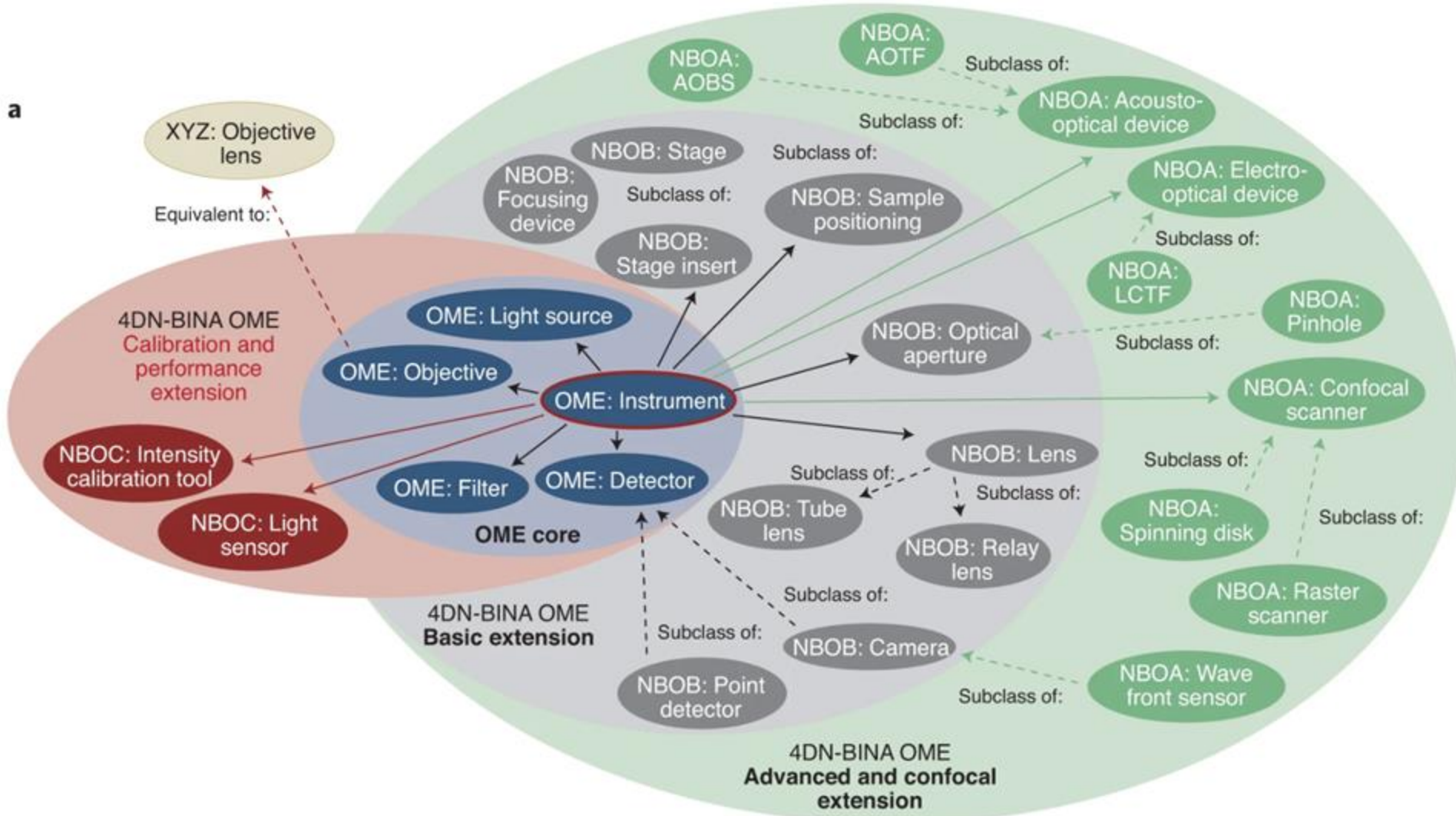
Image
Acquisition
NBO-Q



Community standards: Microscopy Metadata Specifications to expand the OME-data model



a



Community standards: Microscopy Metadata Specifications to expand the OME-data model



NBO-Q Light Microscopy Metadata Model

- Hosted and maintained by QUAREP-LiMi
- Covers hardware configuration, image acquisition settings and quality control metadata
- Revision process codified by Best Practices document
- Large community of imaging scientists, microscopy experts, manufacturers and standards organizations stakeholders

NBO-Q

Home / Working Groups / WG 7 – Metadata / NBO-Q

NBO-Q

Harmonize the description of light microscopy hardware, acquisition settings, and quality-control metrics in order to enhance image quality, reproducibility, and to fulfill the **FAIR** (Findable, Accessible, Interoperable, and Reusable) data principles.

[Join QUAREP WG7 \(Metadata\)](#)

Purpose

- Promote the harmonized generation and pre-publication management of image datasets from the ground up.
- Facilitate the deposition of microscopy datasets to public image data repositories (e.g., [BioImage Archive](#), [OME-Image Data Resource](#), [RIKEN SSBD](#), [Brain Image Library](#), etc.).
- Facilitate data reuse and the extraction of quantitative information from image data using advanced bioimage analysis techniques, including AI/ML.
- Define the light-microscopy implementation of the Image Acquisition module of the [Recommended Metadata for Biological Images](#) (REMBI) guidelines.

Deliverables

- A flexible and adaptable community-agreed vocabulary to describe microscopy hardware, image acquisition settings, and their associated quality control measurements.
- A metadata model to structure the vocabulary and organize the data.
- A set of machine-actionable representations of the metadata model leveraging the latest Linked Data technology.



Microscopy metadata is essential for image data QC, interpretation, analysis and sharing.

Governance gives QUAREP a path forward towards NBO-Q v3.0 in partnership with key stakeholders



The making of microscope camera standards

Cameras are a crucial part of microscopes and are also built into many kinds of instruments. To make their output comparable takes standards.

Vivien Marx

The academics and company scientists in the group Quality Assessment and Reproducibility for Instruments & Images in Light Microscopy (QUAREP-LiMi) are developing standards for microscope camera output.

As in other areas of standards development, working with companies is crucial, "after all they are the expert of the hardware they are producing," says Caterina Strambio-de-Castillia, a researcher at the University of Massachusetts Medical School's Program in Molecular Medicine and a Chan Zuckerberg Imaging Scientist, who spearheads this effort within QUAREP-LiMi. A separate story in this issue of *Nature Methods* about emerging standards in microscopy can be found in this issue.

Part of the work in developing standards for cameras in microscopy and imaging is about creating common definitions as a public resource. "The QUAREP-ers are moving on all that quite well," says Jason Swedlow of the University of Dundee, who



Cameras are a crucial part of microscopes and imaging systems. Agreeing on standards to provide defined descriptions for aspects such as gain or readout speed is tricky. Credit: W. Bulgar/Science Photo Library

technology feature

Check for updates

Imaging standards to ease reproducibility and the everyday

Imaging and microscopy technology advances in leaps and bounds. To address accumulated pain points, academics and companies are making headway on standards.

Vivien Marx

With a view to transparency and reproducibility in microscopy, scientists are hammering out standards to address, for instance, the surprises of fluctuating illumination power, the jungle of file formats, the mysteries of missing metadata and the diversity of camera outputs. A second story in this issue of *Nature Methods* focused on camera standards can be found here.

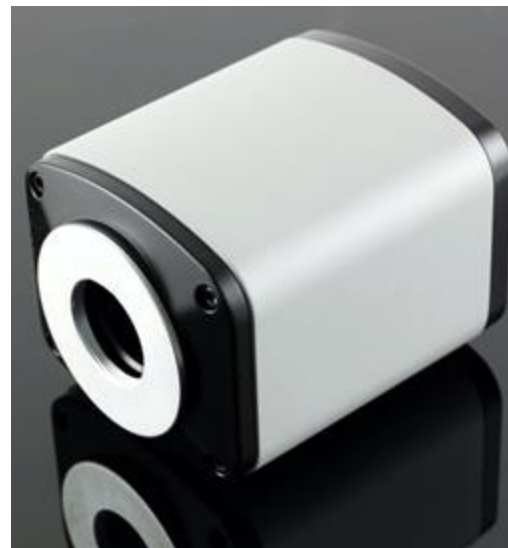
"We need standards," says Roland Nitschke of the University of Freiburg. Developing standards in imaging is a noble deed that can make some eyes glaze over even beyond the glare arising from long hours at the microscope. Those who feel they lack the time to pinch in on standards might be glad to hear that some not-so-distant developments stand to help microscopy users pull out their hair a bit less. Here's a peek at how some emerging standards could address real-world pain points.

Standards development is not a task for



Emerging standards in microscopy are being set up to address many pain points in the field. Credit: TEK Image/Science Photo Library

- **January – August 2022:** 10+ focused feedback sessions to build consensus
- **Completed first parsing of camera hardware specifications and image acquisition settings!**
- **Due SOON:** Revision of **4DN-BINA-OME-QUAREP** Camera Metadata model + vocabulary



Camera

- Manufacturer: **XYZ**
- Catalog Nr: **0000**
- Mount: **C-mount**
- FrameRate: **20 fps**
- ReadOutRate: **30 MHz**

EVIDENT
OLYMPUS

ZEISS

Leica
MICROSYSTEMS

Nikon

pcO.

Ψ Scientifica

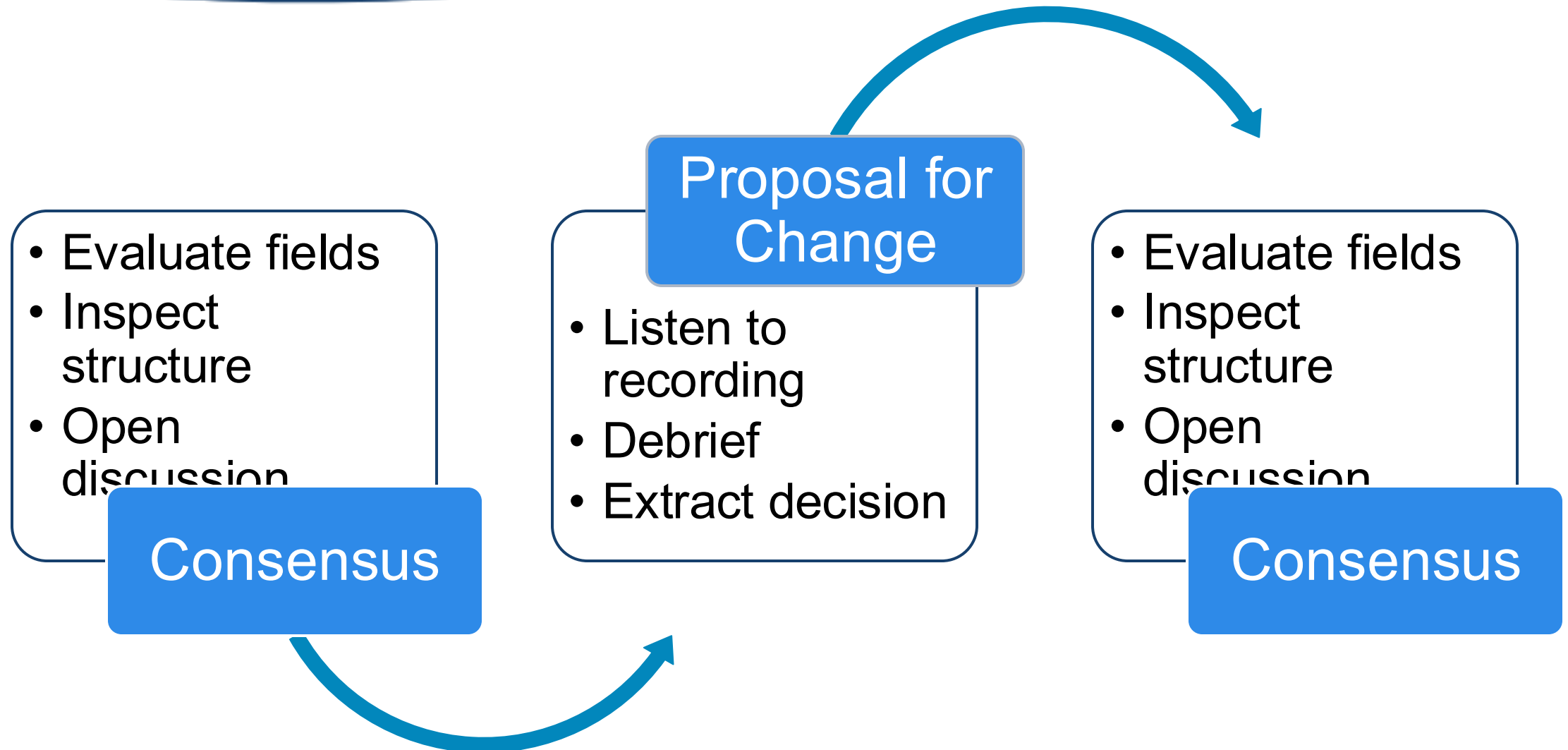
OXFORD INSTRUMENTS **ANDOR**

TELEDYNE
PHOTOMETRICS

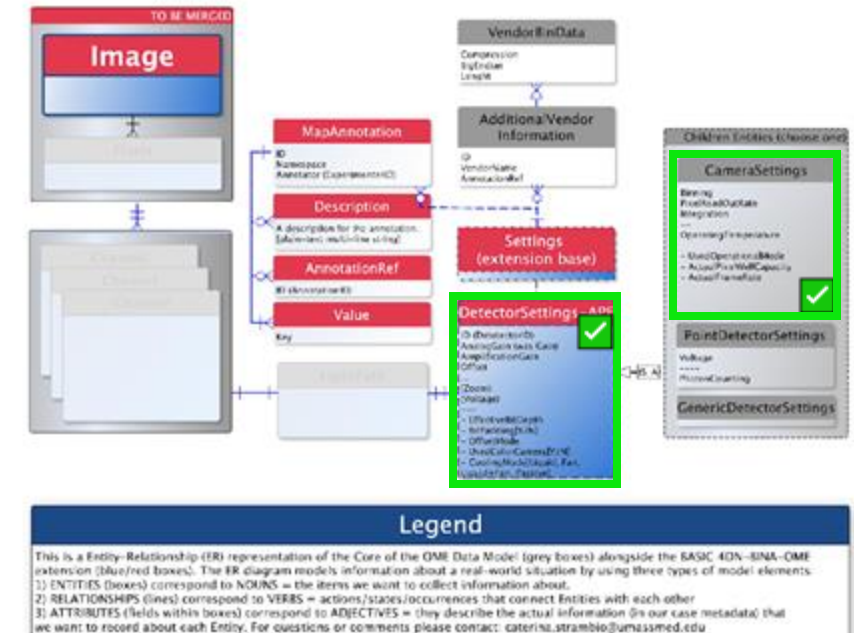
HAMAMATSU
PHOTON IS OUR BUSINESS



Focus groups to review model elements and attributes



OME Core vs. NBO Basic Extension vs. NBOQ DETECTIONSYSTEM Acquisition Settings



Core Marketplace + RRID: supporting the persistent identification of core-facilities



[SEARCH](#) [HELP](#)

[POSTINGS](#)



**Vermont
Biomedical
Research
Network**
An IDeA Network of Biomedical Research Excellence (NBRE)



[SEARCH](#) | [ADD/EDIT MY FACILITY](#)

[SEARCH THE COREMARKETPLACE](#)



RESEARCH RESOURCE IDENTIFICATION PORTAL

This is the Resource Identification Portal,
supporting guidelines for Rigor and Transparency
in scientific publications.

[Learn More](#)



[Find Plasmids](#)



[Find Cells](#)



[Find Organisms](#)

Core Marketplace + RRID: supporting the persistent identification of core-facilities




SEARCH HELP

POSTINGS




Vermont
Biomedical
Research
Network
An IDeA Network of Biomedical Research Excellence (IDeA NBRE)

Rigor, Reproducibility, Ruse
Use-Case in Light Microscopy
Identification of Instrument Instances +
Standardized Hardware, Settings and
Quality Control Description

 Find Plasmids

 Find Cells

 Find Organisms

NSF CSSI #2513921: Imaging-PHD



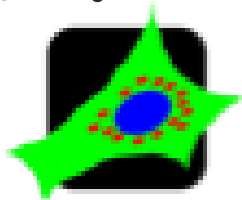
David Grunwald
Physics, Photonics



James Chambers
Core Manager



Judith Lacoste
Quality-Control



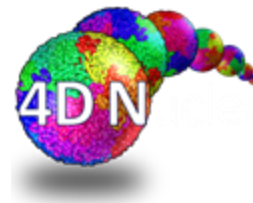
Josh Moore
Next Gen Metadata



BioImaging
North America



QUAREP-LiMi



HuBMAP
Human BioMolecular Atlas Program



Adrian Zai
Research Informatics



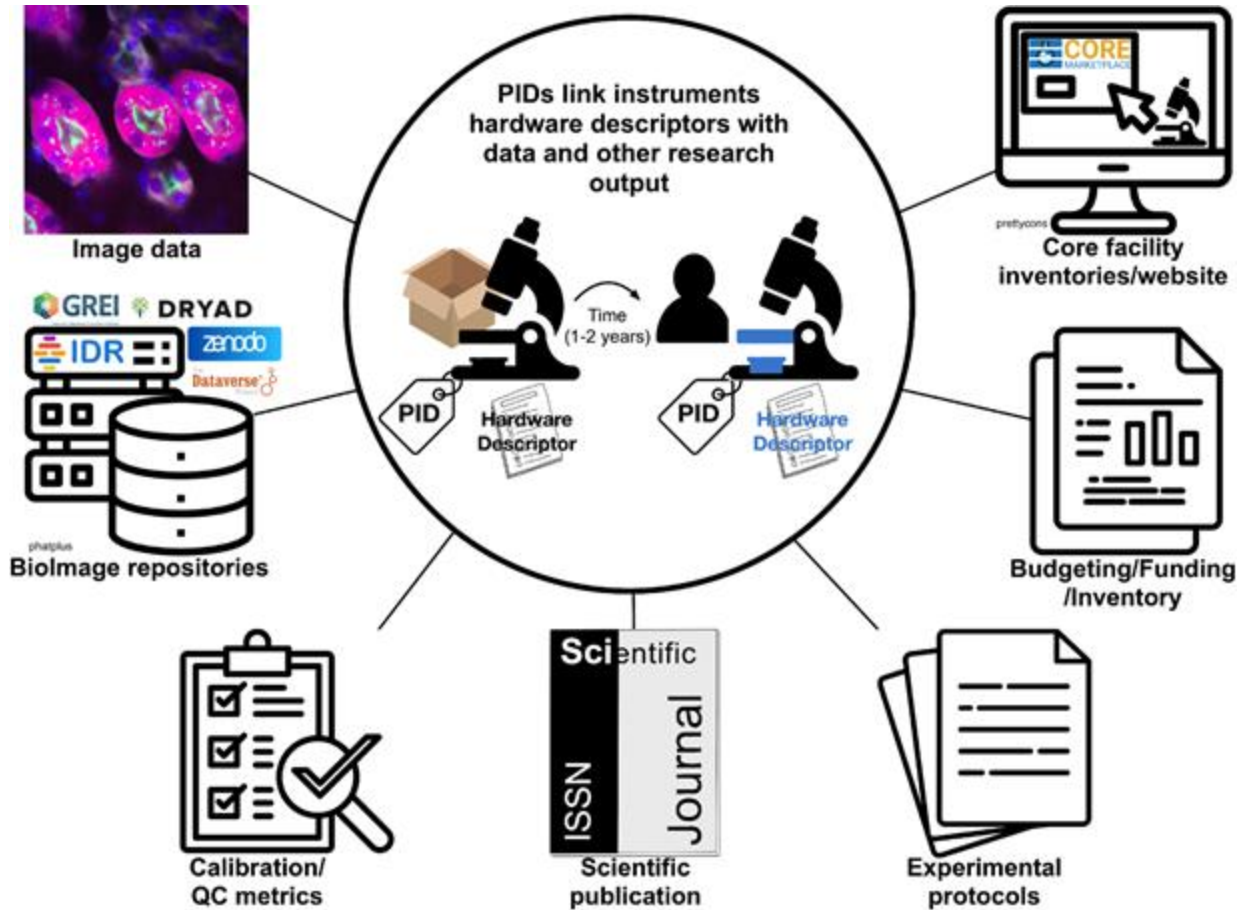
Anita Bandrowsky
RRID



Nate Herzog
CoreMarketplace



PIDs form a cornerstone of research



Metadata is Scattered

- Critical imaging metadata is stored across disparate locations (files, devices, documents).
- This fragmentation hinders reproducibility, reuse, and proper attribution.

What Are Persistent Identifiers (PIDs)?

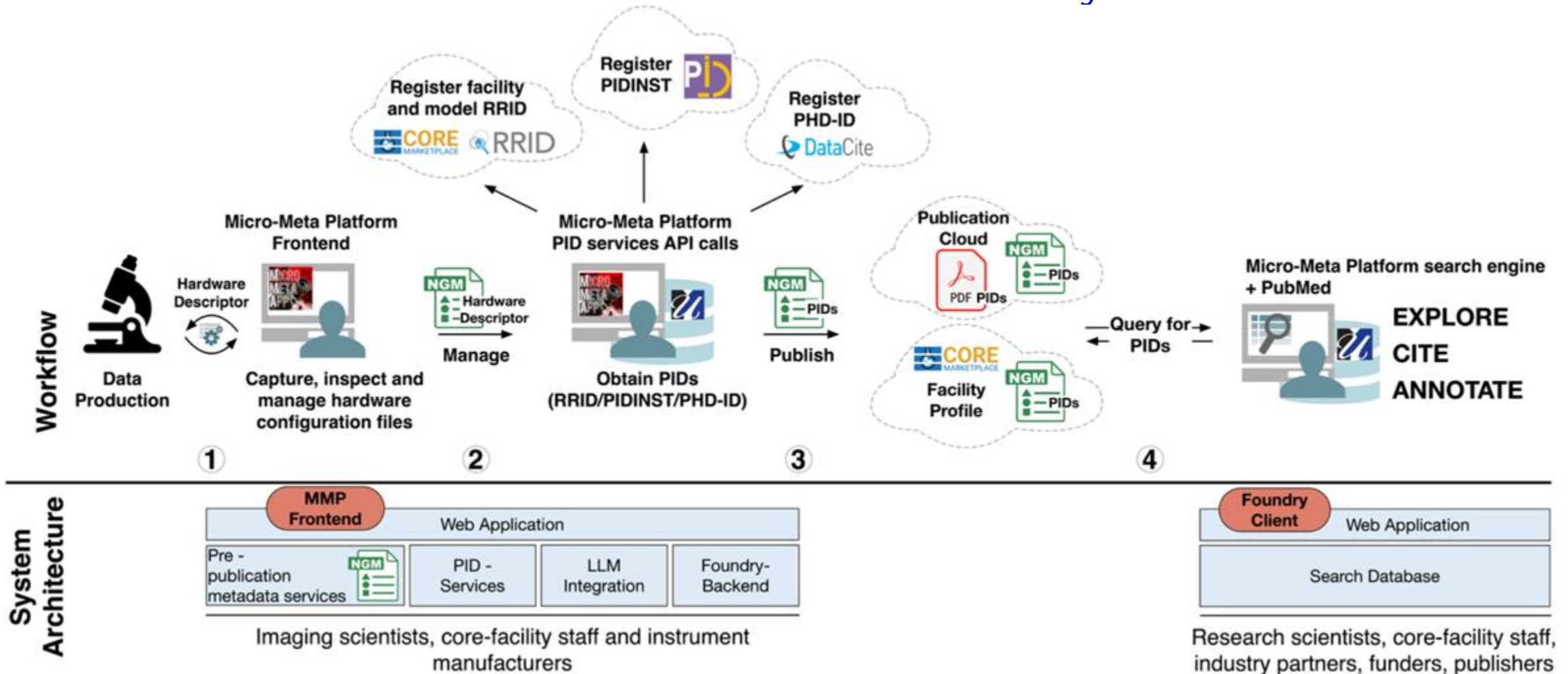
- Unique, long-lasting digital codes assigned to entities like instruments, datasets, and people.
- Maintained by trusted authorities and resolve to stable landing pages with rich metadata.

Why PIDs Are Essential

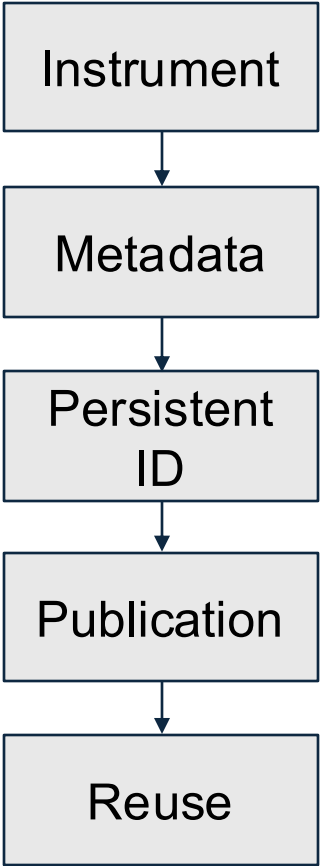
- **Linking:** Connect hardware, datasets, publications, and contributors.
- **Preservation:** Maintain long-term accessibility and integrity of research assets.

Deliverable - Micro-Meta Platform Workflow and Architecture

Capturing, registering, and reusing persistent hardware metadata across the research lifecycle.



Intellectual Merits - How this Work Advances Science



Merit Area	Imaging-PHD Contribution
Democratizing Scientific Infrastructure	Makes detailed, standardized instrument metadata openly available via persistent identifiers. Enables smaller labs and under-resourced institutions to build on others' hardware setups.
Ensuring Long-Term Research Quality	PHDs improve instrument lifecycle tracking and quality assurance, supporting replicability and reducing hidden sources of error.
Enabling Workforce Development	Empowers core facility staff and early-career researchers with tools and training for metadata best practices.
Catalyzing New Discovery	Harmonized metadata enables data pooling and cross-study reanalysis, accelerating multi-institutional discoveries.

“Our technical design promotes long-term reuse, community adoption, and the scalability of reproducible research.”

Broader Impacts - Empowering Researchers, Core Facilities, and Industry Partners

Who Benefits	How Imaging-PHD Helps
Researchers	Gain access to well-documented instrument configurations, improving reproducibility and enabling meta-analyses
Educators & Trainees	Use PHD-linked metadata for real-world training on instrumentation and FAIR practices
Core Facility Staff	Receive credit for their contributions via PID linkage and gain tools for quality tracking
Under-resourced Institutions	Can reuse metadata and design experiments modeled after advanced facilities
Software Developers & Industry Partners	Integrate their tools with standardized APIs, enhancing interoperability and adoption

“Broader impact is embedded in every layer of our platform—tools, people, and community.”



Light
Microscopy
metadata

PHD-ID:0000

```

graph TD
    A[IDType - DOI] --> B[LightSource]
    B --> C[Stage]
    C --> D[Filter]
    D --> E[Camera]
  
```

IDType - DOI

LightSource

Stage

Filter

Camera

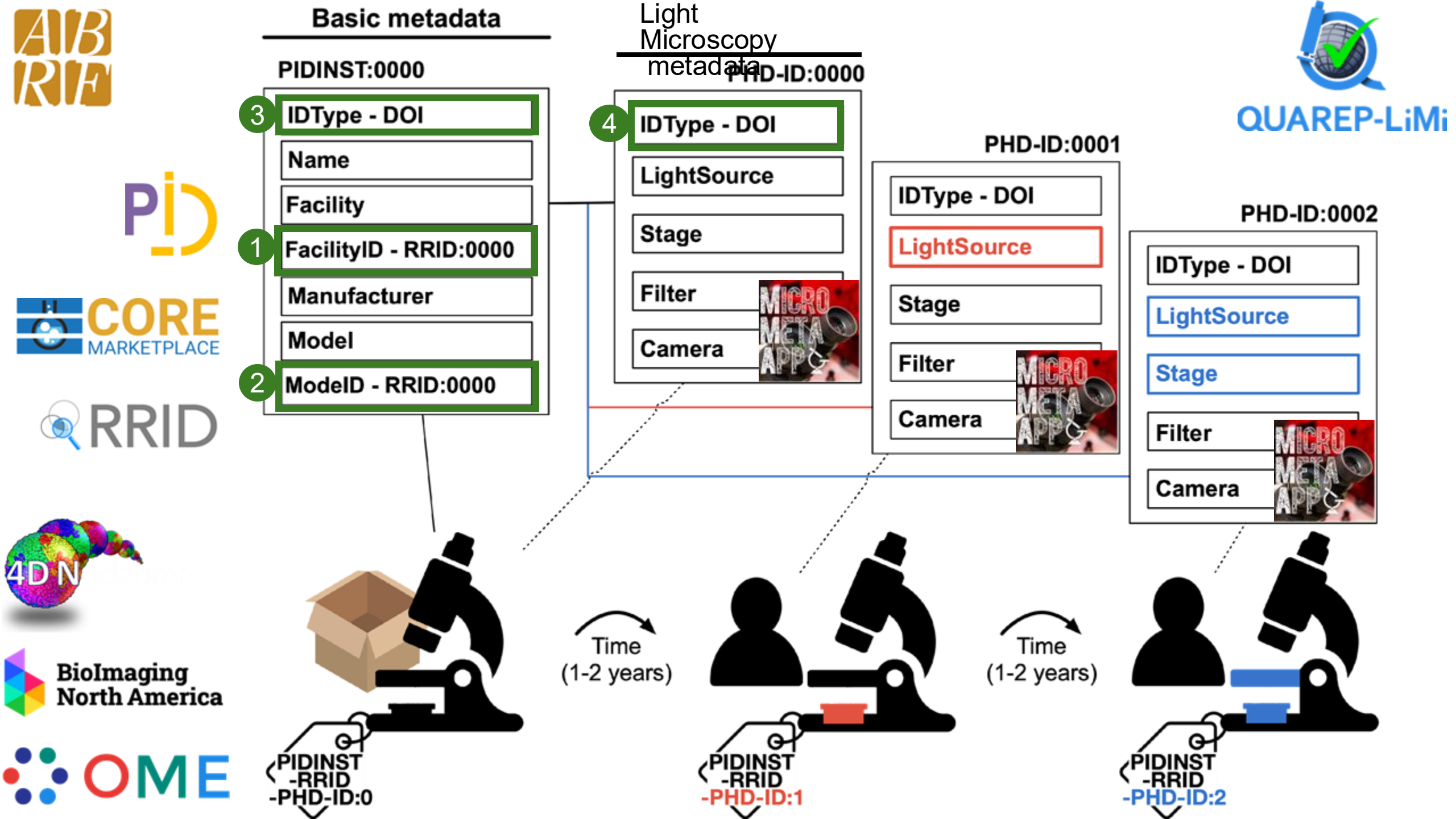
**MICRO
META
APP**

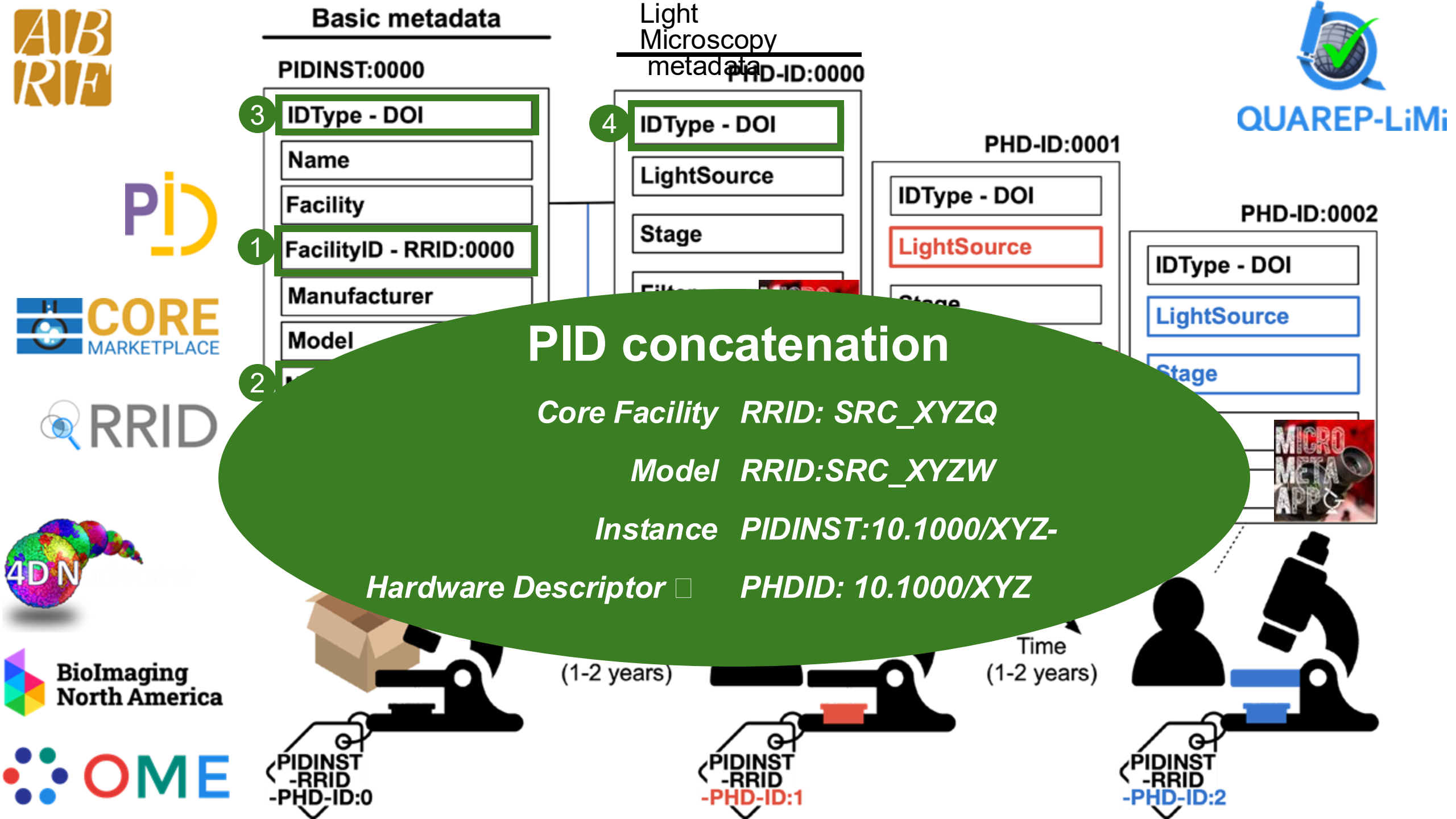
Diagram illustrating the components of a microscope system:

- IDType - DOI
- LightSource
- Stage
- Filter
- Camera

The diagram shows a vertical stack of components. The top component is 'IDType - DOI'. Below it is 'LightSource'. Then 'Stage'. Then 'Filter'. Then 'Camera'. To the right of the 'Filter' and 'Camera' components, there is a small inset image showing a hand holding a camera lens, with the text 'MICRO META APP' overlaid.







FAIR Facilities and Instruments: PID recommendations

1. Flexible PID

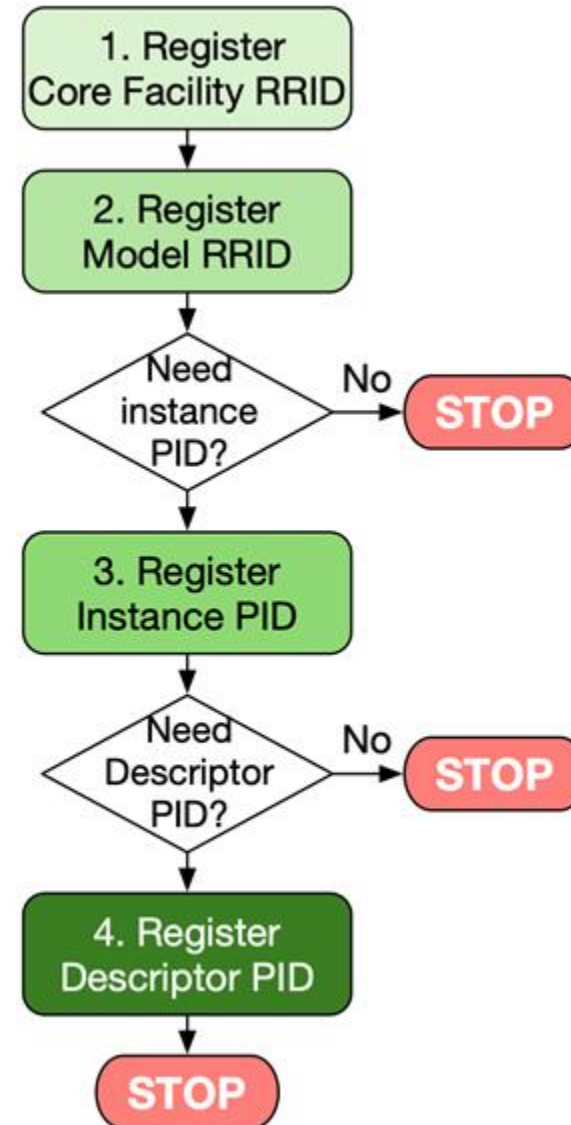
recommendations: based on the requirements of different use cases and different scientific domains

2. Capability of assigning PID in different tiers. For example:

1. Core Facilities
2. Instrument Model/Type
3. Instrument Instance
4. Descriptor (Hardware Configuration / Settings / Parameters)

3. PID concatenation

4. PID connection



FAIR Facilities and Instruments: PID recommendations

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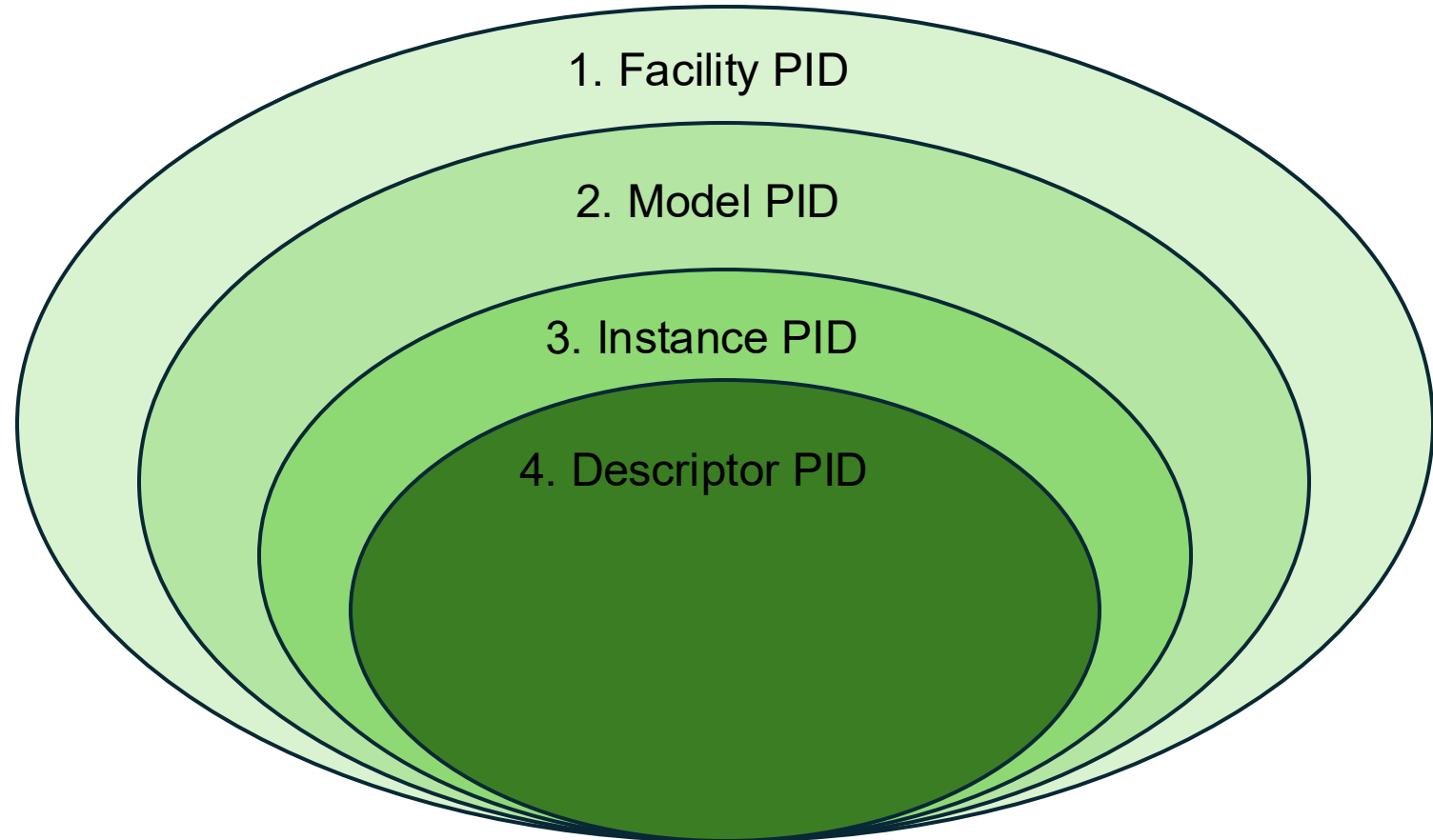
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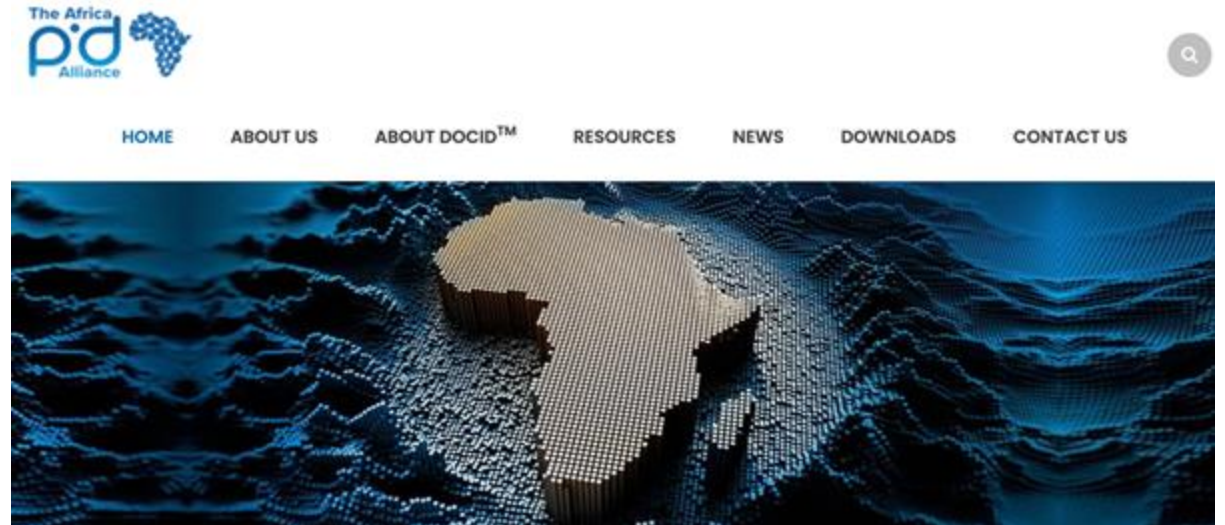
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4. Descriptor (Hardware Configuration / Settings / Parameters)

3. PID concatenation

4. PID connection



<https://africapidalliance.org/>

THANK YOU!

UMass Med + Canada Bioimaging



Judith
Lacoste



Thomas
Stroh



Claire
Brown



Pina
Colarusso



Alex
Rigano



Alice
Kang



Gabriel
Pelletier



Joel
Ryan



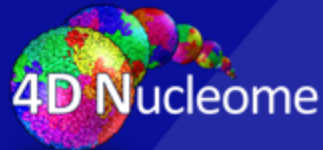
Stephen
Ogg



Alex
Kiepas

BINA+QUAREP-LiMi

- Alison North, The Rockefeller University
- Roland Nitschke, Uni Freiburg
- Britta Schroth-Diez, Max Plank, Dresden
- Damir Sudar, Uni Oregon, QIS
- Caroline Miller
- Nikki Bilay + Vanessa Orr, BINA
- [BINA Quality Control and Data Management WG](#)
- [QUAREP-LiMi WG7 – Metadata](#)



Grunwald lab – UMMS-RTI

- David Grunwald
- Mathias Hammer
- Max Huisman
- Farzin Farzam



4DN Community

- 4DN IWG: Sarah Aufmkolk, Laca Bintu, Alistair Boettinger, Steve Wang, Ting Wu
- DCIC: Burak Alver, Andrea Cosolo, Shannon Ehmsen, Koray Kirli, Rahi Navelkar, Peter Park, Andrew Schroder, Serkan Utku Ozturk



HuBMAP Community and Pittsburgh Supercomputing Center (PSC)

- Katy Borner, Phil Blood, Chris Csonka, Stephen Fisher, Brendan Honick, Ajay Pillai, Alex Ropelewski



Imaging Scientists Community

- Lisa Cameron, Duke
- Michelle Itano, CZI, UNC
- Paula Montero-Llopis, HMS
- Jennifer Waters, CZI, HMS



OME community

- Jason Swedlow, OME
- Josh Moore, OME
- Shuichi Onami, RIKEN

