Neurodata Without Borders – An Ecosystem for Standardizing Diverse Neuorophysiology Data

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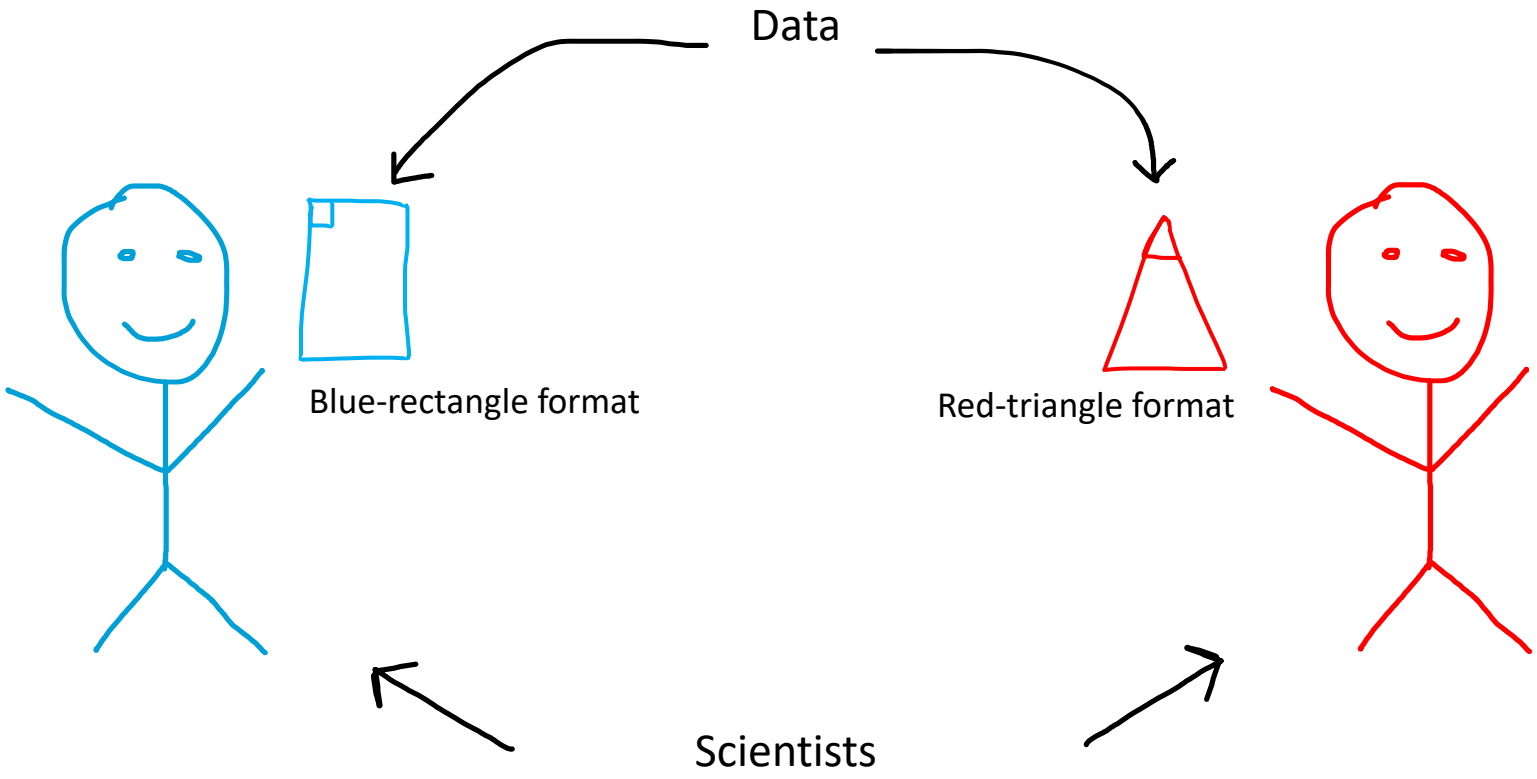
nwb.org

Community science…



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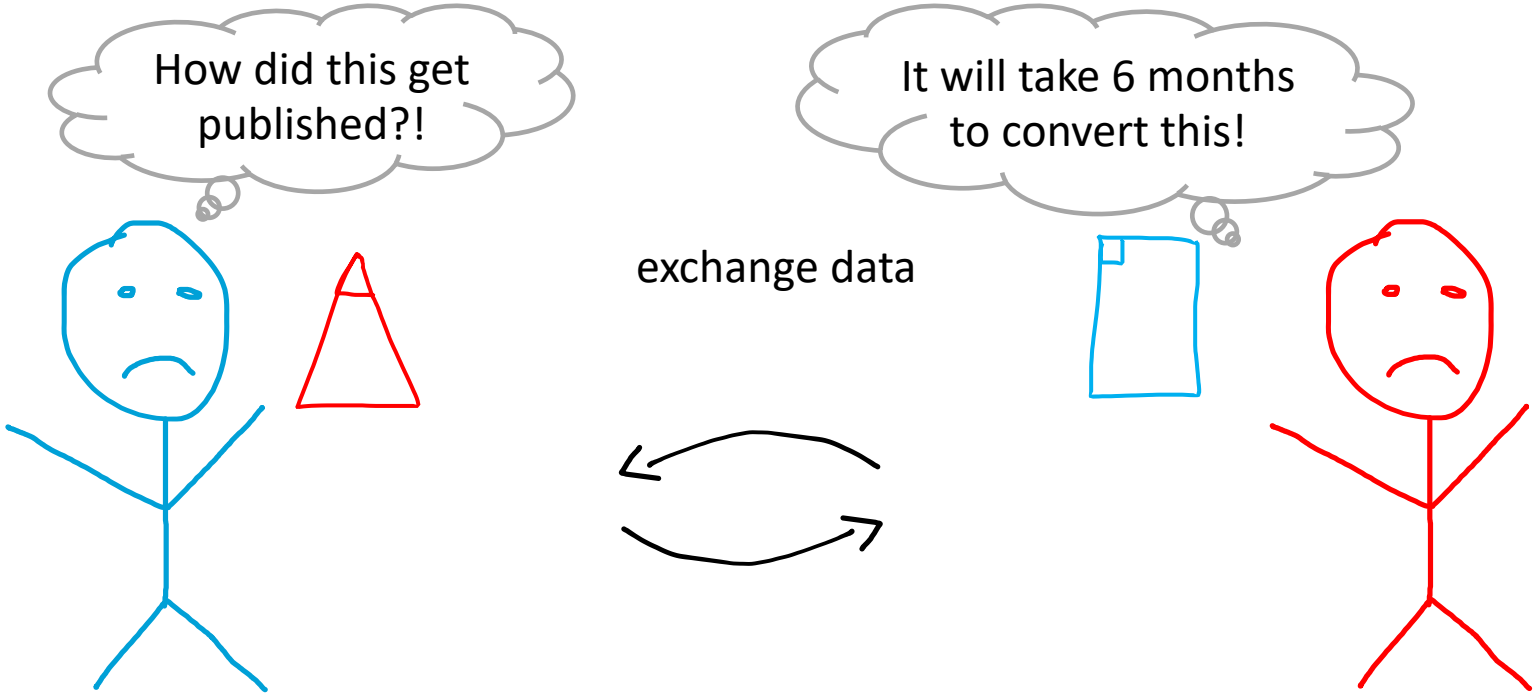

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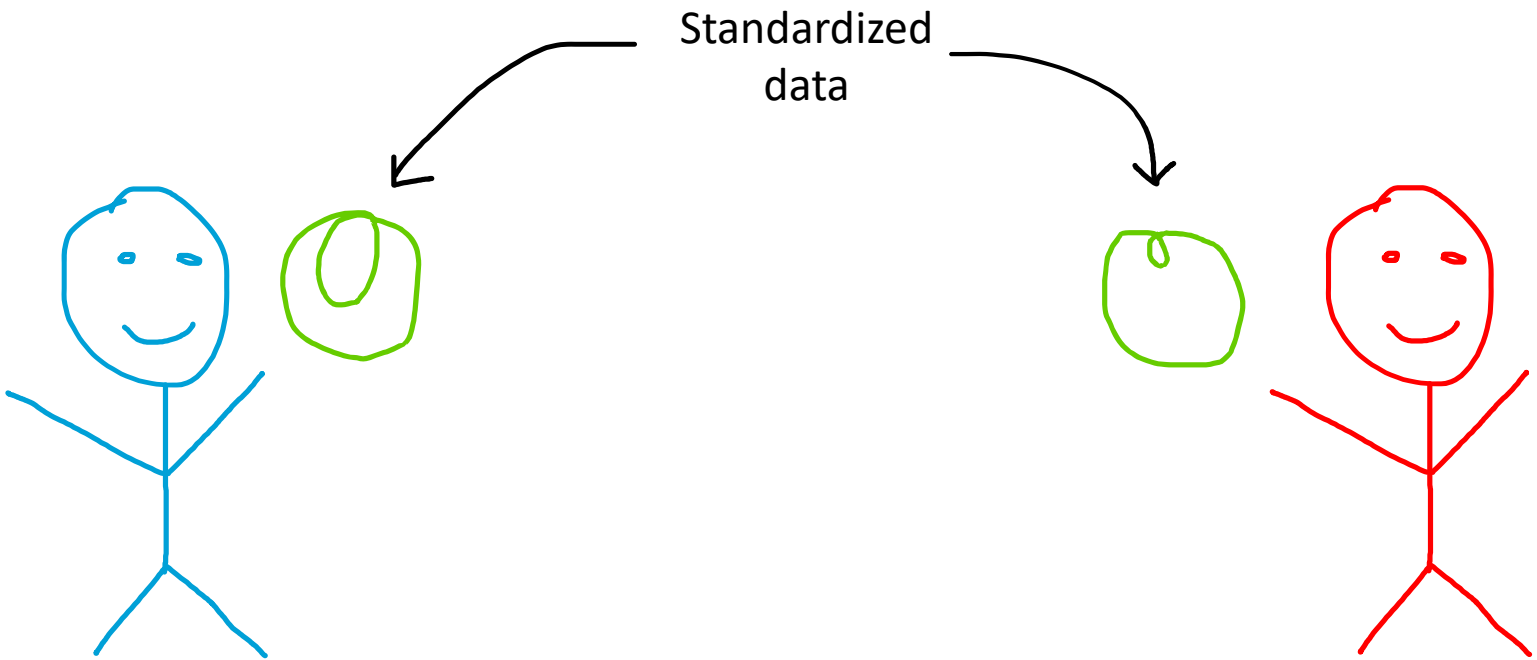

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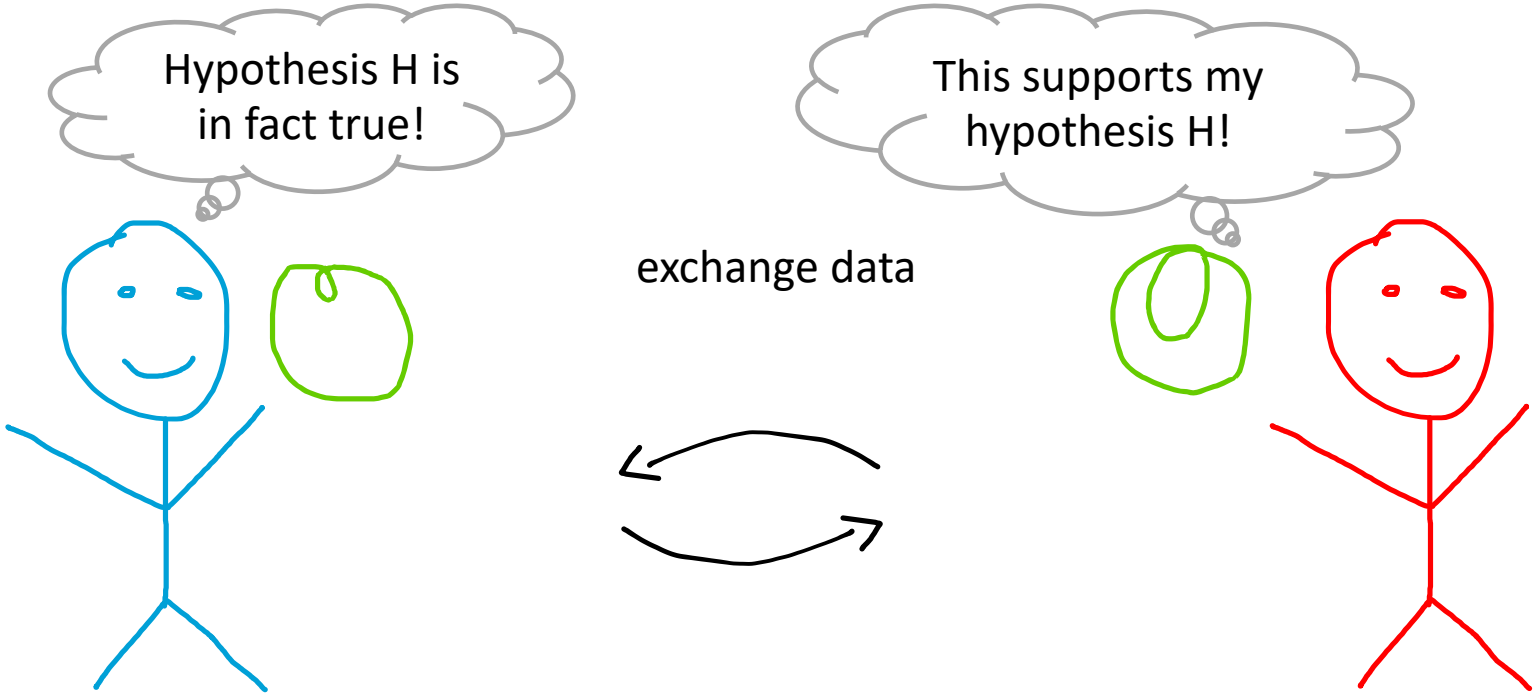


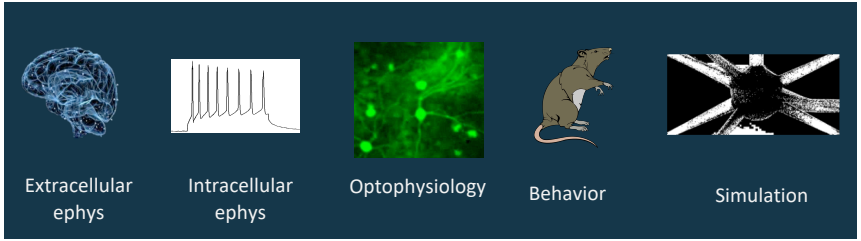
Neurodata Without Borders

Motivation: community science needs a stable target for data

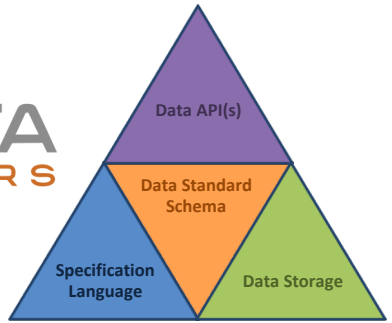
NWB – An Ecosystem for Neurophysiology Data Standardization

- Defines a unified format for neurophysiology data
  → focus on dynamics of groups of neurons

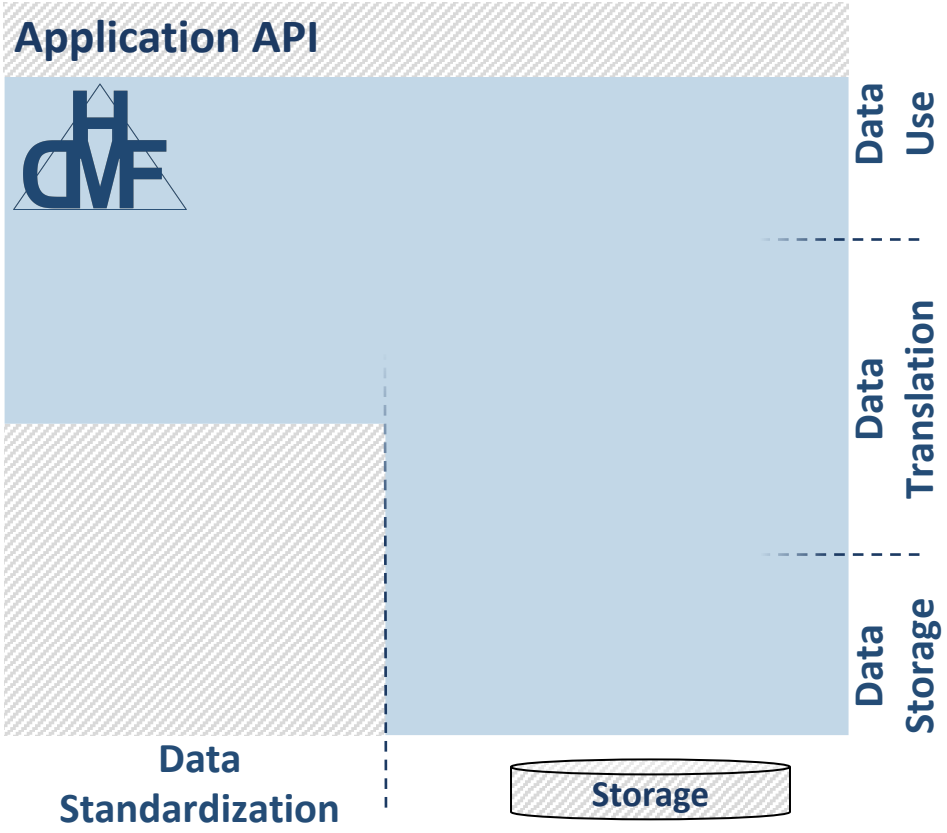
- More than just a file format
  - tools, methods, and standards for storing, sharing, and analyzing complex neurophysiology data

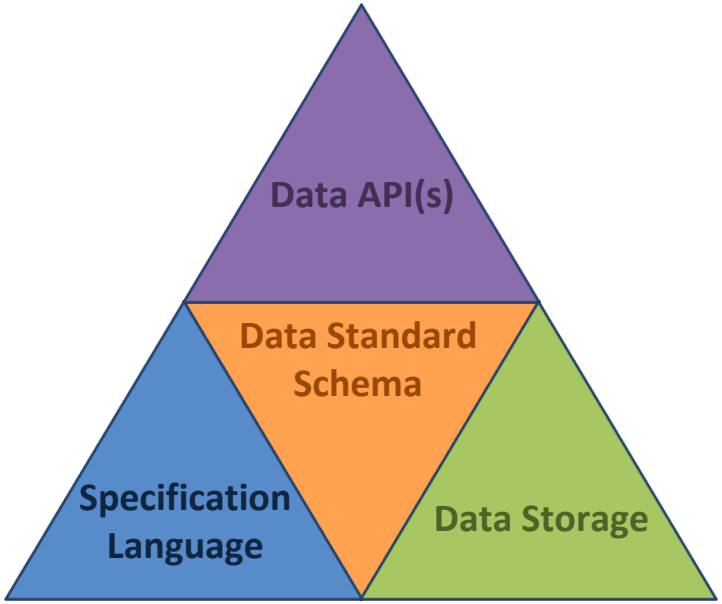


NEURODATA WITHOUT BORDERS



HDMF Software Stack





Specification language

Goal:

- Enable the formal definition of data standards that is *machine and human* readable

Format specification language

- Schema for defining hierarchical data schemas

Main primitives of the specification language:

- **Object primitives**
- **Data type specifications**
- **Namespace specification**

Specification language

Object primitives:

- **Group:** collection of objects i.e. subgroups, datasets, links
- **Dataset:** n-dimensional array with associated data type, dimensions, etc.
- **Attribute:** metadata attached to a Group or Dataset
- **Link:** a soft link to given target data_type

Specification language

Data type specifications

- **Basic data types:** strings and numeric types
- **Compound data types:** complex data types
- **isodatetime:** ISO8061 date-time string
  - e.g. 2018-09-28T14:43:54.123+02:00
- **Object reference:** a link that can be as a value
- **Region reference:** a link to a dataset that also stores slice

Defining reusable data types

`data_type`: Defines reusable type

- Similar to a class in OOP
- All objects must have either a unique name or `data_type`

Enables reuse of types through inheritance and:

- **`data_type_inc`**: include an existing type
- **`data_type_def`**: defines a new type

A schema is a collection of reusable `data_types`

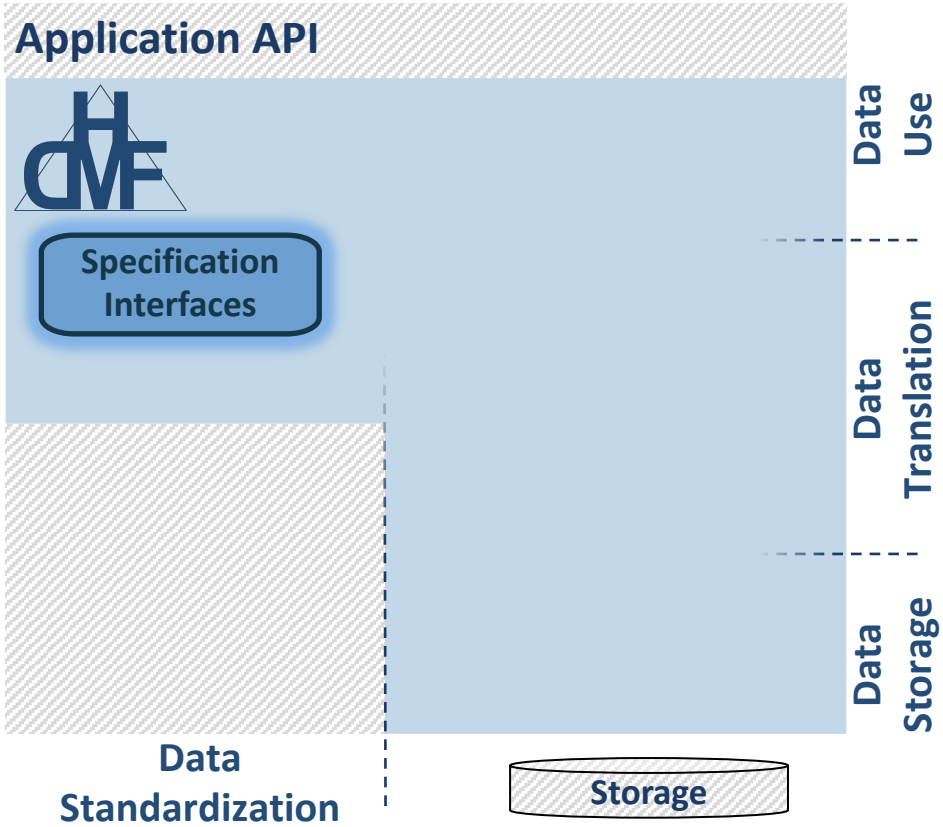
- Extend by:
  - defining new `data_types`
  - extending existing `data_types`

Specification language

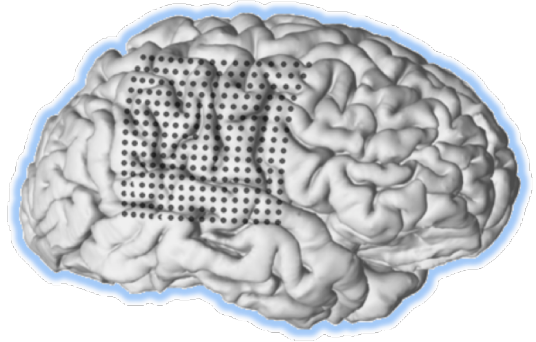
Namespace specification:

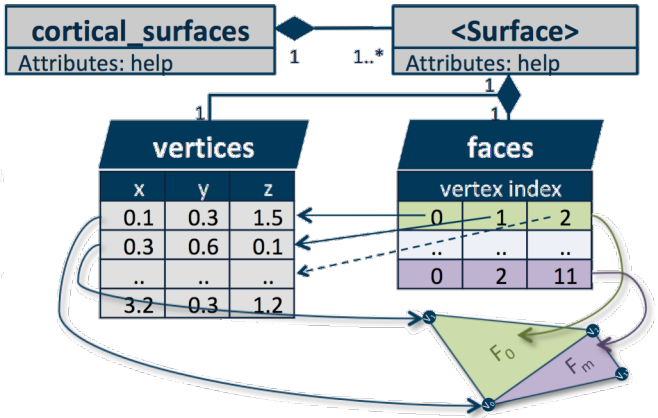
- define a standard
- insulate extensions from each other
- enable the creation of new data standards
- extensions shared in the form of a namespace

Specification Language API



Specification



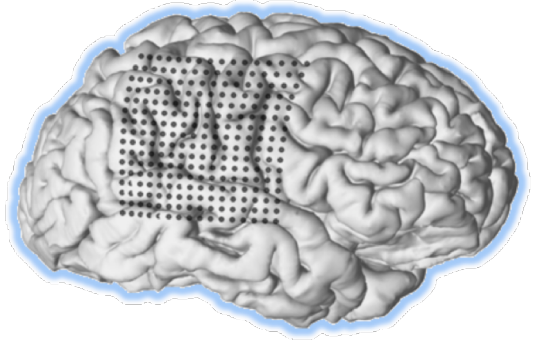


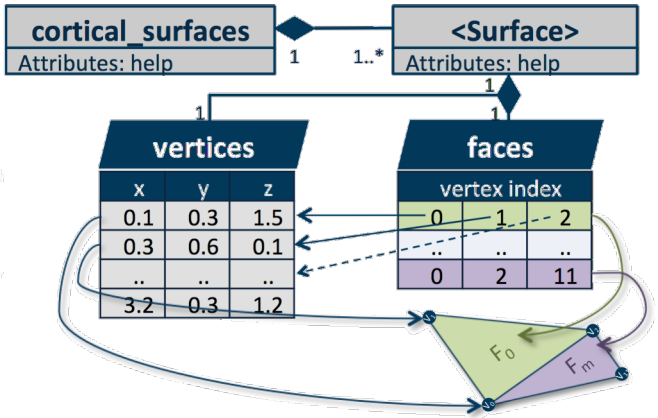
Creating the extension

```
from pynwb.spec import NWBDatasetSpec, NWBNamespaceBuilder,
                       NWBGroupSpec, NWBAttributeSpec
surface = NWBGroupSpec(neurodata_type_def='Surface',
           neurodata_type_inc='NWBDataInterface' ,
           quantity='+', doc='brain cortical surface')
surface.add_dataset(NWBDatasetSpec(
           doc='..' , shape=(None, 3),
           name='faces', dtype='uint' , dims=...)
surface.add_dataset(NWBDatasetSpec(
           doc='..', shape=(None, 3) ,
           name='vertices', dtype='float', dims=...)
surface.add_attribute(...)

ns_builder = NWBNamespaceBuilder(doc=..., name='ecog',
                    version='1.0', author='Ben Dichter', ...)
ns_builder.add_spec('ecog.extensions.yaml', surface)
ns_builder.export('ecog.namespace.yaml')
```

Specification





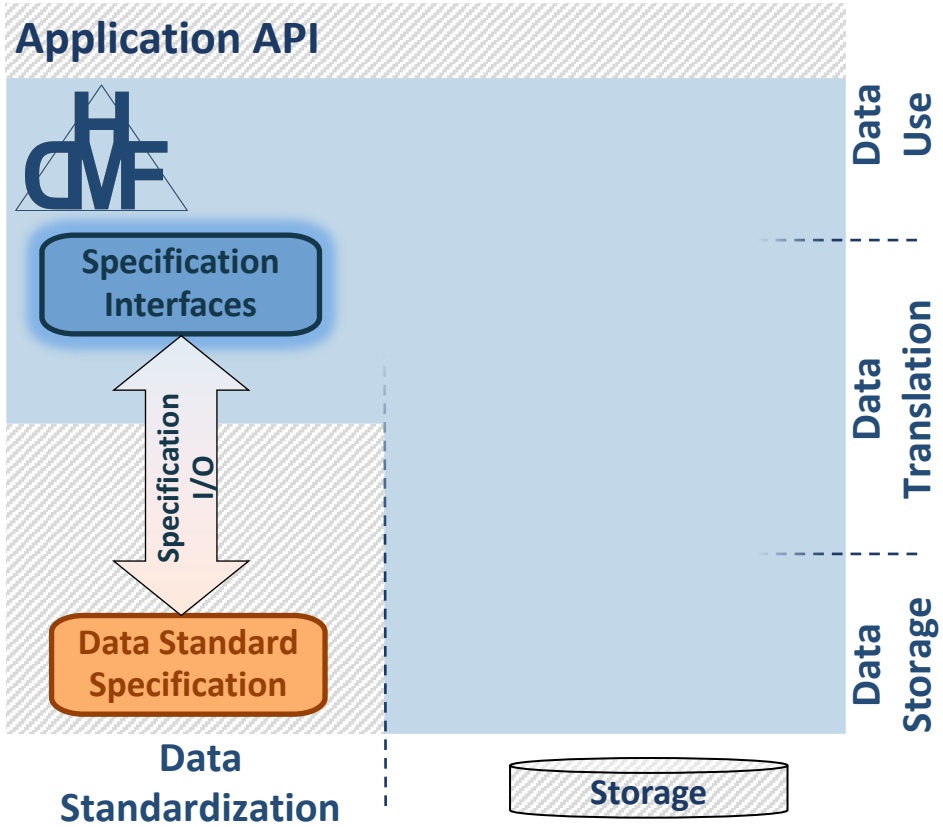
Write data

```
from pynwb import load_namespaces, get_class,
                  NWBHDF5IO, NWBFile ...
nwbfile = NWBFile(...)
load_namespaces('ecog.namespace.yaml')
Surface = get_class('Surface', 'ecog')
surf = Surface(faces=... , vertices=..., name='Surface_1')
nwbfile.add_acquisition(surf)
with NWBHDF5IO('surface_example.nwb', 'w') as io:
      io.write(nwbfile)
```

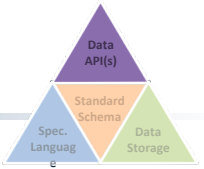
Read data

```
load_namespaces('ecog.namespace.yaml' )
io = NWBHDF5IO('surface_example.nwb', 'r')
nwbfile = io.read()
nwbfile.get_acquisition('Surface 1').vertices
```

Specification Language API



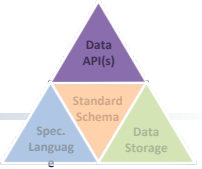
Data API

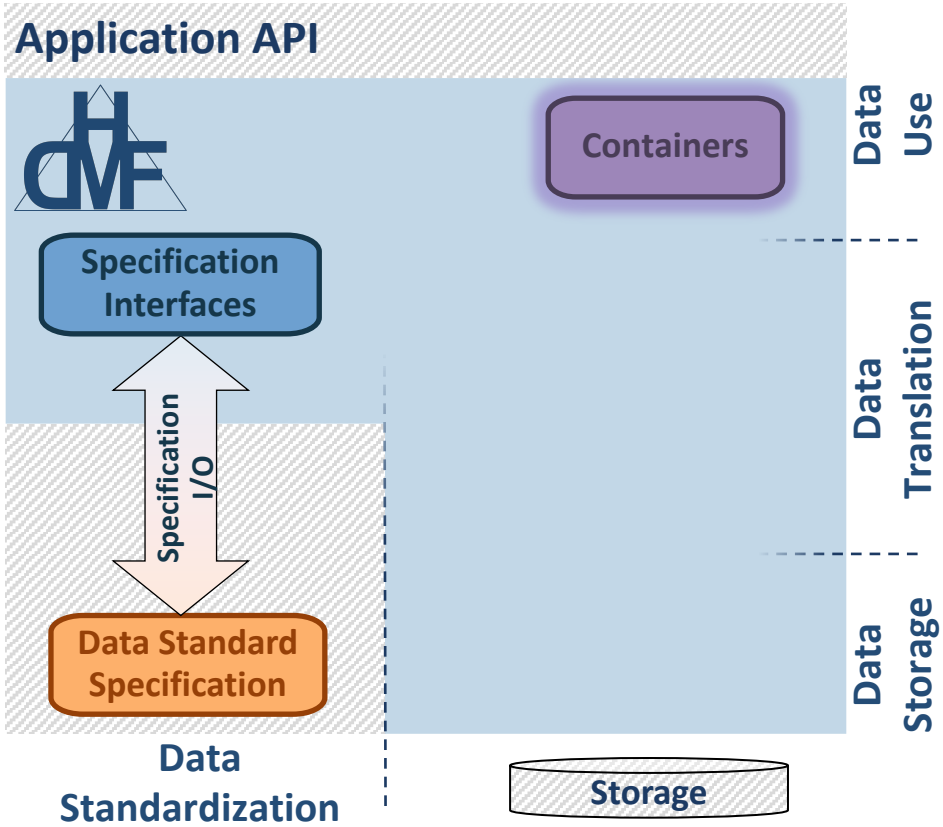


Container: Main in-memory data interface for applications

- One for each `data_type` in the standard schema
  - Class dynamically generated if one does not exist
- HDMF provides base classes and decorators to facilitate the implementation of new Container classes
- Containers hold handles to on-disk data → data lazily loaded
  - backend dependent

Data API


Data API(s)
Standard Schema
Spec. Languag e
Data Storage


Application API
Containers
Specification Interfaces
Specification I/O
Data Standard Specification
Data Standardization
Storage
Data Use
Data Translation
Data Storage

Data storage

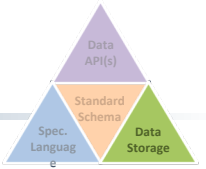
Primary function:

- Map primitives to storage
- Decouple backend from specification and in-memory data structures

- **Builders:** Intermediary objects for I/O representing data primitives
  - GroupBuilder, DatasetBuilder, LinkBuilder, ReferenceBuilder, RegionBuilder

- **HDMFIO:** I/O Interface for reading/writing builders
  - Need to define: read_builder, write_builder, open, close, and __init__ functions
  - HDF5IO and ZarrIO

Data storage

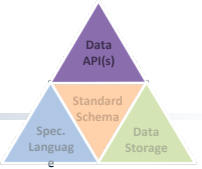


Primary function:

- Map primitives to storage
- Decouple backend from specification and in-memory data structures

- **Data I/O wrappers:**
  - **DataIO:** Define chunking, compression, linking, modular storage etc. to optimize storage and I/O
  - **DataChunkIterator:** Iterator to produce data chunks for iterative data write (e.g., for data streaming or large data import)

Data API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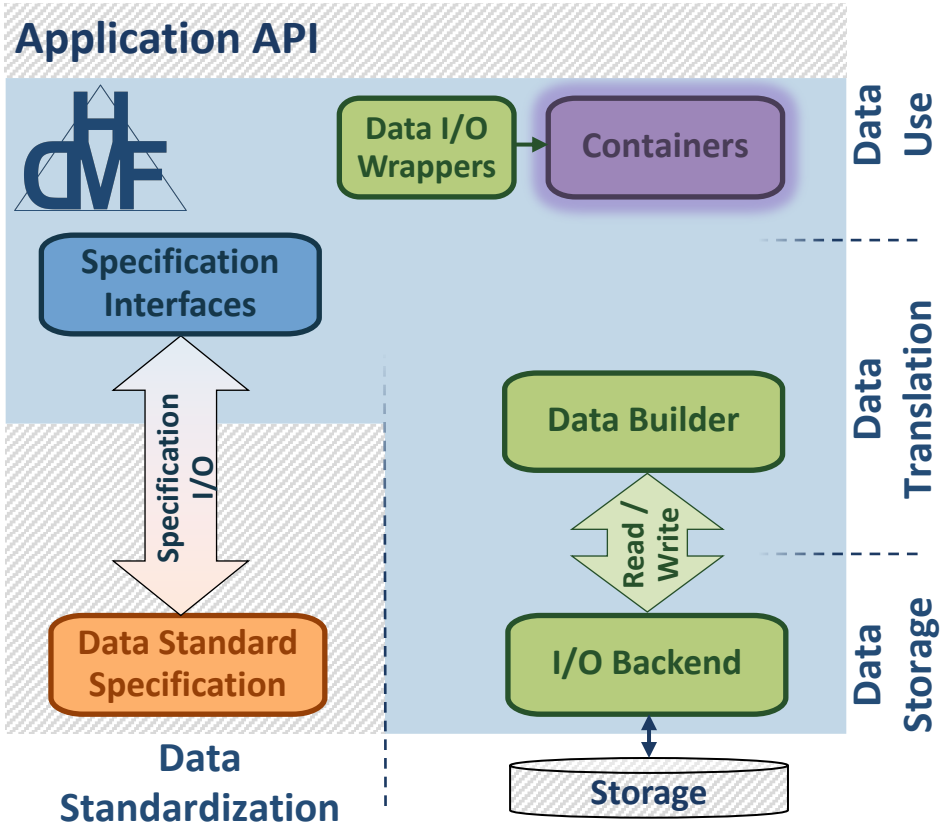
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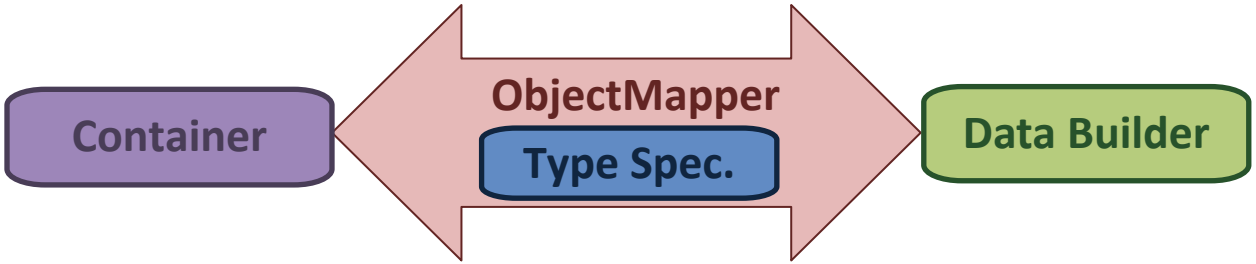
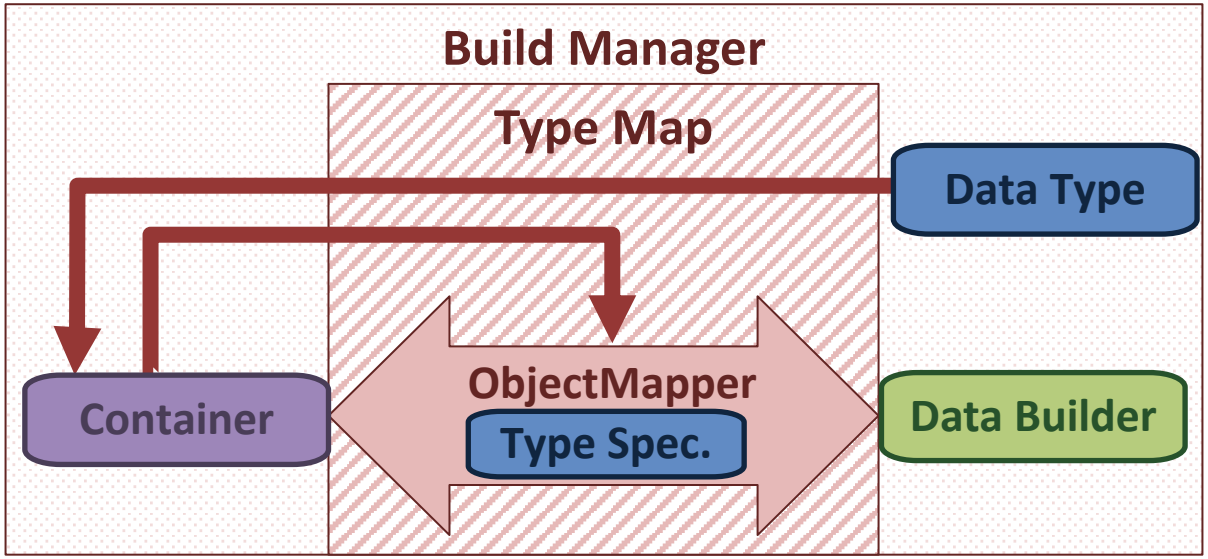
Data Standardization

ObjectMapper



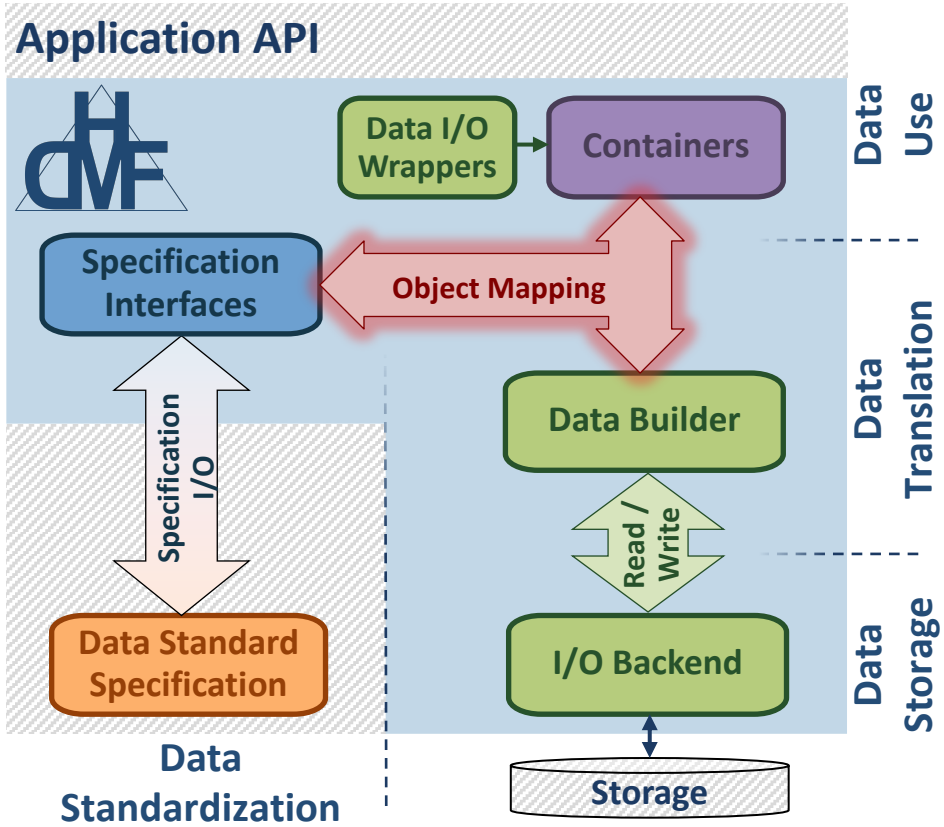
- Maintains mapping between *Container attributes* and *specification components*
- Constructed from a `data_type` specification
- One for each `data_type`
  - base functionality or provided by user

Data mapping API



- **TypeMap:** Map between: `data_types`, Container classes and ObjectMapper classes
  - Given `data_type`, return Container class
  - Given Container class, return ObjectMapper
- **BuildManager:** Responsible for memoizing Builders and Containers
  - Given a Builder, return a Container and vice versa

HDMF Software Stack



Neurodata Without Borders

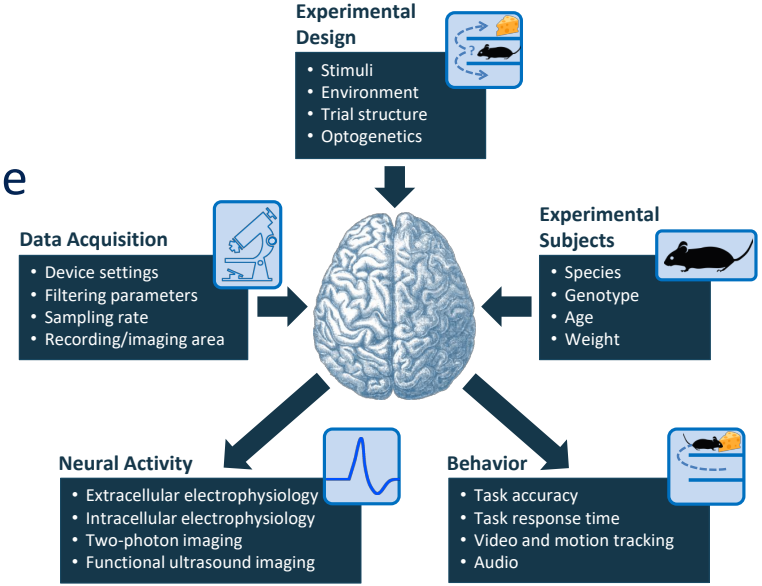
A format schema (a.k.a. specification)

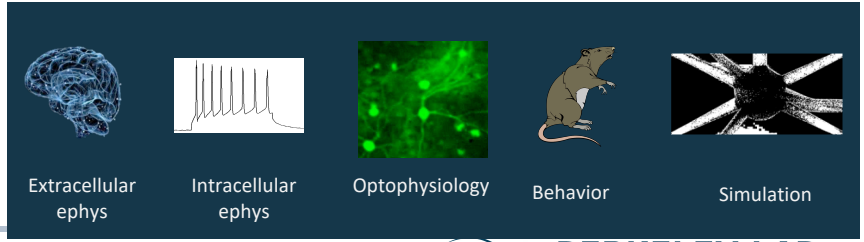
- a collection of YAML files that formally describes the organization of data
- covers data types throughout data life cycle

The **NWB data standard** defines:

- **A catalog of `neurodata_types`**
  - 20 different TimeSeries data types
  - 22+ analysis data types

- **Base hierarchy to logically group data**
  - acquisition, data processing, experimental metadata





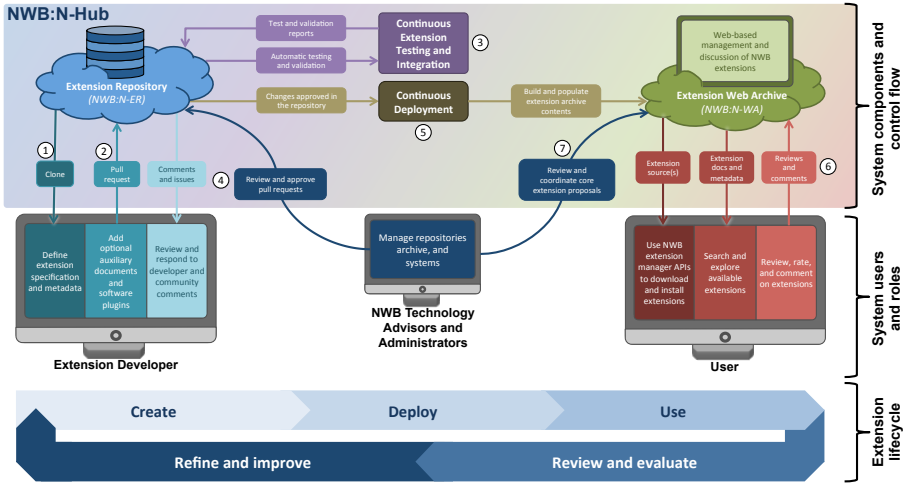
NDX Catalog

Goal: Enable community adoption, extension, and curation of NWB and integration of **new use cases**

Neurodata Extensions Catalog

Approach:

- Tools for creating extensions (PyNWB, nwb-docutils, git template)
- Recipe for deploying extension
- Online catalog for sharing
- Guidelines for versioning, sharing, and review of extension



Resources: https://nwb-extensions.github.io/

Online resources

Visit us online at

neurodatawithoutborders.github.io

and

nwb.org

Contribute

Create issues for bugs, feature request and pull requests on GitHub for schema, PyNWB and MatNWB. For details see: neurodatawithoutborders.github.io/contributing