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

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UMass Chan MEDICAL SCHOOL

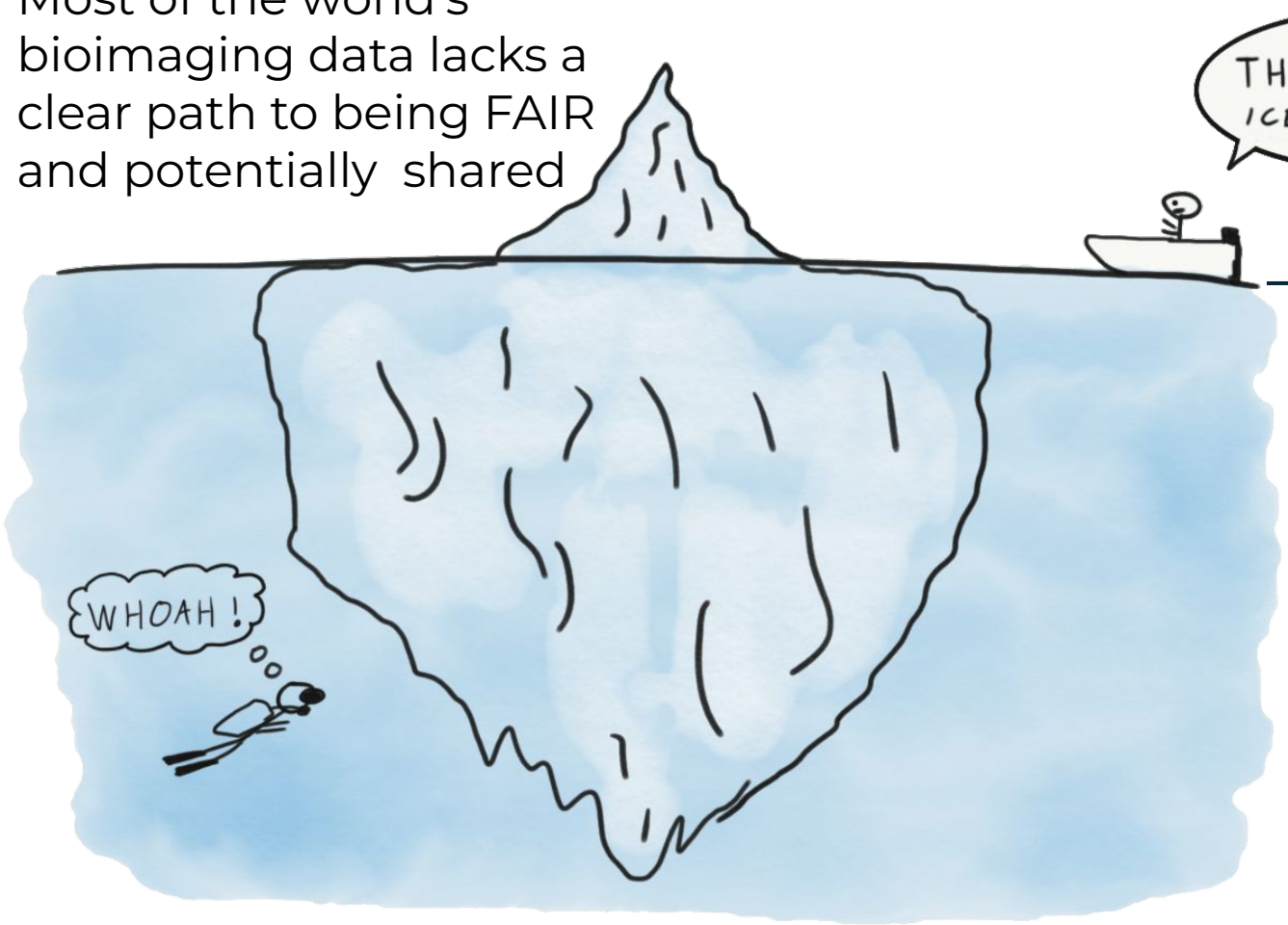
2025-9-22 FAIR Facilities and Instrument Workshop 3

NIH National Institutes of Health

Chan Zuckerberg Initiative

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...

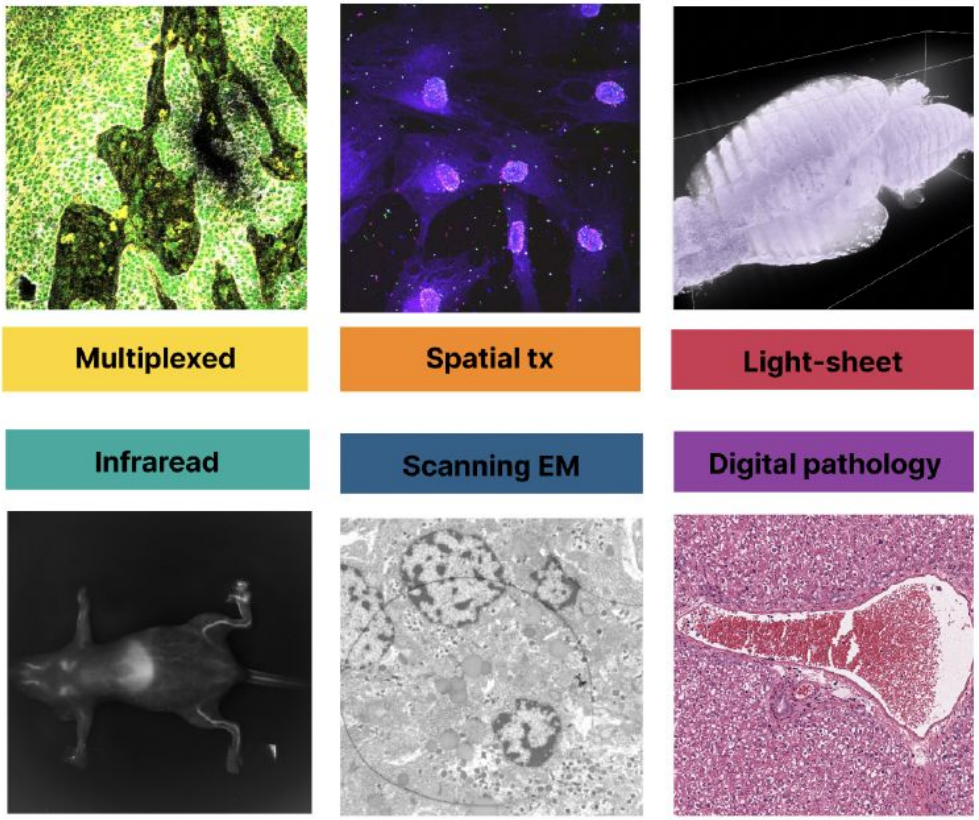
... hidden treasure

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

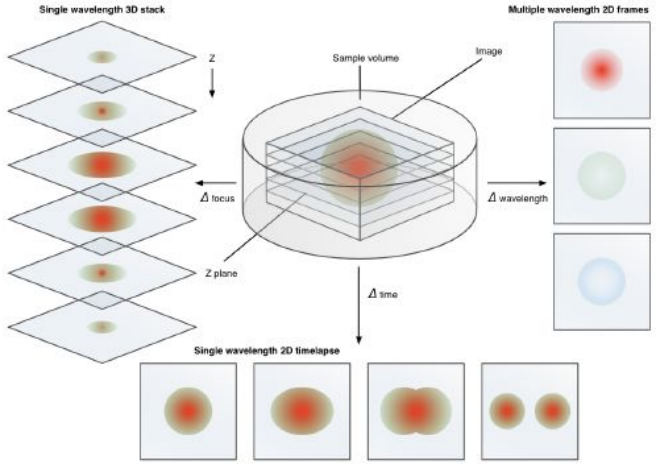
Moore and Kunis, 2024; https://doi.org/10.5281/zenodo.11235513

Bioimages: complex data and metadata

Diversity in imaging applications/modalities



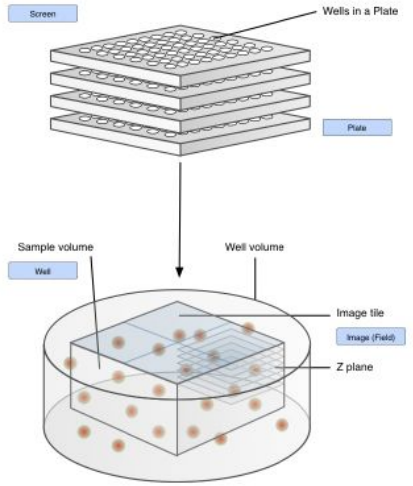
Moore and Kunis, 2024; https://doi.org/10.5281/zenodo.11235513



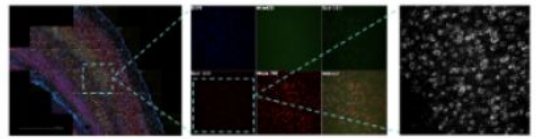
5D Images

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

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



Complex Acquisitions

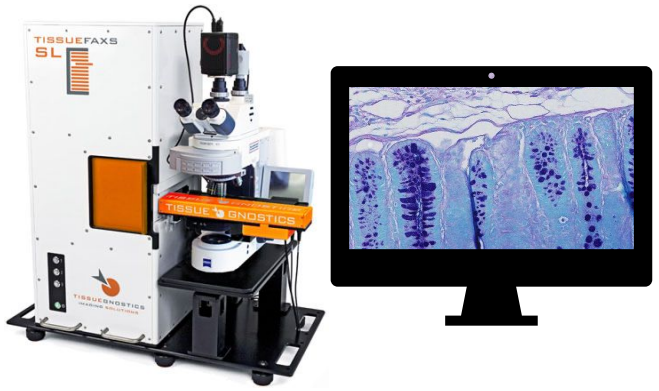


High-content Screen

Single-cell tissue

Microscopy Core Facilities

Full-service core-facilities



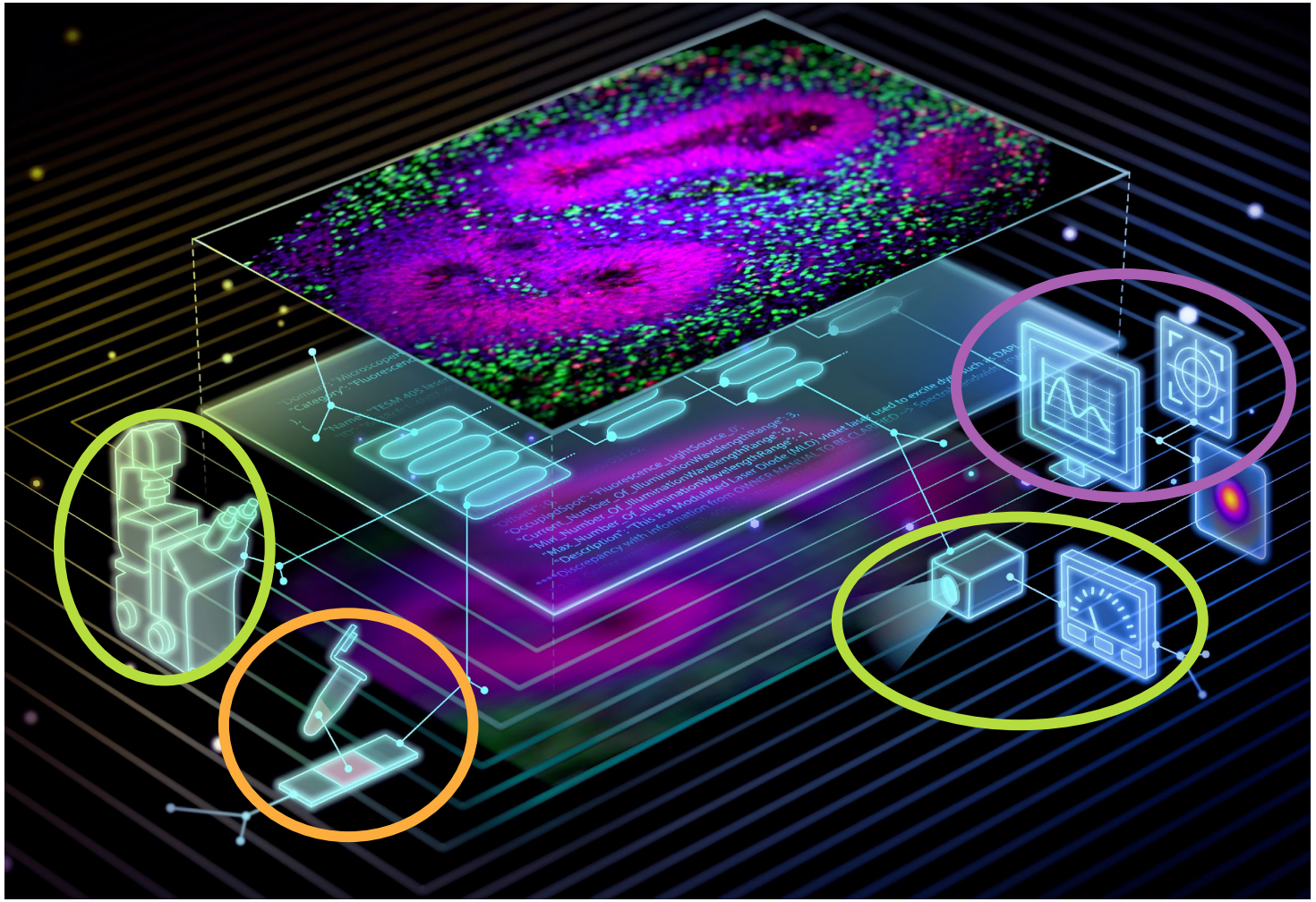
- Digital pathology (brightfield and fluorescence slide scans)
- Spatial omics
- Multiplexed FISH/RNA Scope

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

BioImage Metadata

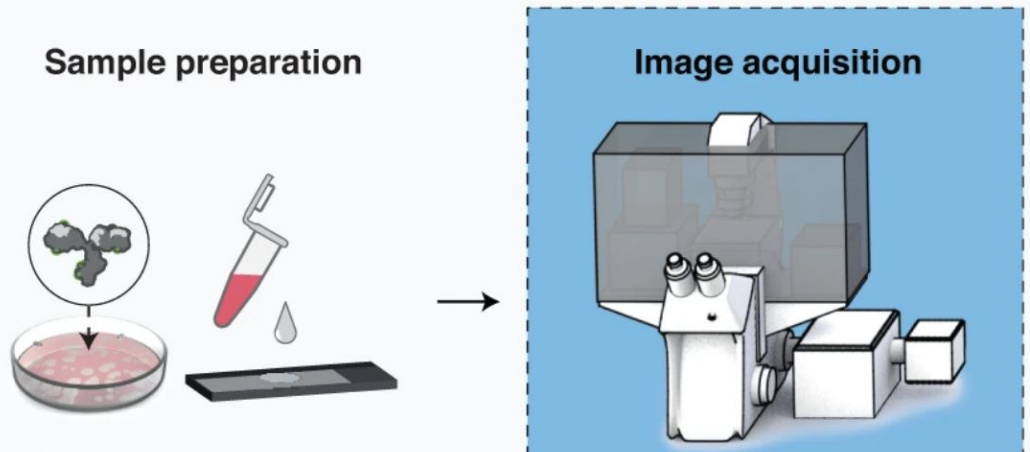


© Thao Do (Allen Institute, Seattle, WA, USA)
Nature Methods FOCUS issue on Reporting and Reproducibility in Microscopy:
https://www.nature.com/collections/djiciihhjh

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



Experimental and Sample Metadata

- Notebooks (Paper or ELN)
- Excel sheets
- Word docs etc.

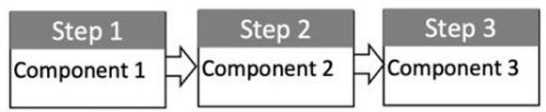
Microscopy Metadata

- Log files
- Proprietary Image files
- OME-TIFF (via BioFormats)
- Microscope hardware descriptions
- Personal notes during acquisition

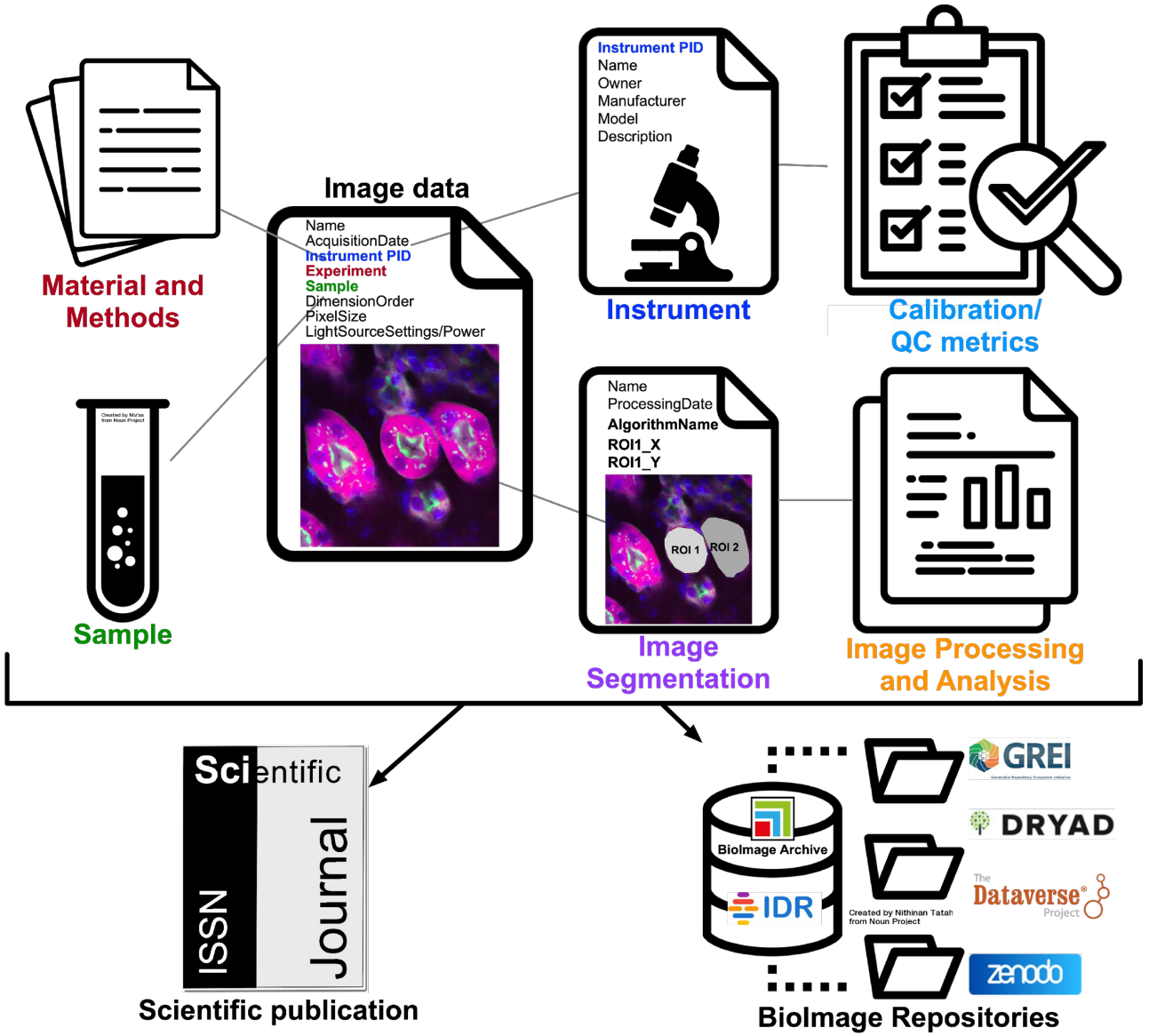
OME-TIFF

Analysis and Visualization Metadata

- Log files
- Personal notes
- Script/Workflow/Pipeline code
- Often not reported

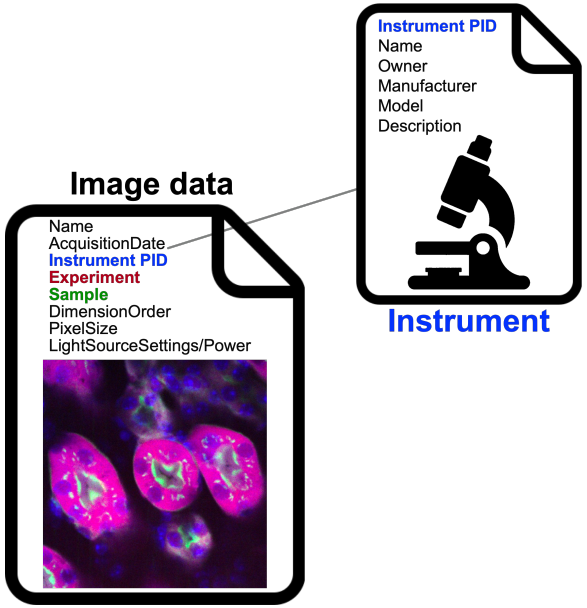


Where is bioimage metadata?



PIDs can help maintain links between different essential information

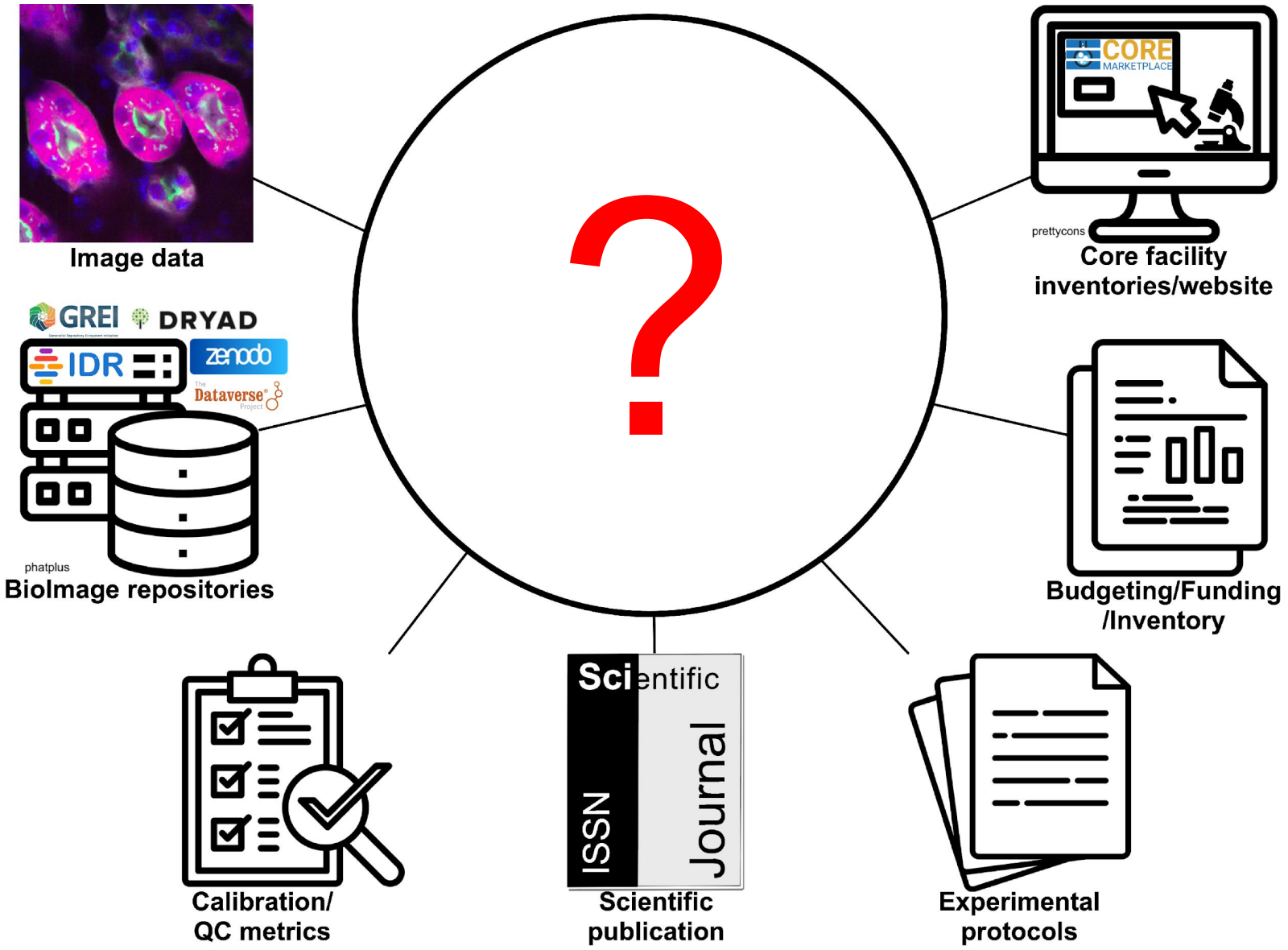
Persistent Hardware Descriptors help making data FAIR



Linked PIDs for

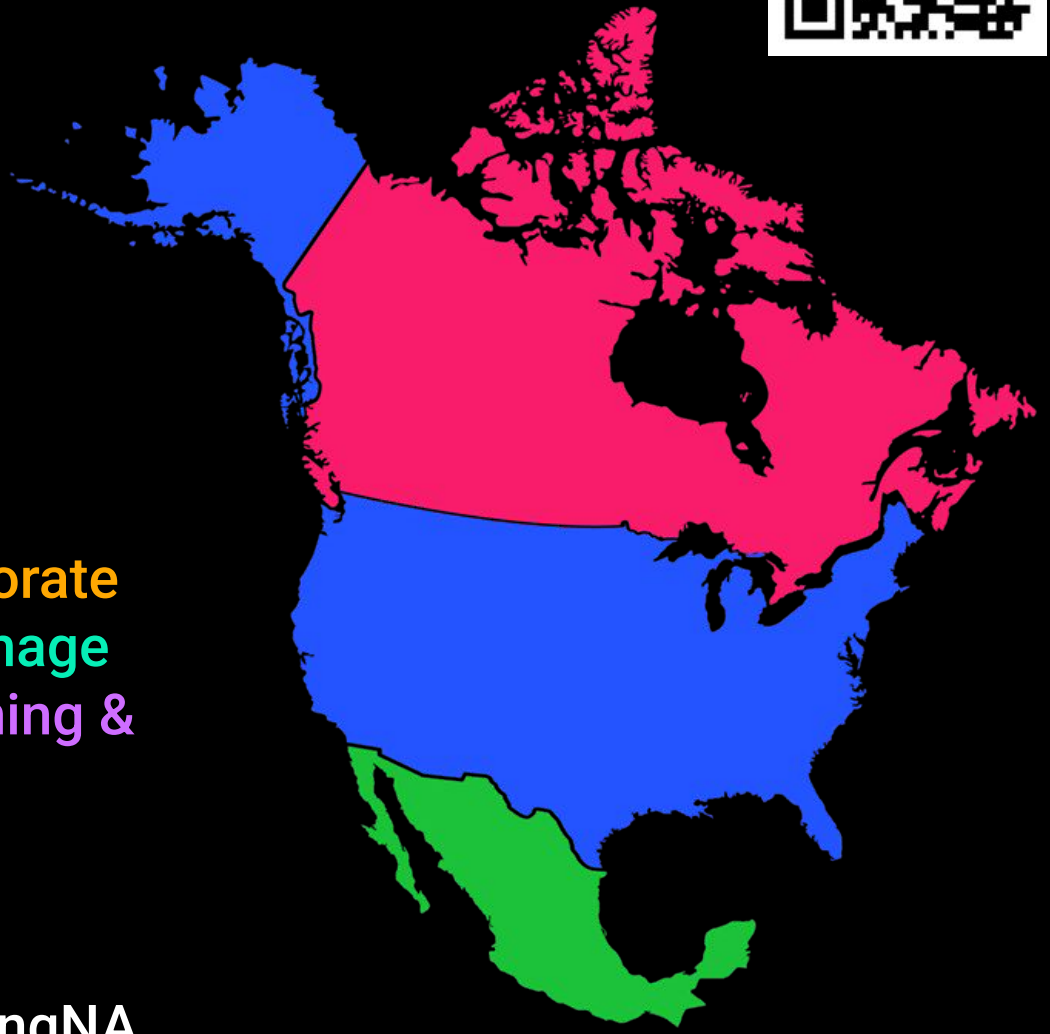
- Instrument instance
- Instrument model
- Hardware configuration

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

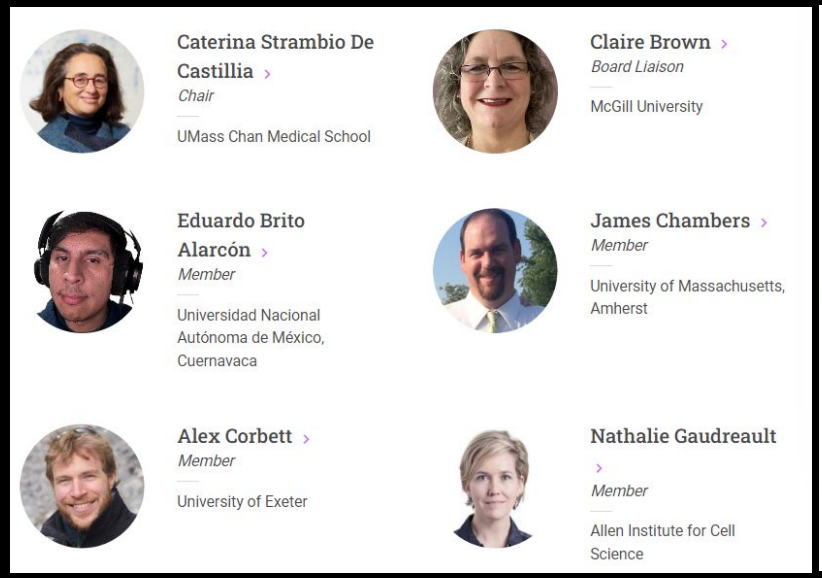
8 Working Groups: Builders, Communications, Corporate Partners, Diversity, Equity & Inclusion, Early Career, Image Informatics, Quality Control & Data Management, Training & Education

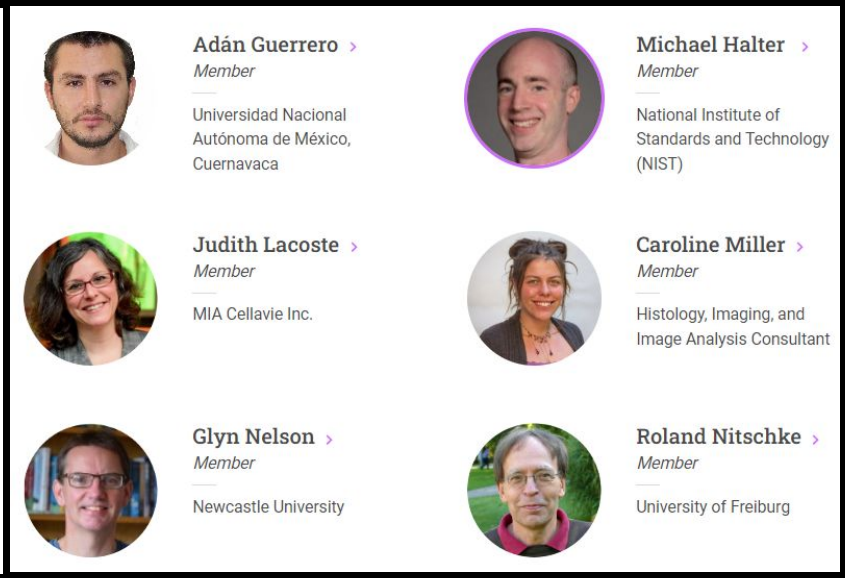
www.BioImagingNorthAmerica.org/join

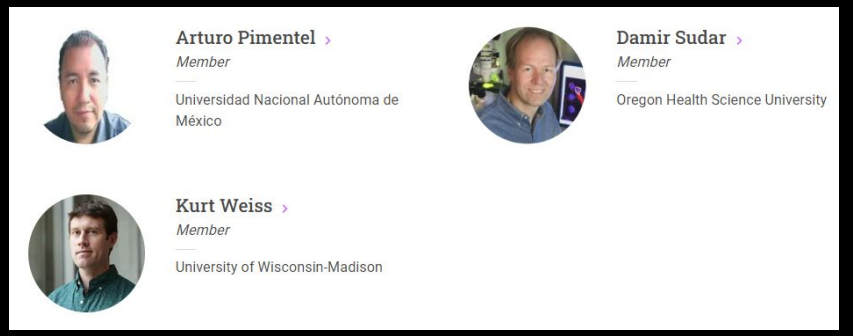
contact@bioimagingna.org

@BioimagingNA

Quality Control & Data Management Working Group

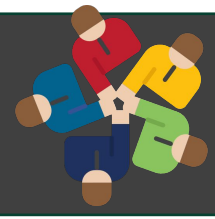






- Quantitative assessment and calibration of microscope performance,
- Rigorous record-keeping of data generation and processing conditions
- Connection of imaging dataset with machine-readable metadata describing its “provenance.”

BINA belongs to a network of international organizations spanning the globe



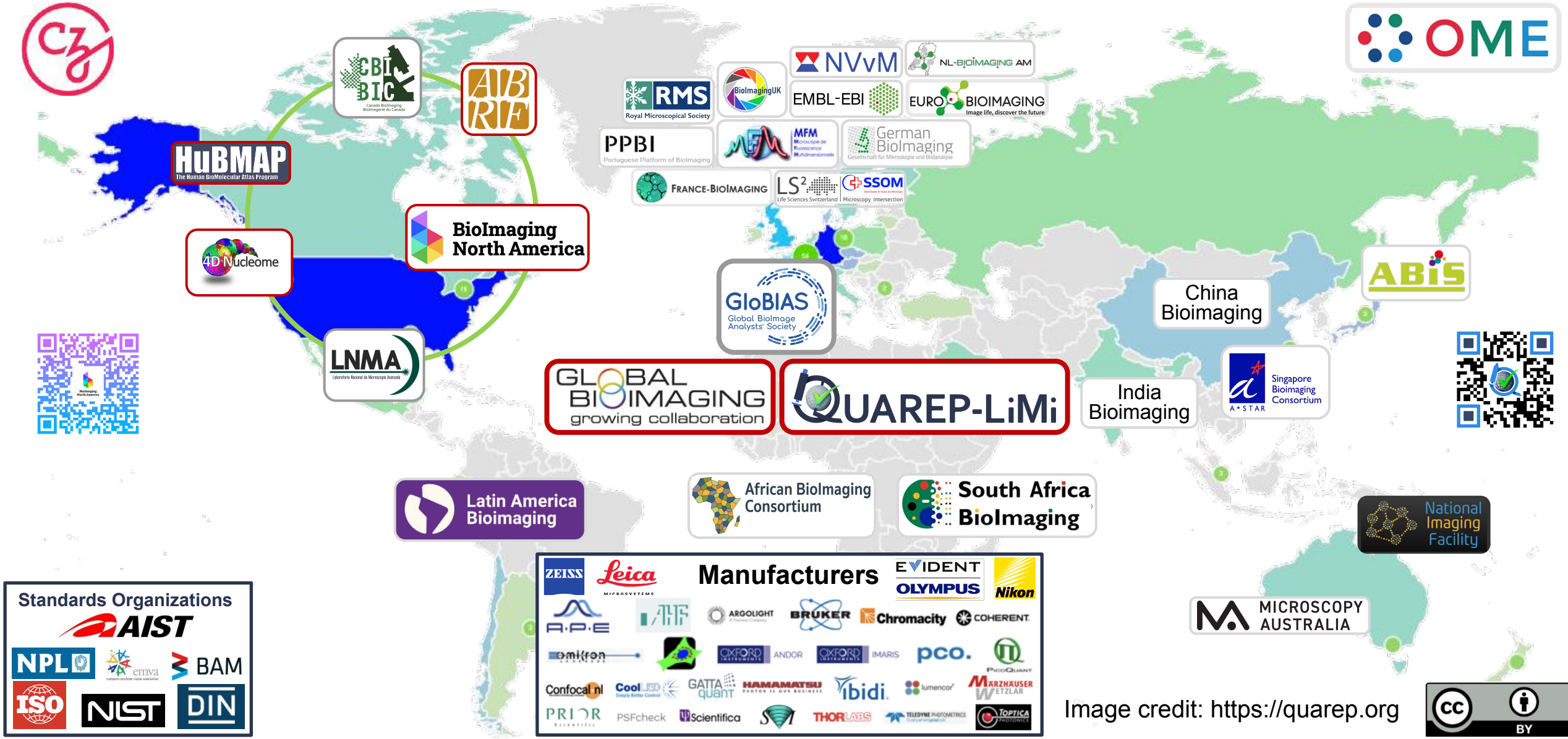
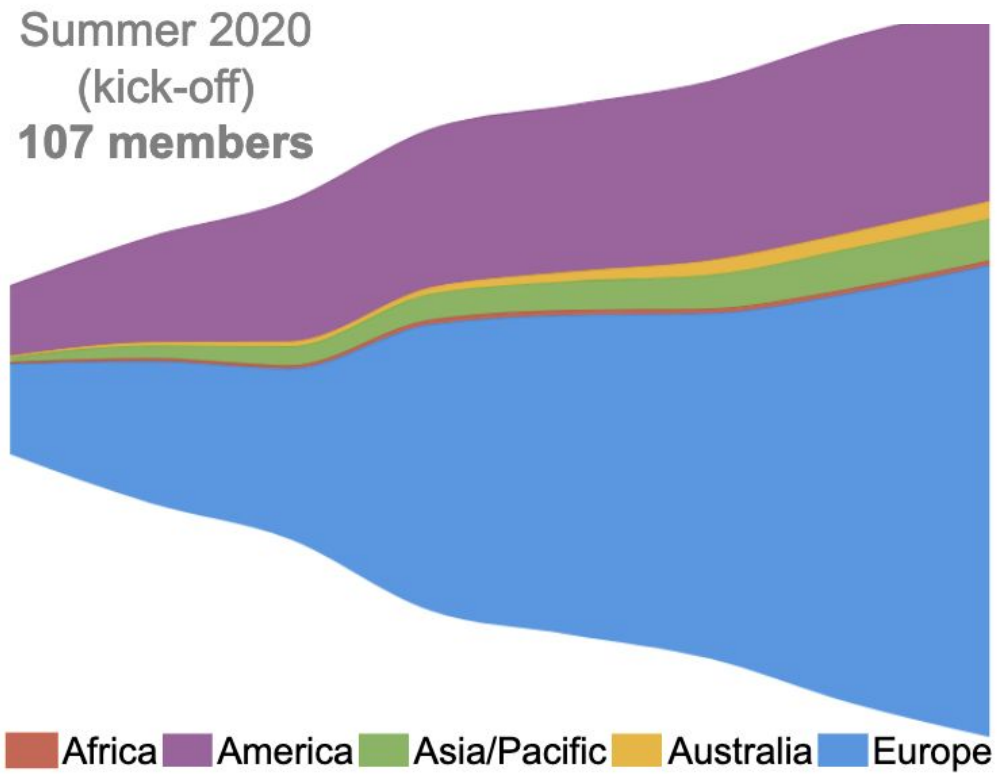


Image credit: https://quarep.org

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

Membership growth



Membership composition

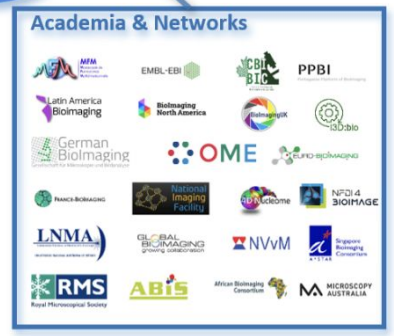
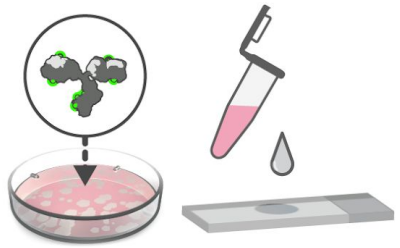


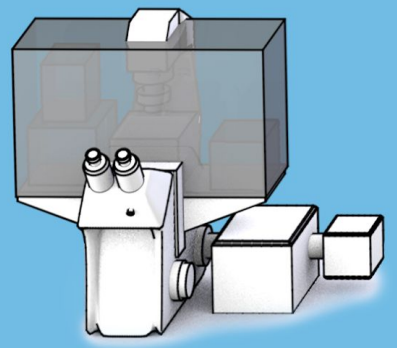
Image Acquisition Metadata

Sample preparation



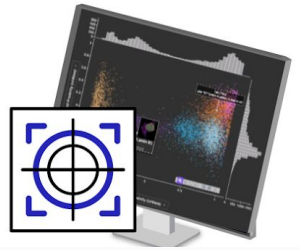
Experimental &
Sample metadata

Image Acquisition



Pixel image data

Image Data analysis



Analysis Metadata

Microscopy Metadata

Provenance

Microscope Hardware Specifications:

- Microscope modality and configuration
- Hardware components

Image Acquisition Settings

- Acquisition settings
- Arrangement of parts

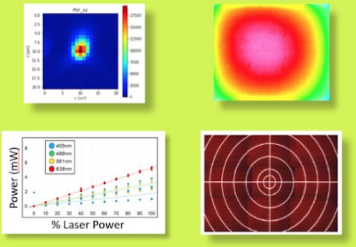
Image Structure

- Pixel size
- Number of pixels, focal planes, channels and timepoints
- Dimension order

Quality Control

Optical Calibration

- Resolution characterization
- Chromatic registration
- Illumination uniformity



Intensity Calibration

- Illumination power
- Illumination wavelength
- Illumination stability
- Detector performance

Mechanical calibration

- Repeatability
- Reproducibility
- Stability (settling time)

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

Comment

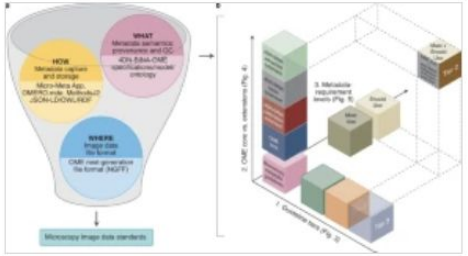
3 Dec 2021

Nature Methods

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

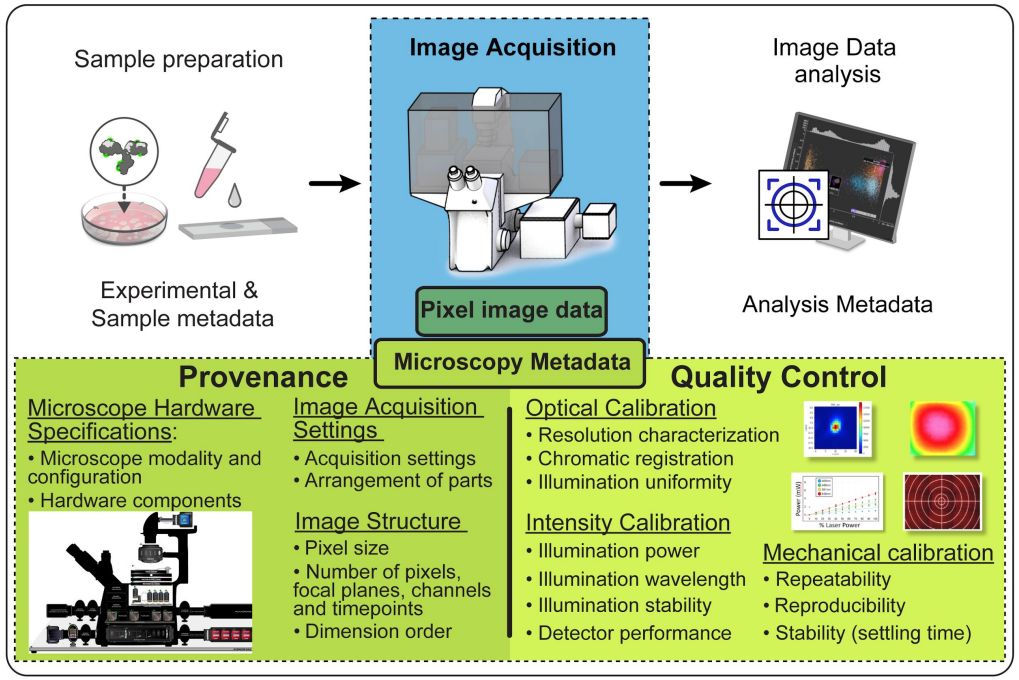
Rigorous record-keeping and quality control are required to ensure the quality, reproducibility and value of imaging data. The 4DN Initiative and BINA here propose light Microscopy Metadata Specifications that extend the OME Data Model, scale with experimental intent and complexity, and make it possible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

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



4D Nucleome

BioImaging North America



OME

QUAREP-LiMi

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

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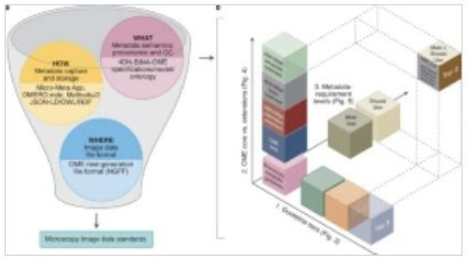

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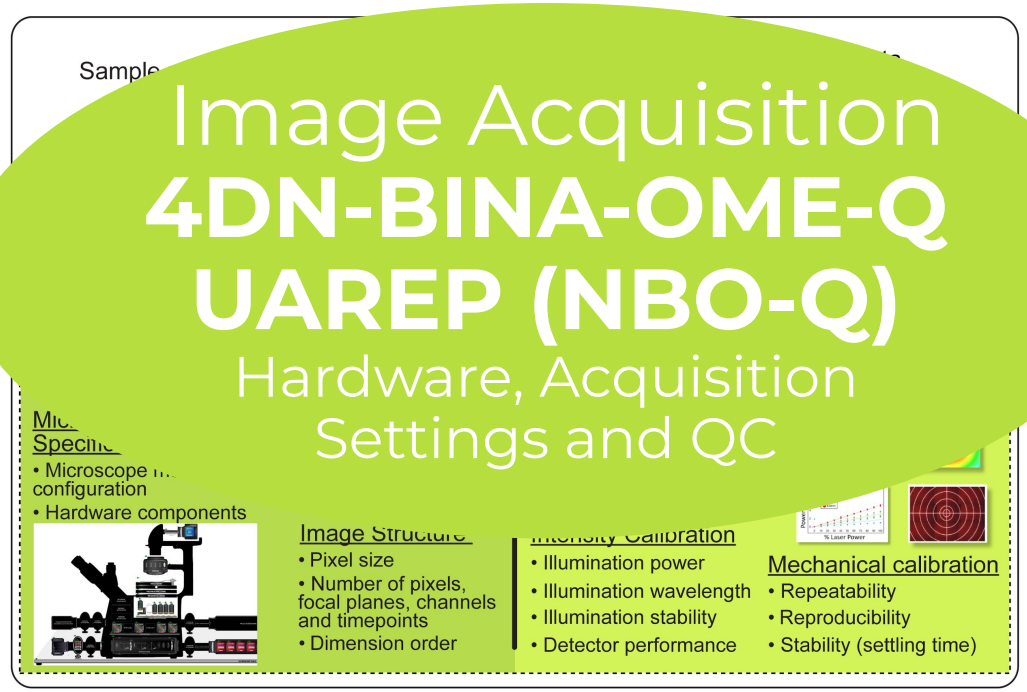
BioImaging North America



OME

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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

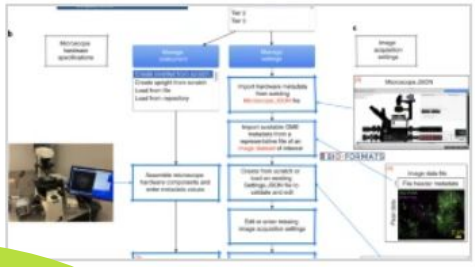
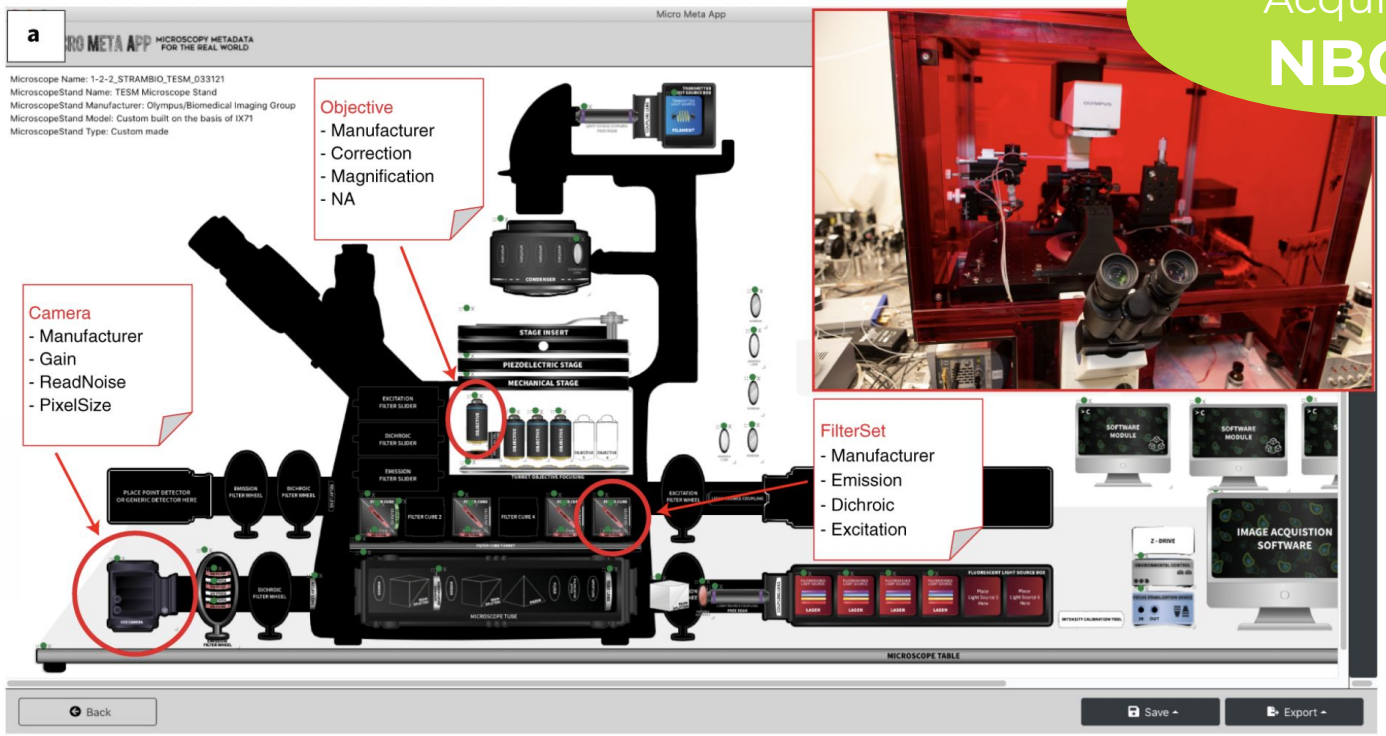


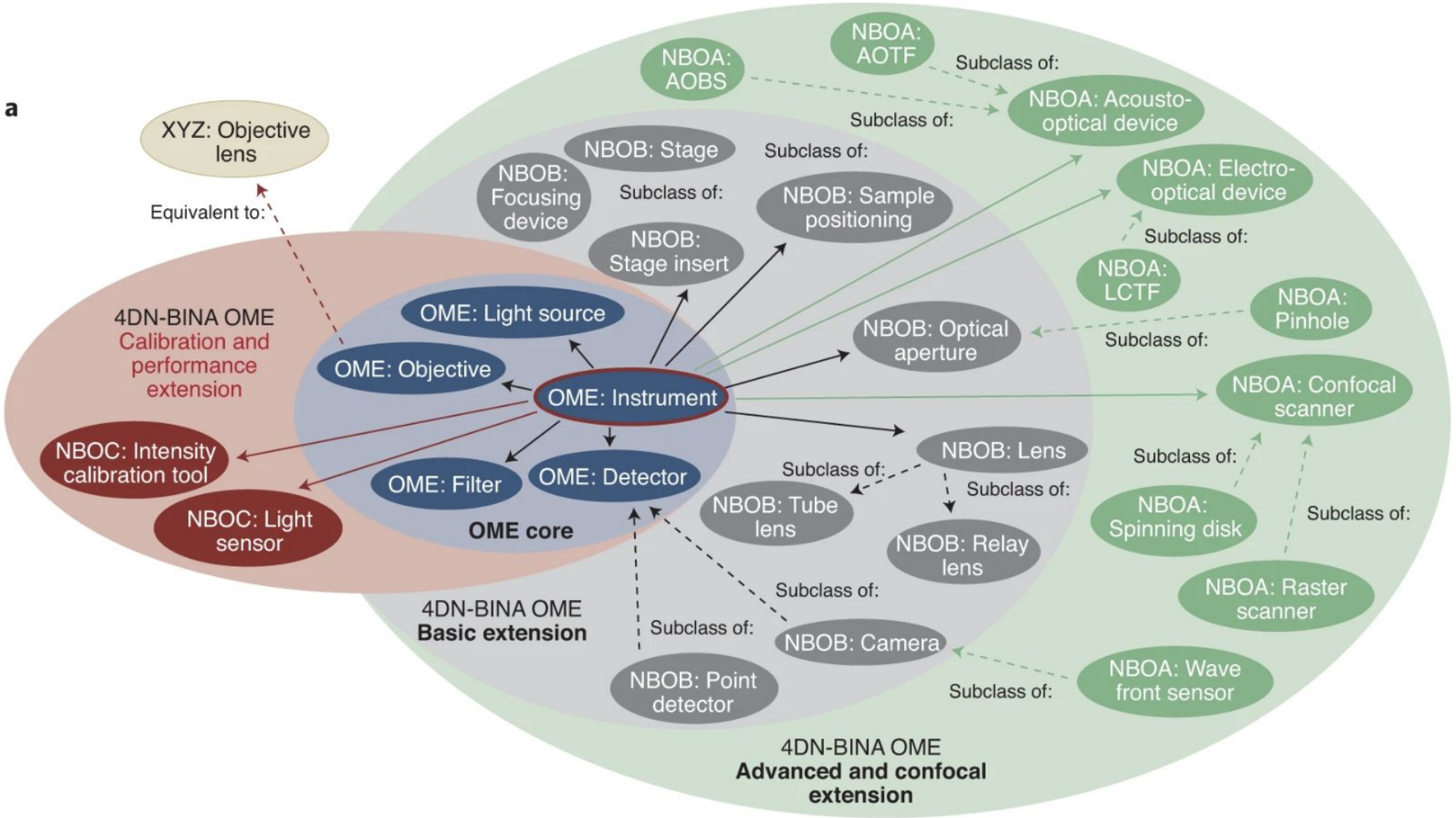
Image Acquisition **NBO-Q**



4D Nucleome

BioImaging North America

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



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

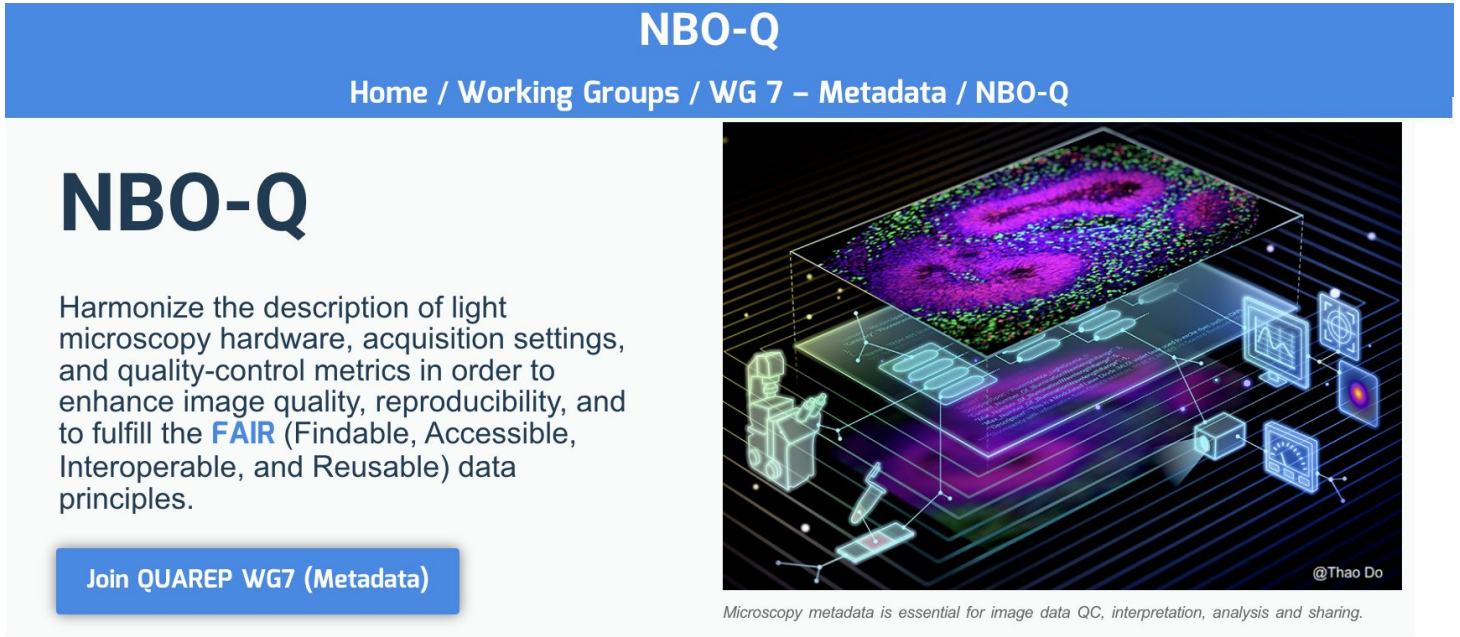
QUAREP-LiMi

Now the official host and responsible party!

NBO-Q Light Microscopy Metadata Model

QUAREP-LiMi

- 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



https://quarep.org/working-groups/wg-7-metadata/

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

QUAREP-LiMi

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 microscopy 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

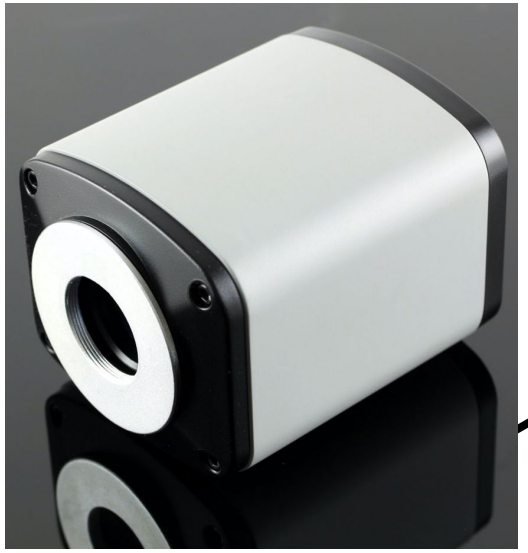
With a view to transparency and reproducibility in microscopy, scientists are hammering out standards to address, for instance, the surprises of fluctuating illumination power, the jungle of file formats, the mysteries of missing metadata and the diversity of camera outputs. A second story in this issue 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 glaze arising from long hours at the microscope. Those who feel they lack the time to pitch 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

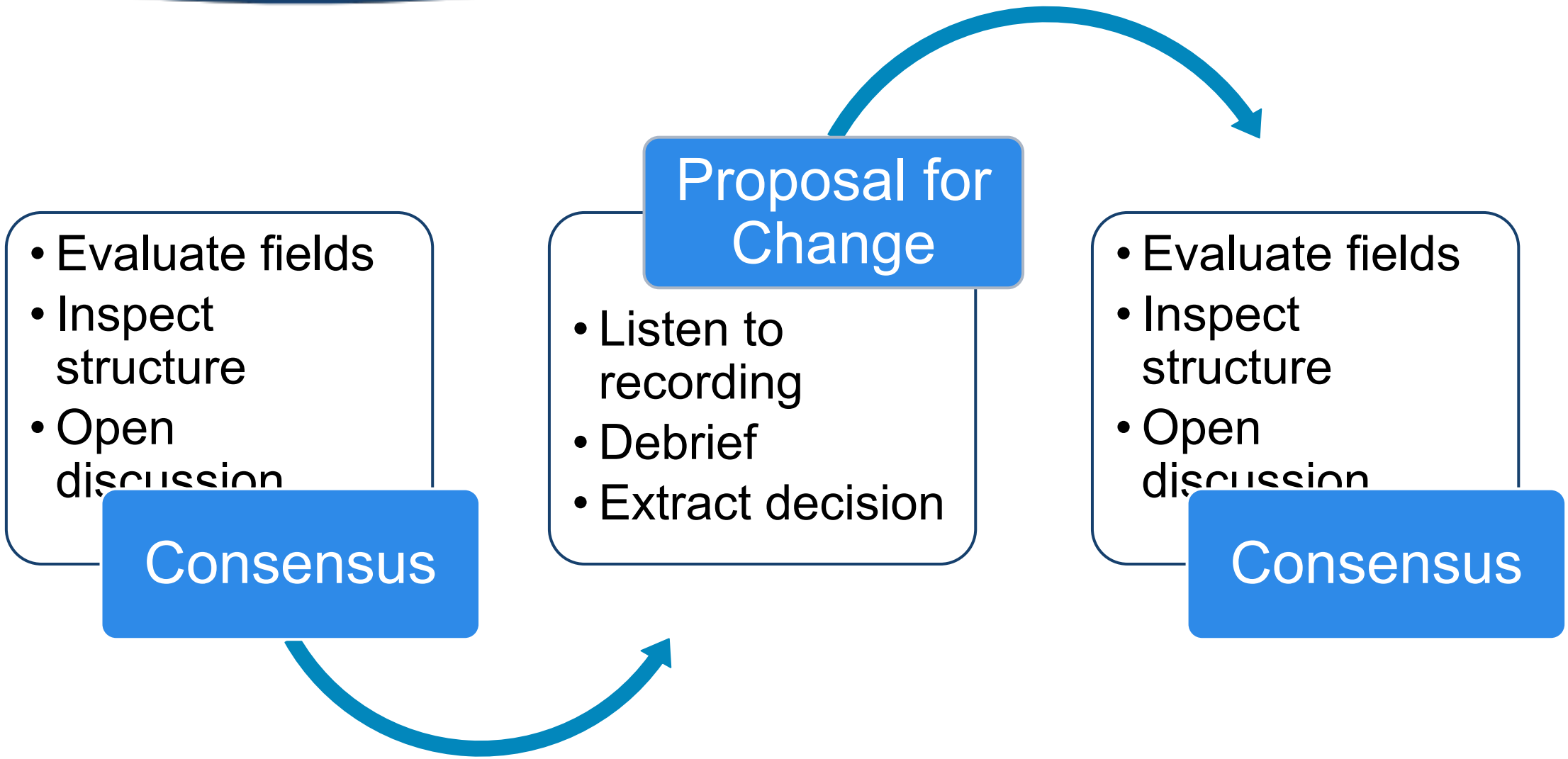


Camera
- Manufacturer: *Xyz*
- Catalog Nr: *0000*
- Mount: *C-mount*
- FrameRate: *20 fps*
- ReadOutRate: *30 MHz*

EVIDENT
OLYMPUS
ZEISS
Leica MICROSYSTEMS
Nikon
pco.
Scientifica
OXFORD INSTRUMENTS
ANDOR
TELEDYNE PHOTOMETRICS
HAMAMATSU
PHOTON IS OUR BUSINESS

WG2 & WG7 joint endeavor

Focus groups to review model elements and attributes

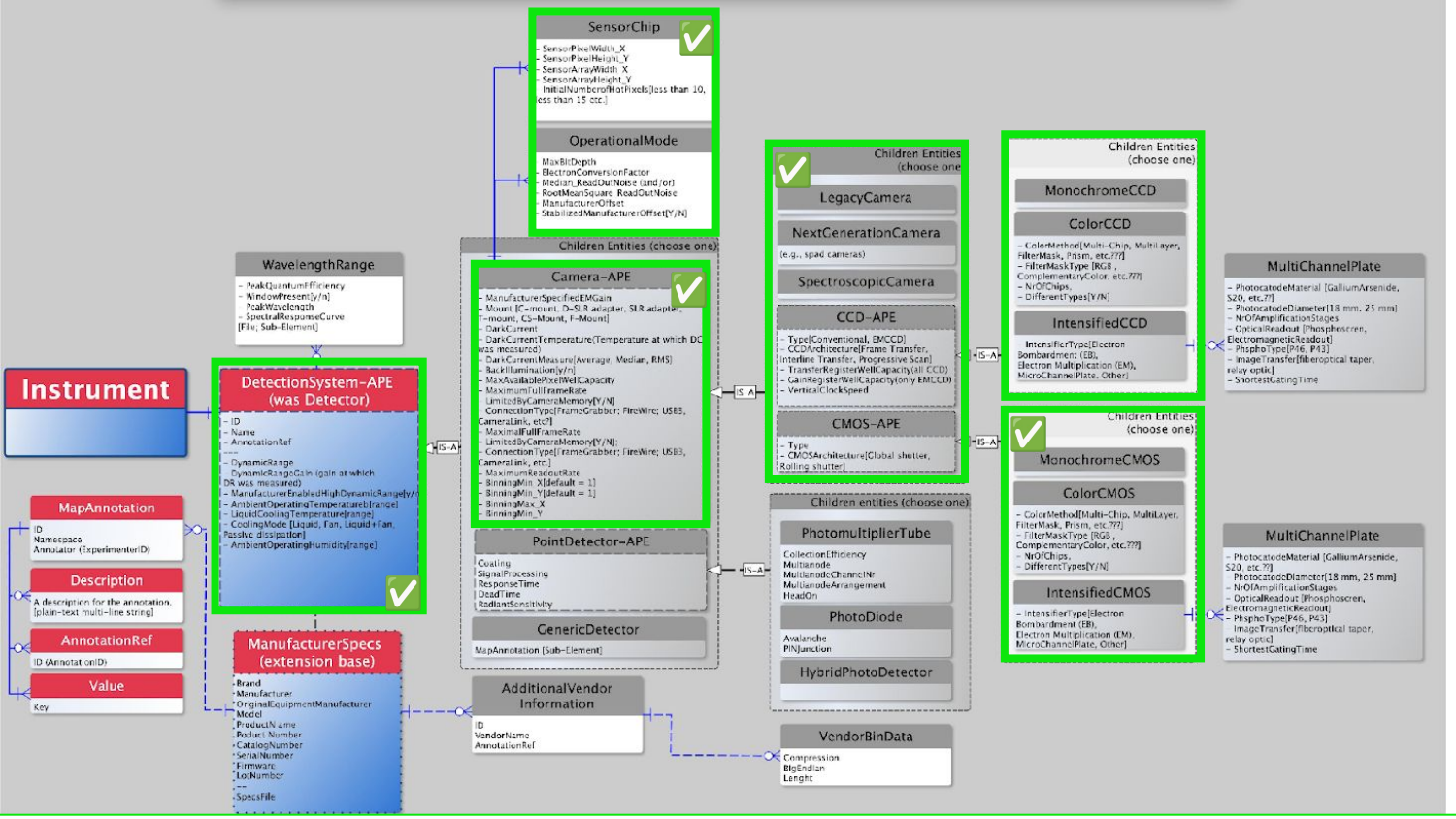


QUAREP-LiMi

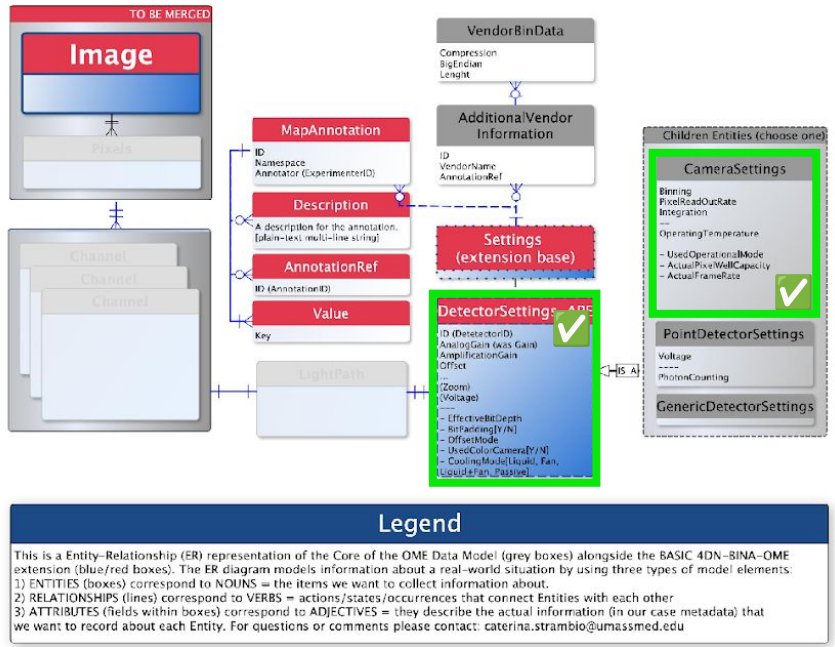
WG2 & WG7 joint endeavor

Outcome NBO-Q 2025 version

OME Core vs. NBO Basic Extension vs. NBOQ DETECTIONSYSTEM Hardware Specifications



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



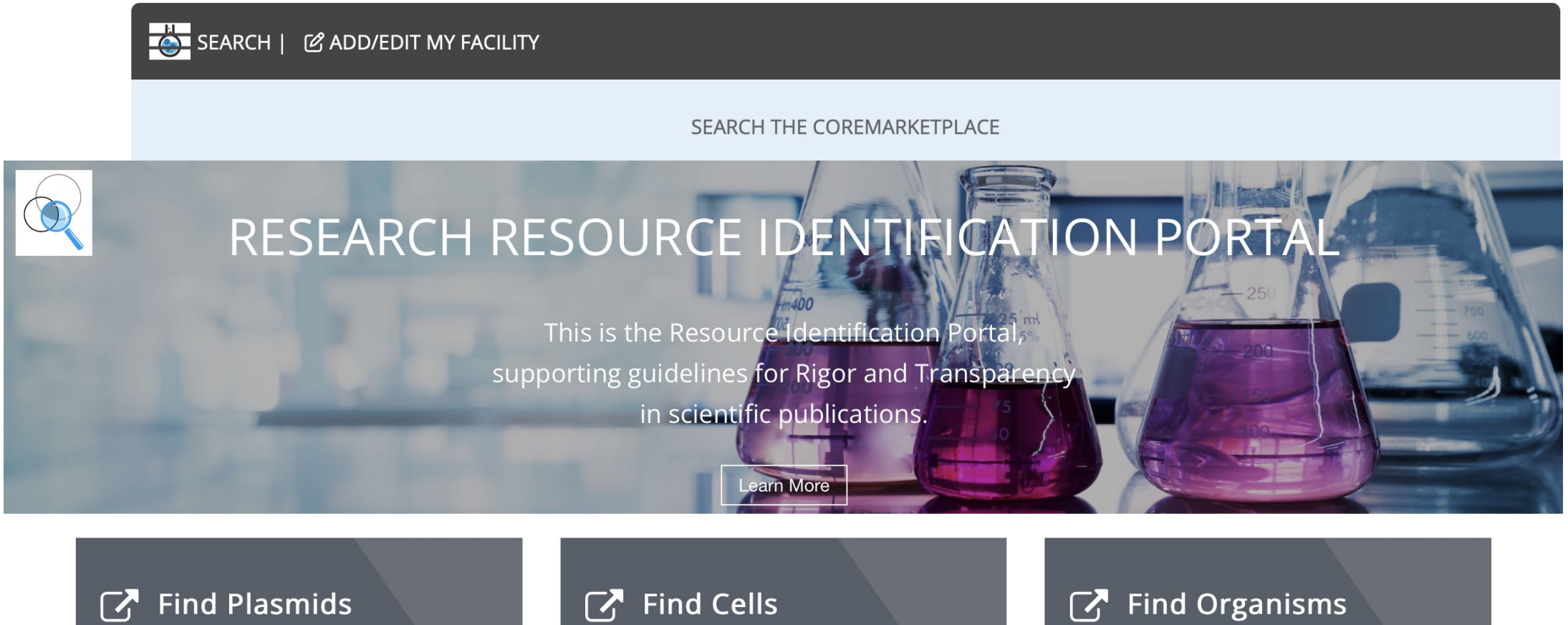
Core Marketplace + RRID: supporting the persistent identification of core-facilities

CORE MARKETPLACE SEARCH HELP POSTINGS

USEDit UNIVERSAL SCIENTIFIC EQUIPMENT DISCOVERY TOOL

AIB RIF

VBRN Vermont Biomedical Research Network
An IDeA Network of Biomedical Research Excellence (INBRE)



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

CORE MARKETPLACE

SEARCH HELP POSTINGS

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UNIVERSAL SCIENTIFIC EQUIPMENT DISCOVERY TOOL

AIB RIF

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

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

UMass Chan MEDICAL SCHOOL

James Chambers
Core Manager

UMASS

Judith Lacoste
Quality-Control

Josh Moore
Next Gen Metadata

German BioImaging
Gesellschaft für Mikroskopie und Bildanalyse

BioImaging North America

QUAREP-LiMi

CBI BIC
Canada BioImaging
BioImagerie du Canada

OME

4D Nucleome

HuBMAP
Human BioMolecular Atlas Program

Adrian Zai
Research Informatics

UMass Chan MEDICAL SCHOOL

Anita Bandrowsky
RRID

SciCrunch
FDI Lab
FAIR Data Informatics

Nate Herzog
CoreMarketplace

Vermont Biomedical Research Network
VBRN
An IDeA Network of Biomedical Research Excellence (INBRE)

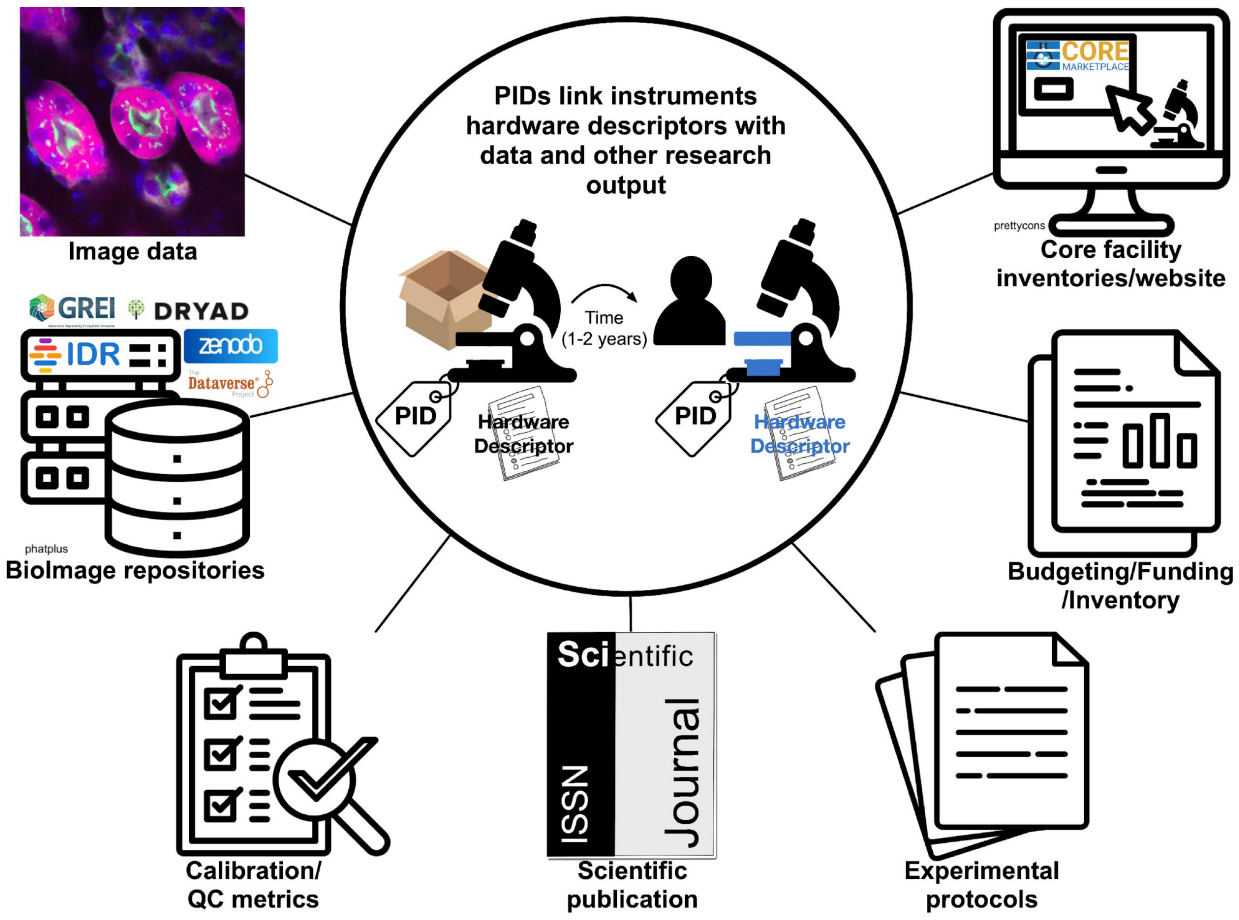
AIBRIF

CORE MARKETPLACE

RDA

DataCite

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)?

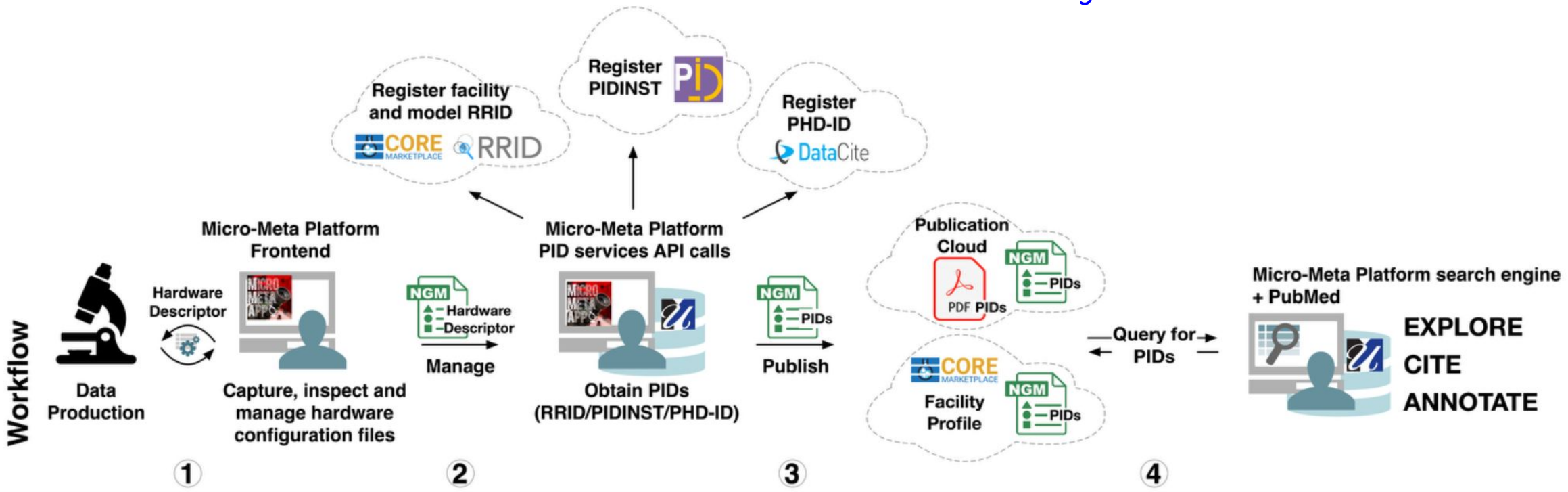
- Unique, long-lasting digital codes assigned to entities like instruments, datasets, and people.
- Maintained by trusted authorities and resolve to stable landing pages with rich metadata.

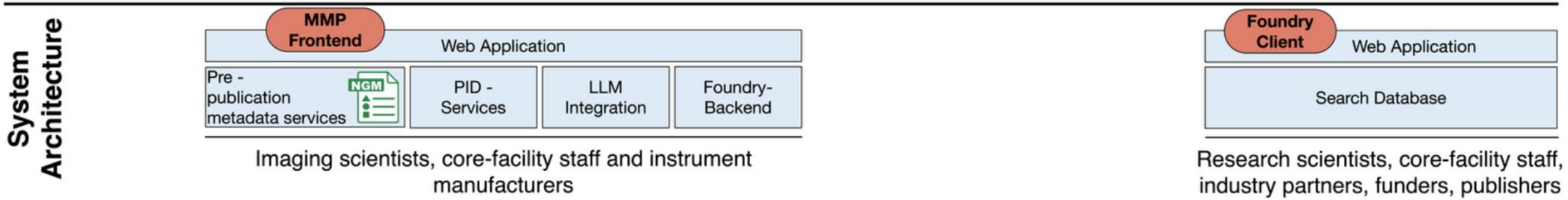
Why PIDs Are Essential

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

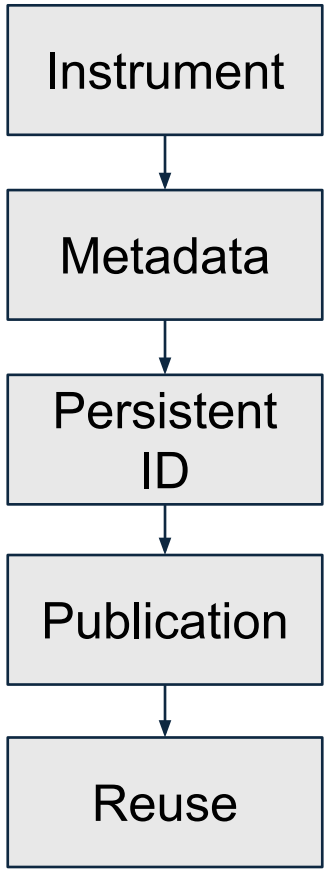
Deliverable - Micro-Meta Platform Workflow and Architecture

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





Intellectual Merits - How this Work Advances Science



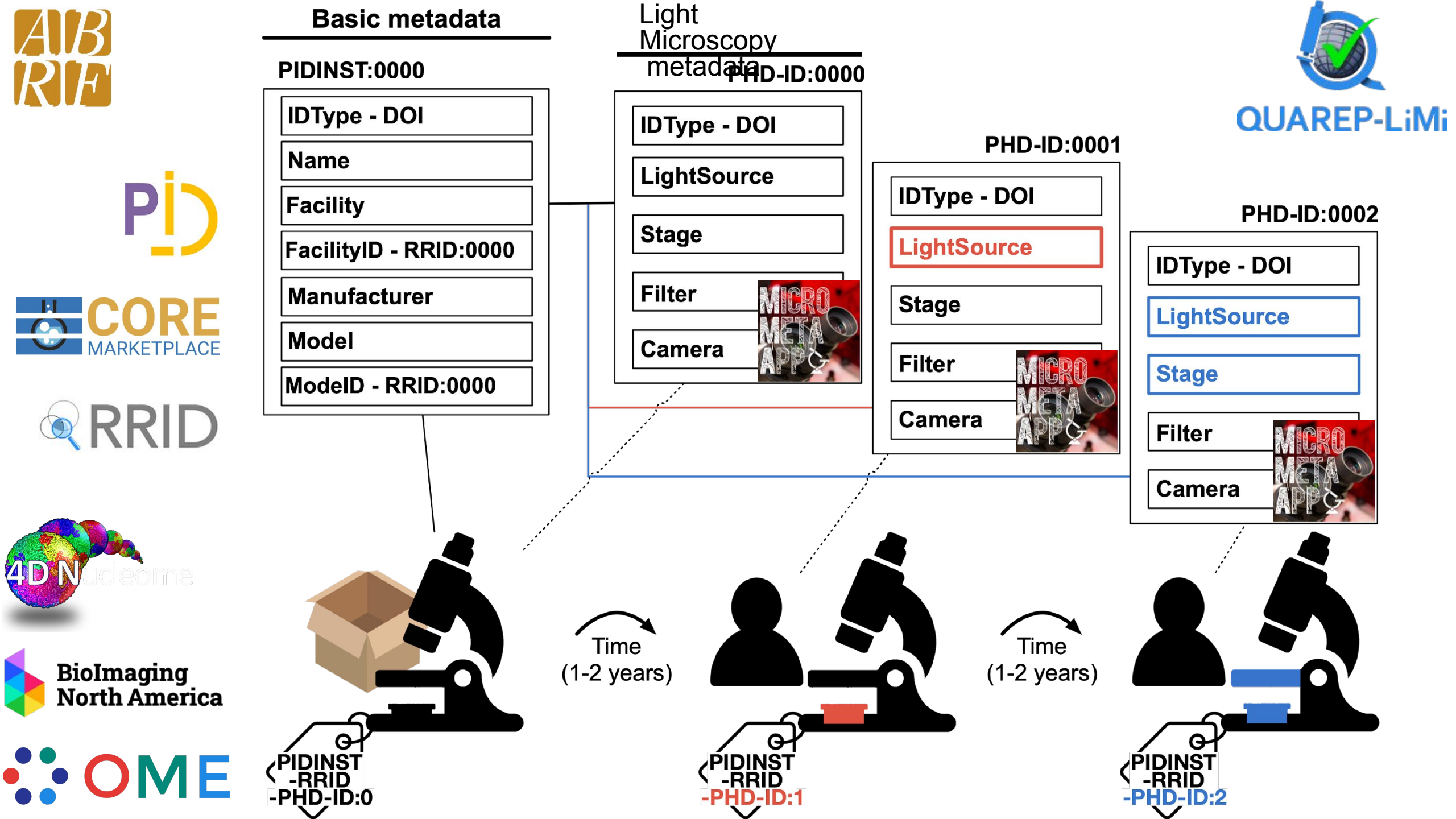
Merit Area	Imaging-PHD Contribution
Democratizing Scientific Infrastructure	Makes detailed, standardized instrument metadata openly available via persistent identifiers. Enables smaller labs and under-resourced institutions to build on others' hardware setups.
Ensuring Long-Term Research Quality	PHDs 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.”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Facility
FacilityID - RRID:0000
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Model
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Light Microscopy metadata
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LightSource
Stage
Filter
Camera
PHD-ID:0001
IDType - DOI
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Stage
Filter
Camera
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IDType - DOI
LightSource
Stage
Filter
Camera
QUAREP-LiMi
Time (1-2 years)
Time (1-2 years)
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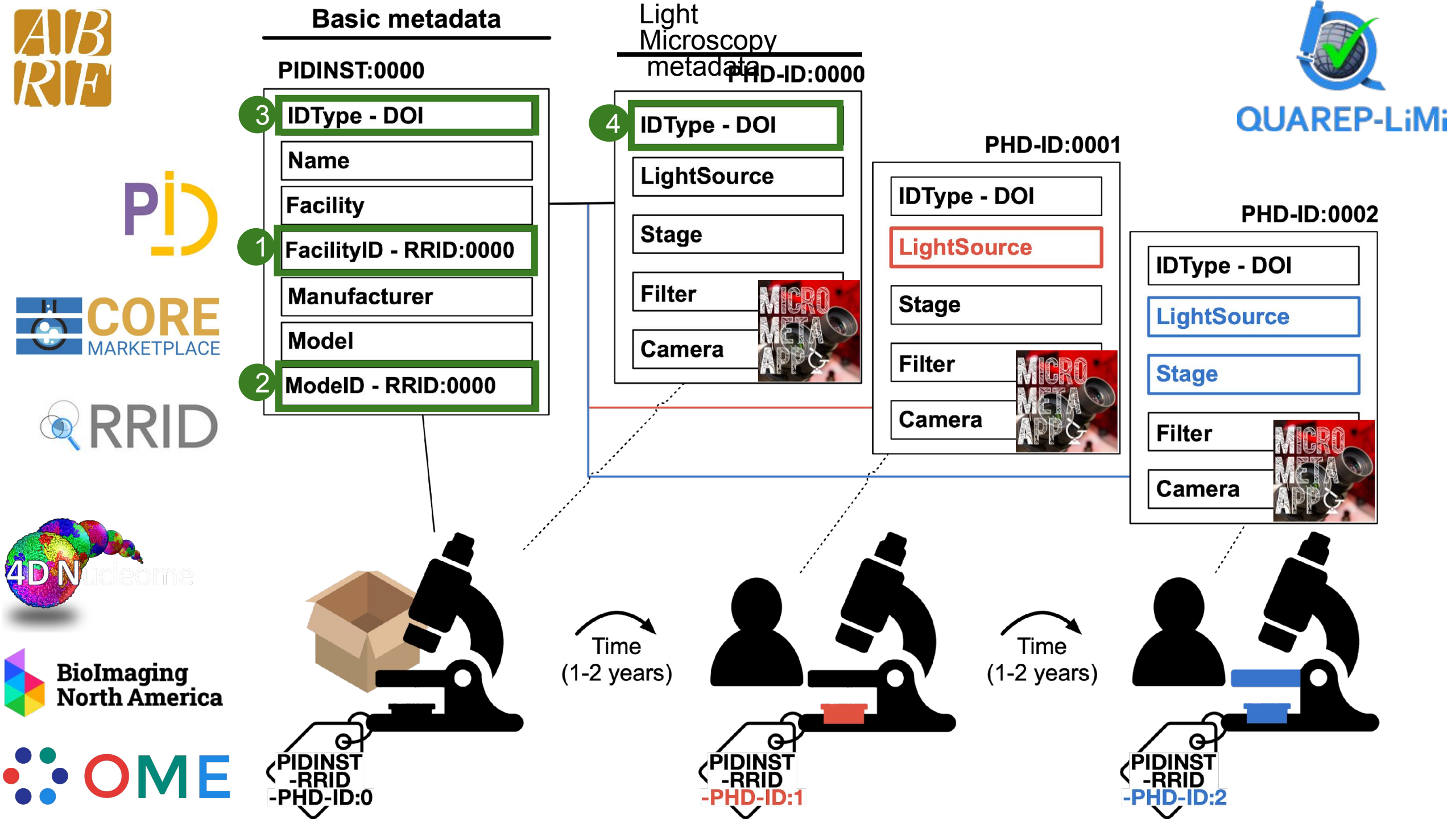
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4 IDType - DOI
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Stage
Filter
Camera
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IDType - DOI
LightSource
Stage
Filter
Camera
PHD-ID:0002
IDType - DOI
LightSource
Stage
Filter
Camera
QUAREP-LiMi
CORE MARKETPLACE
RRID
4D Nucleome
BioImaging North America
OME
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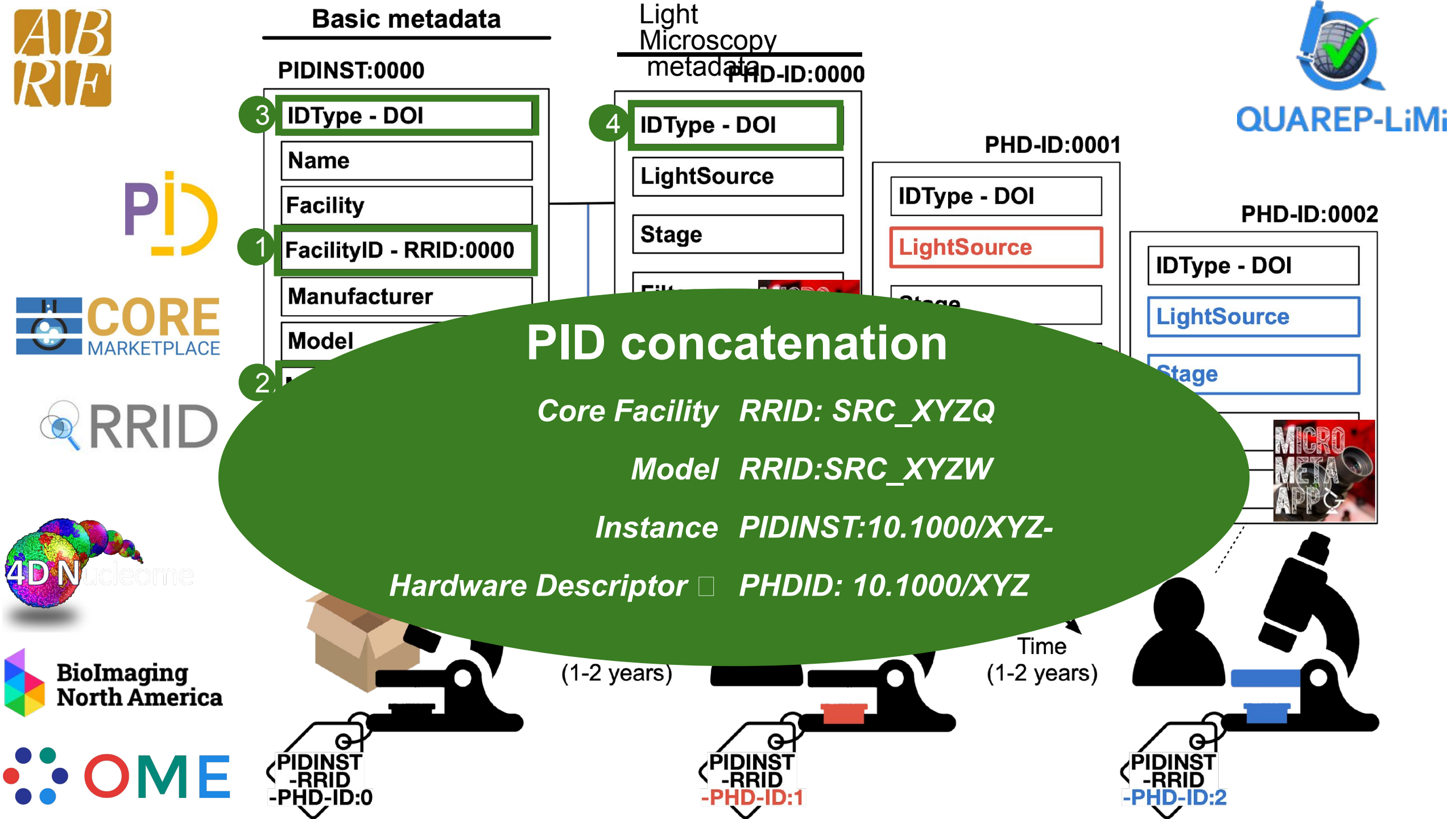
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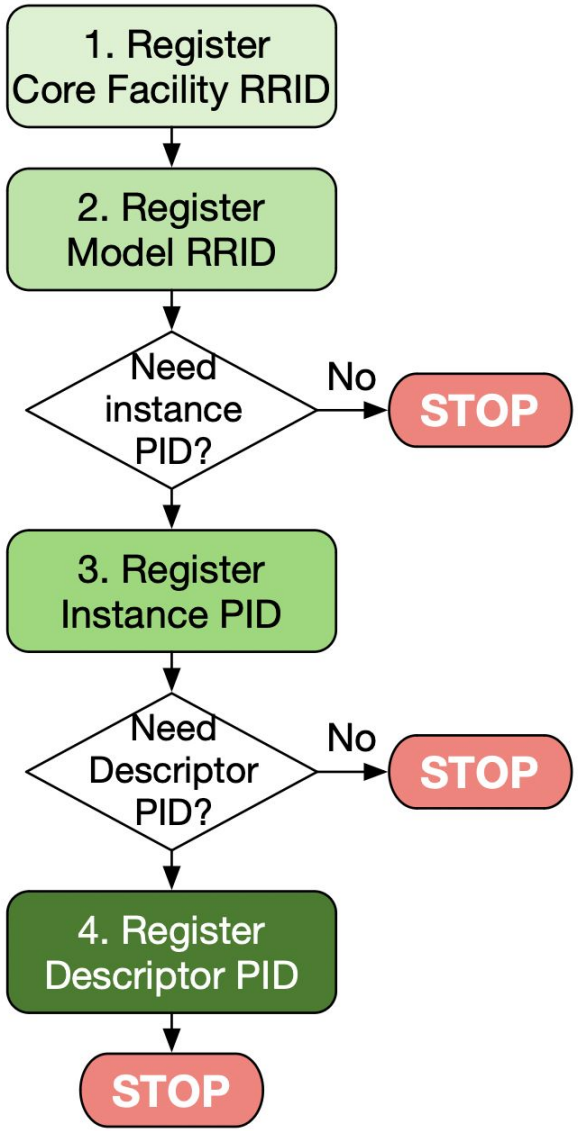
4 IDType - DOI
LightSource
Stage
PHD-ID:0001
IDType - DOI
LightSource
PHD-ID:0002
IDType - DOI
LightSource
Stage
PID concatenation
Core Facility RRID: SRC_XYZQ
Model RRID:SRC_XYZW
Instance PIDINST:10.1000/XYZ-
Hardware Descriptor PHDID: 10.1000/XYZ
Time
(1-2 years)
Time
(1-2 years)
PIDINST -RRID -PHD-ID:0
PIDINST -RRID -PHD-ID:1
PIDINST -RRID -PHD-ID:2
QUAREP-LiMi
CORE MARKETPLACE
RRID
4D Nucleome
BioImaging North America
OME

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**



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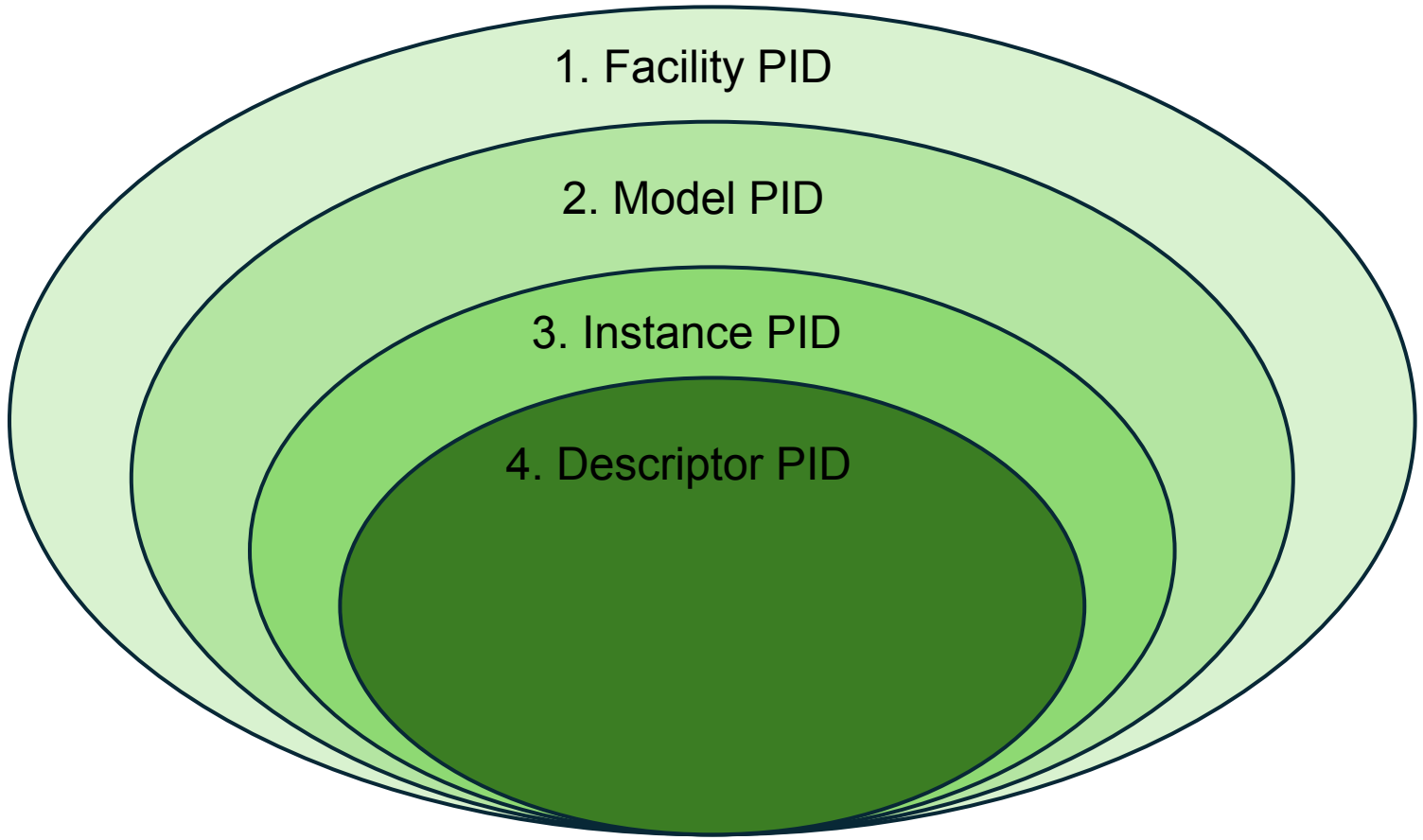

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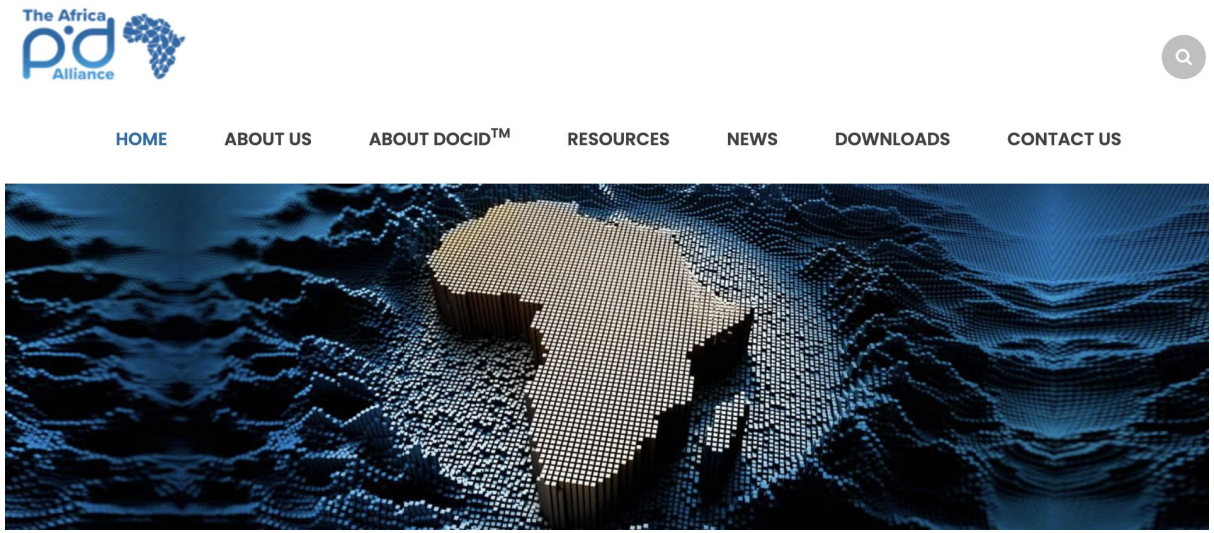

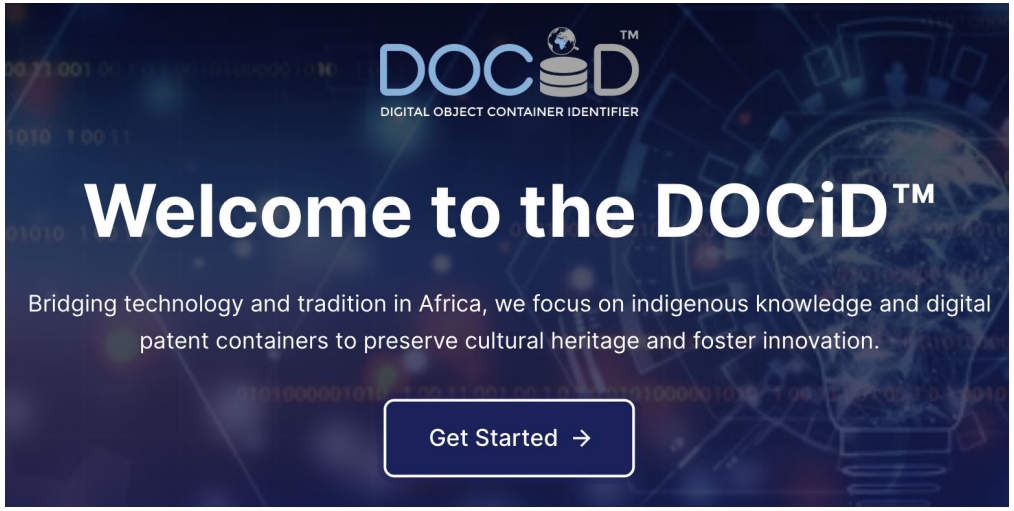

https://africapidalliance.org/

THANK YOU!

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Pina Colarusso


Alex Rigano


Alice Kang


Gabriel Pelletier


Joel Ryan


Stephen Ogg


Alex Kiepas

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- Alison North, The Rockefeller University
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- Damir Sudar, Uni Oregon, QIS
- Caroline Miller
- Nikki Bilay + Vanessa Orr, BINA
- BINA Quality Control and Data Management WG
- QUAREP-LiMi WG7 – Metadata







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



4DN Community

- 4DN IWG: Sarah Aufmkolk, Lacra Bintu, Alistair Boettingerr, 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



UMass Chan MEDICAL SCHOOL

4D Nucleome

BioImaging North America

QUAREP-LiMi

OME

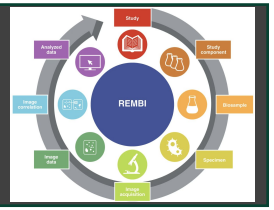
HuBMAP

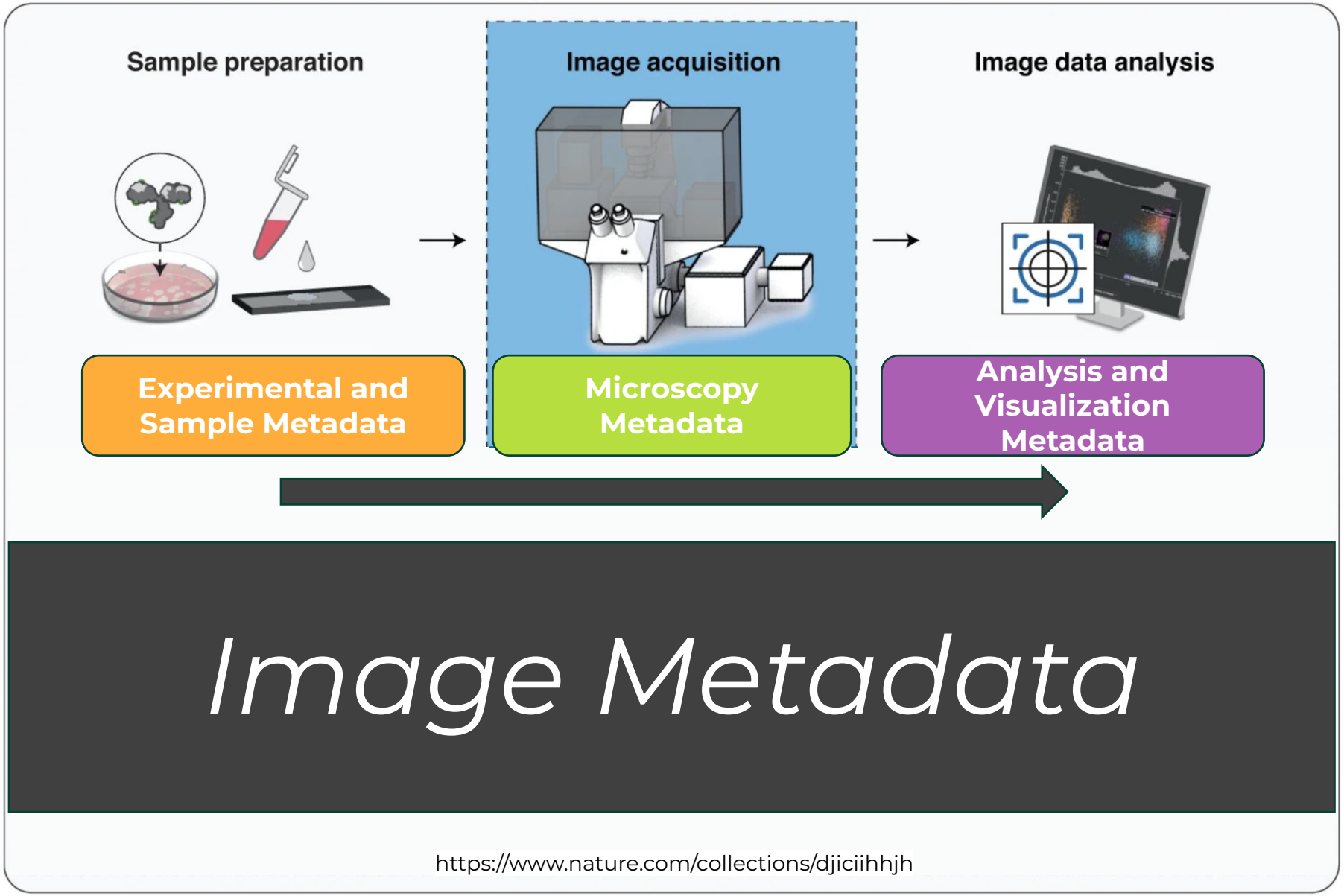
Human BioMolecular Atlas Program

NIH National Institutes of Health

Chan Zuckerberg Initiative

Image Metadata is key for producing high-quality FAIR data

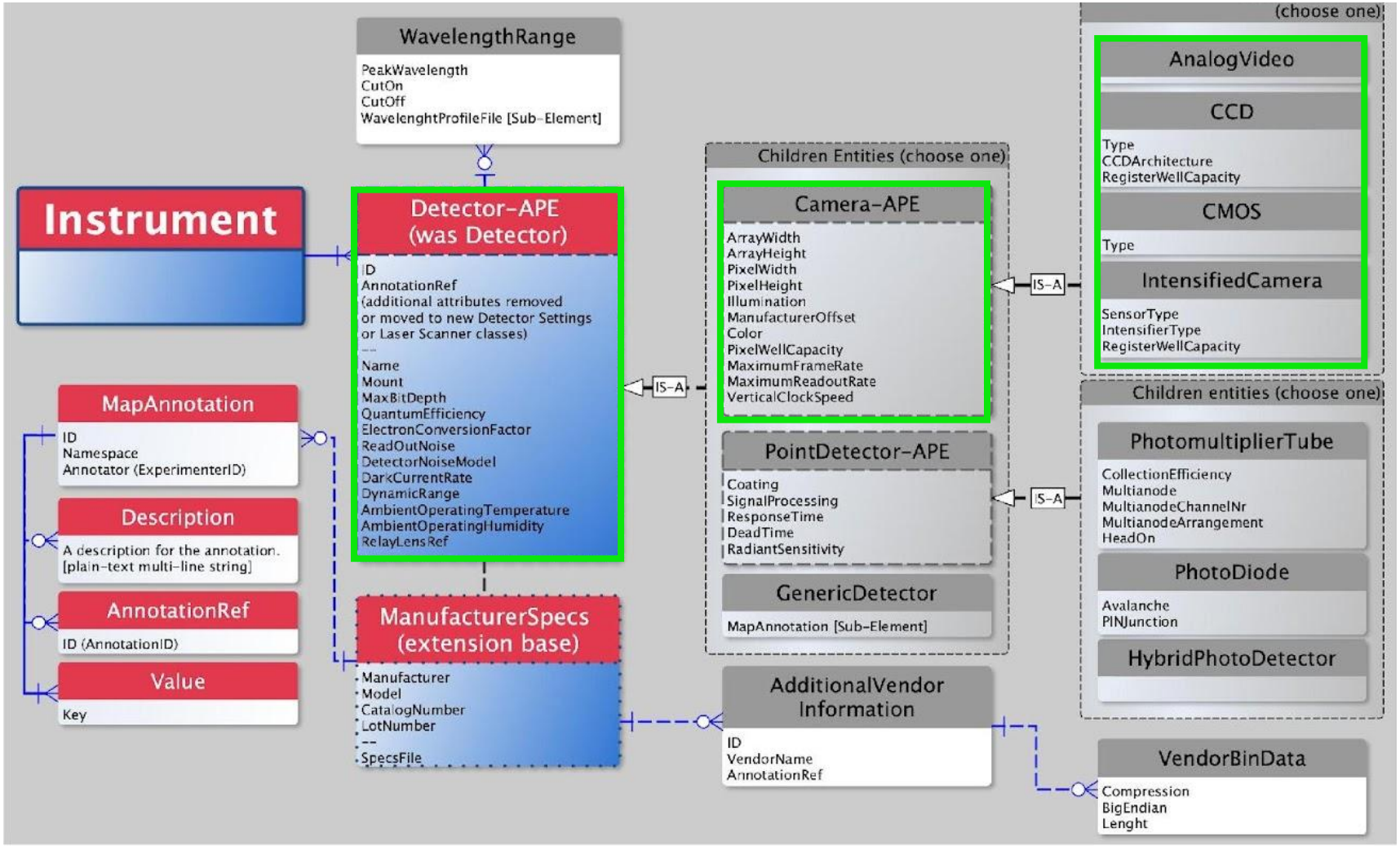




https://www.nature.com/collections/djiciihhjh

WG2 & WG7 joint endeavor

Starting point NBO 2021 published version



PIDINST

metadata

PIDINST:0000

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Name
Facility
FacilityID - RRID:0000
Manufacturer
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ModelID - RRID:0000

PIDINST metadata

PIDINST:0000

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- Name
- Facility
- FacilityID - RRID:0000
- Manufacturer
- Model
- ModelID - RRID:0000

Light Microscopy metadata

PHD-ID:0000

- IDType - DOI
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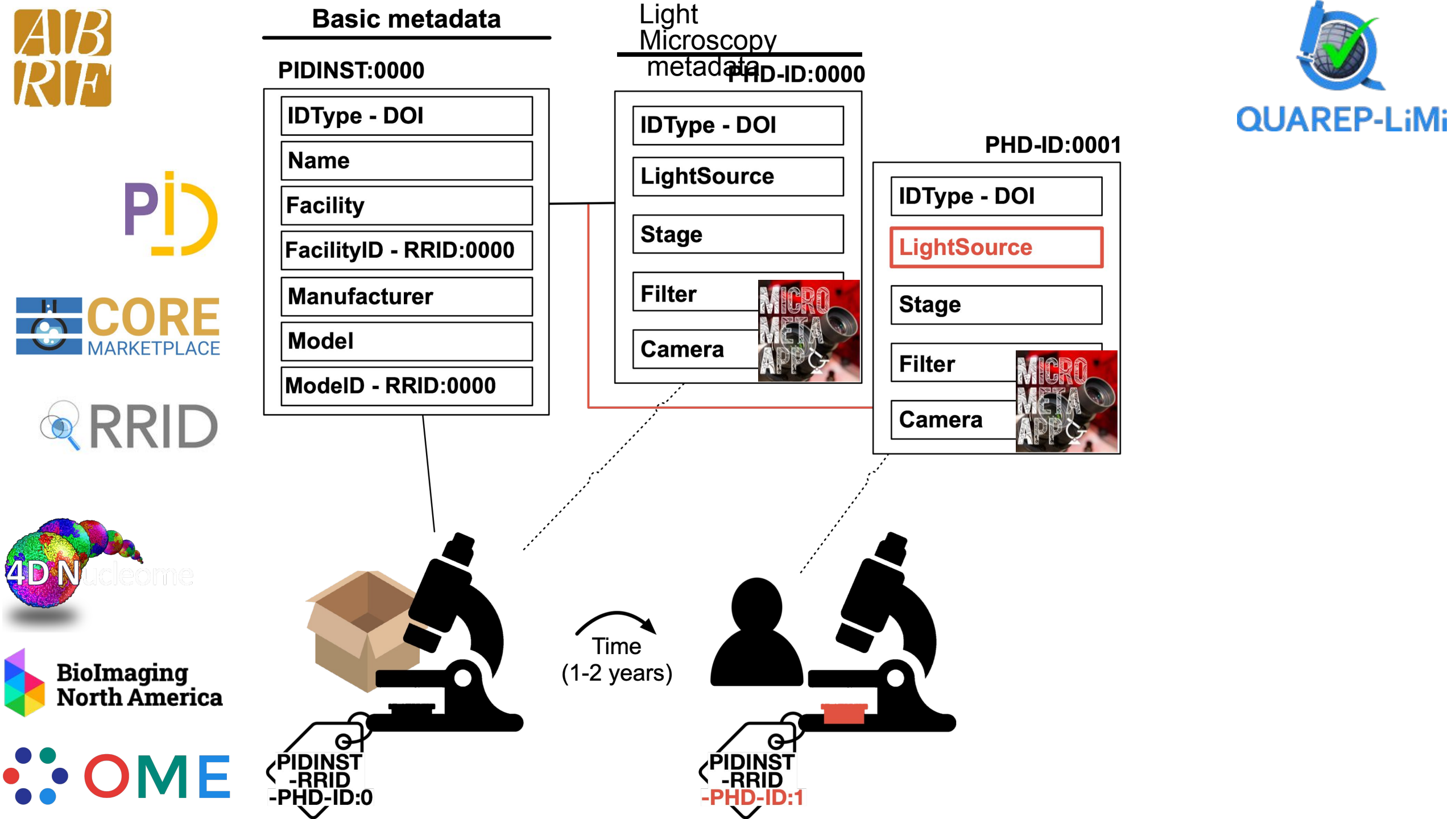
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IDType - DOI
LightSource
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Time
(1-2 years)
PIDINST
-RRID
-PHD-ID:0
PIDINST
-RRID
-PHD-ID:1
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CORE
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