# Network-centric Biomedicne:
## toward a learning healthcare system

**Ken Buetow, Ph.D.**

**Director Computational Science and Informatics Core Program,**
**Complex Adaptive Systems Initiative**
**Arizona State University**

Biomedical Knowledge Cloud:
A Network to Transform Healthcare

Spring 2012 Internet2 Member Meeting

# The Fourth Paradigm:

## Data-Driven Knowledge, Intelligence and Actionable Decisions

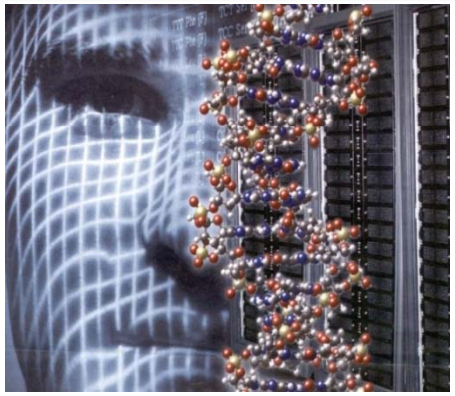
- changing the nature of discovery
  - hypothesis-driven versus hypothesis-generating unbiased analytics of large datasets (patterns, rules)
- changing the nature of explanation
  - statistical probabilities versus unitary values
- changing the cultural process of knowledge acquisition
  - large scale collaboration networks, open systems
- changing knowledge application
  - increased quantification and decision-support systems
- changing cognitive frameworks, intellectual capabilities and competencies for knowledge-intensive competitiveness in multiple domains
- changing education and training

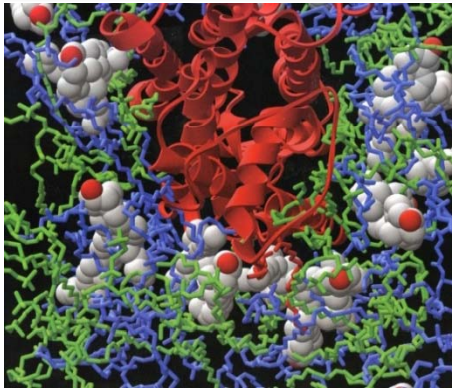
Courtesy G. Poste

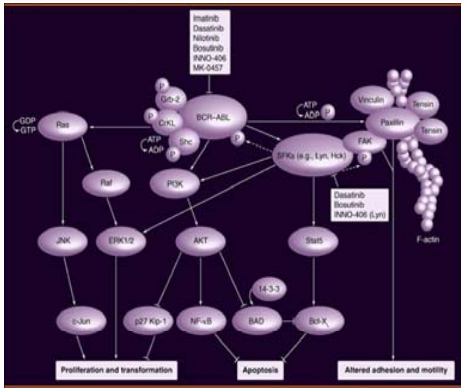
# Determinng The Molecular Basis of Disease:

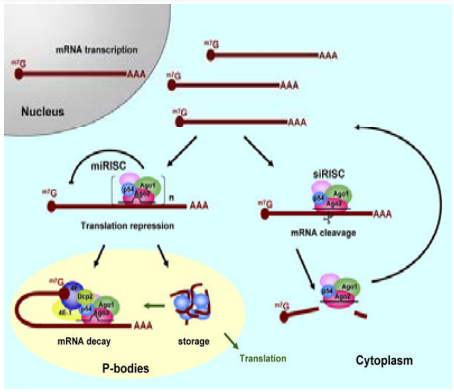
## The Intellectual Foundation of Rational Diagnosis and Treatment Selection

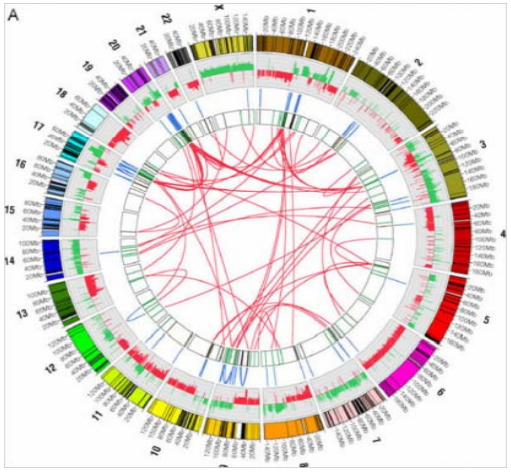
| Genomics | Proteomics | Molecular Pathways and Networks | Network Regulatory Mechanisms |
|---|---|---|---|







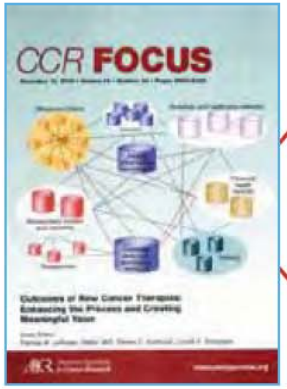
| ID of Causal Relationships Between Network Perturbations and Disease | Patient-Specific Signals and Signatures of Disease or Predisposition to Disease |
|---|---|

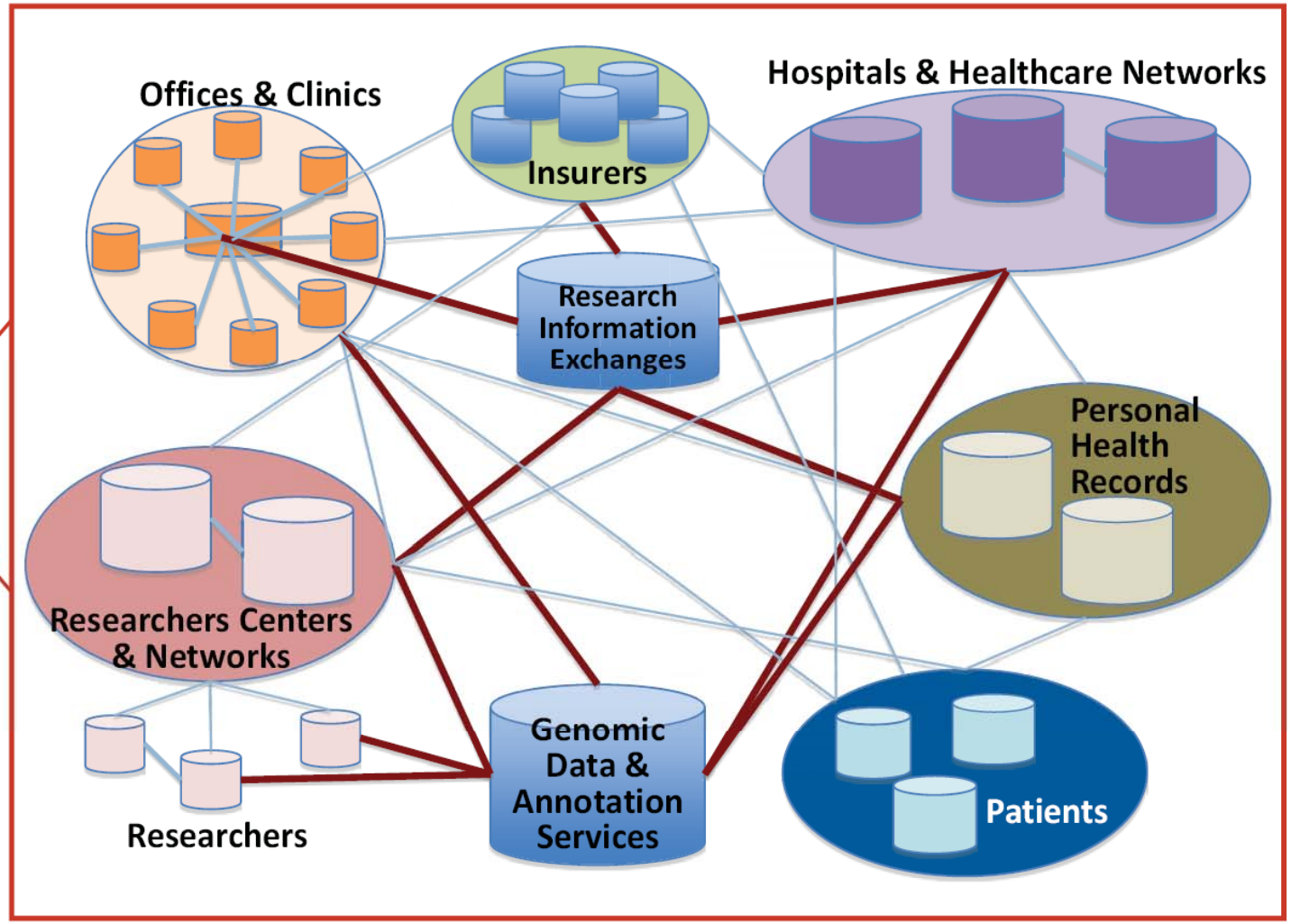
Courtesy G. Poste

# Data are the life blood of biomedicine

- **Diverse types**
  - Clinical Observation
  - Clinical Laboratory
  - Imaging
  - Registry
  - Molecular Characterization
  - Biospecimens
  - Reference
- **Distributed sources**
  - Research Center
  - Care Delivery Setting
    - Hospital
    - Practice
    - Laboratory
  - Registry
  - Consumer
  - Industry

# The Multiple Users and Complex Connectivities for Seamless Information Transfer in the HIT Ecosystem




W. Dalton et al, Clin Cancer Res; 16 (24) December 15, 2010

# The Rise of Data-Driven, Data-Enabled Science and Technology

- data changed by computing
- computing changed by data
- data are now fundamentally networked
- increasing fraction of data is ‘born digital’
- ever larger data sets become increasingly unmovable with existing infrastructure
- simulations using data and meta-analytics amplify the data metaverse

Courtesy G. Poste

# Biomedicine: “fallen and can’t get up”

- Impending “*Pharmageddon*”*: Declining R&D Productivity with Rising Costs
- Healthcare ecosystem is broken
- Poor understanding of the underlying biological complexity – current dominance of reductionist paradigm
- Vertically integrated development model (FIPCo) vs networked model (FIPNet) that dominates other sectors
- Exponential fragmentation of health information

**need to embrace biomedicine as *SYSTEM***

* from M. King Jolly, Pharm.D. Quintiles, Inc. **DIA 2011**

# Biomedicine: a Complex Adaptive System

## "the whole is more than the sum of the parts"

- Diverse stakeholders: multidimensional, interacting ***"ecosystem"***
  - Industry, Academe, Government, ***NGOs***
  - Physicians, Regulators, Researchers, ***Payors, Consumers, Public Health Officials***
  - Biology, Chemistry, Medicine, Business, ***Sociology, Anthropology***
- Adaptive behaviors (dynamic as opposed to static)
- Emergent properties (or unintended consequences)
- Interdependencies
  - Resourses
  - ***Information***

# Strategies for "Managing" Complexity

- **Networking**
  - **Differentiated functions** connected though well-defined **interfaces** – e.g.
    - Biologic processes
    - Manufacturing
- **Layering**
  - **Abstracted combinations of functions** into hierarchical/multidimensional strata which connect through well defined **interfaces** –e.g.
    - Quantum physics – Newtonian physics
    - Biologic complexity : cell, organism, society
    - Organizational hierarchies

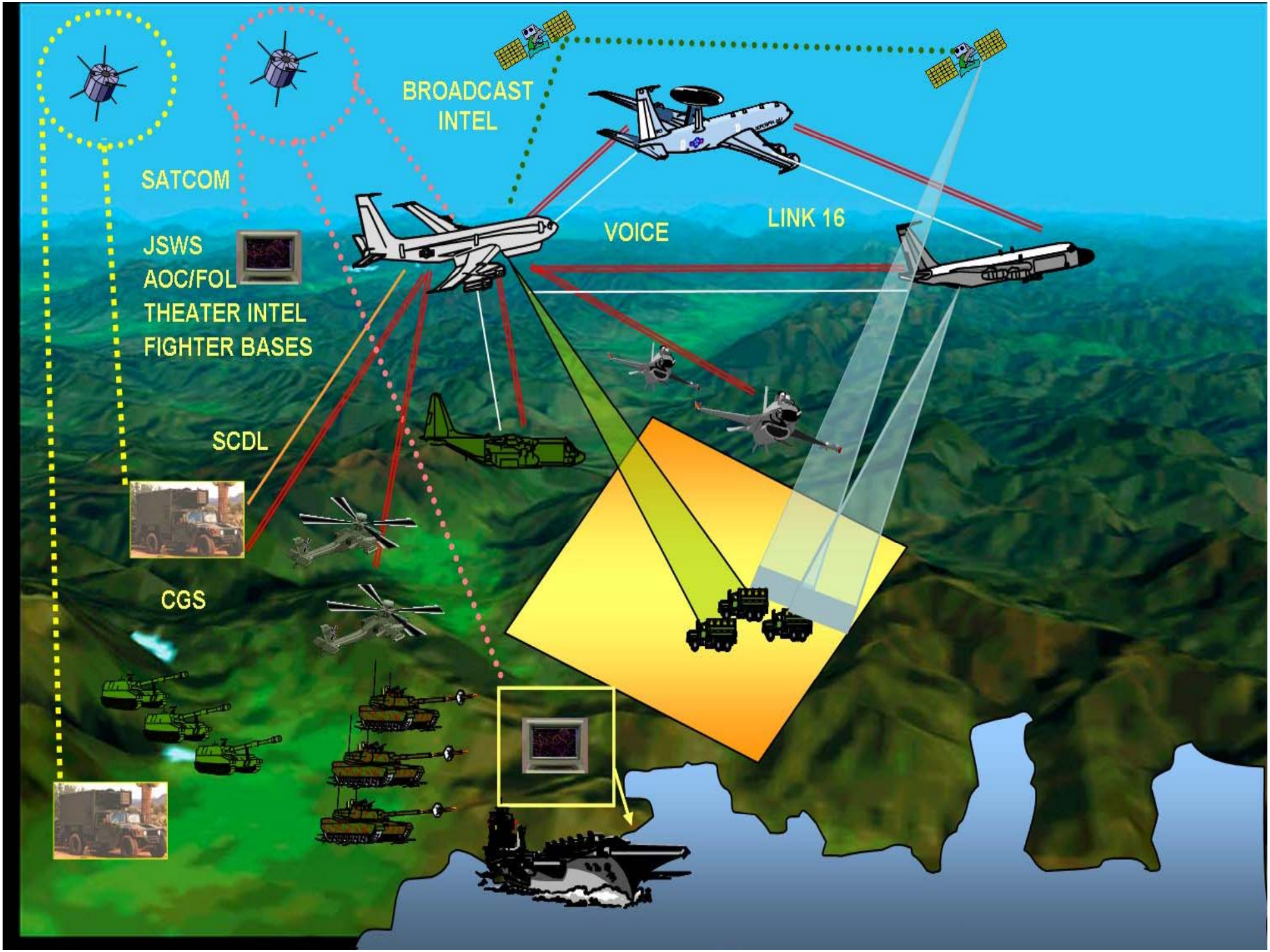
# Network-centric “warfare”

A **military doctrine or theory of war pioneered by the United States Department of Defense**. It seeks to translate an information advantage, enabled in part by information technology, into a competitive warfighting advantage through the **robust networking** of **well informed geographically dispersed forces**. This networking, combined with changes in technology, organization, processes, and people - may allow new forms of organizational behavior.

Specifically, the theory contains the following four tenets in its hypotheses:

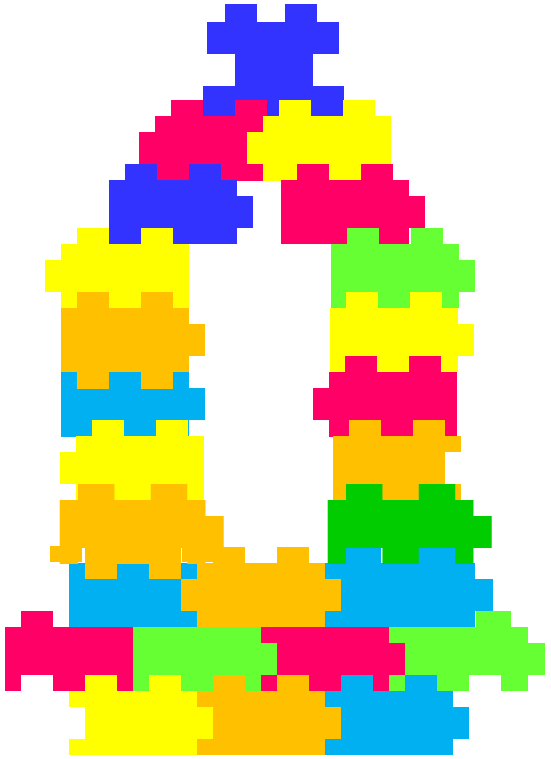
- A robustly networked force **improves information sharing;**
- Information sharing **enhances the quality of information** and shared situational awareness;
- Shared situational awareness **enables collaboration** and **self-synchronization,** and **enhances sustainability** and speed of command; and
- These, in turn, dramatically **increase mission effectiveness.**

(Wikipedia)


BROADCAST
INTEL
SATCOM
JSWS
AOC/FOL
THEATER INTEL
FIGHTER BASES
VOICE
LINK 16
SCDL
CGS

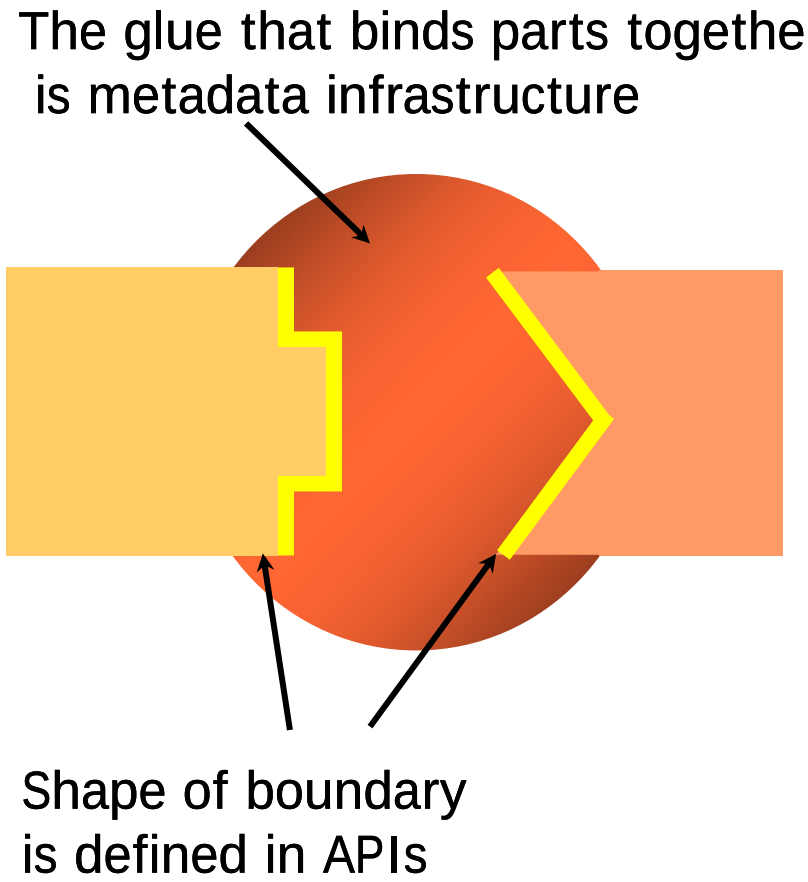
# Applying CAS Principles to Facilitate Information Flow

- Define ***modules*** that address specific needs
- Connect ***through "well-defined electronic interfaces"***
- ***Semantic Interoperability***
  - Defined ***syntax***
  - Defined ***semantics***



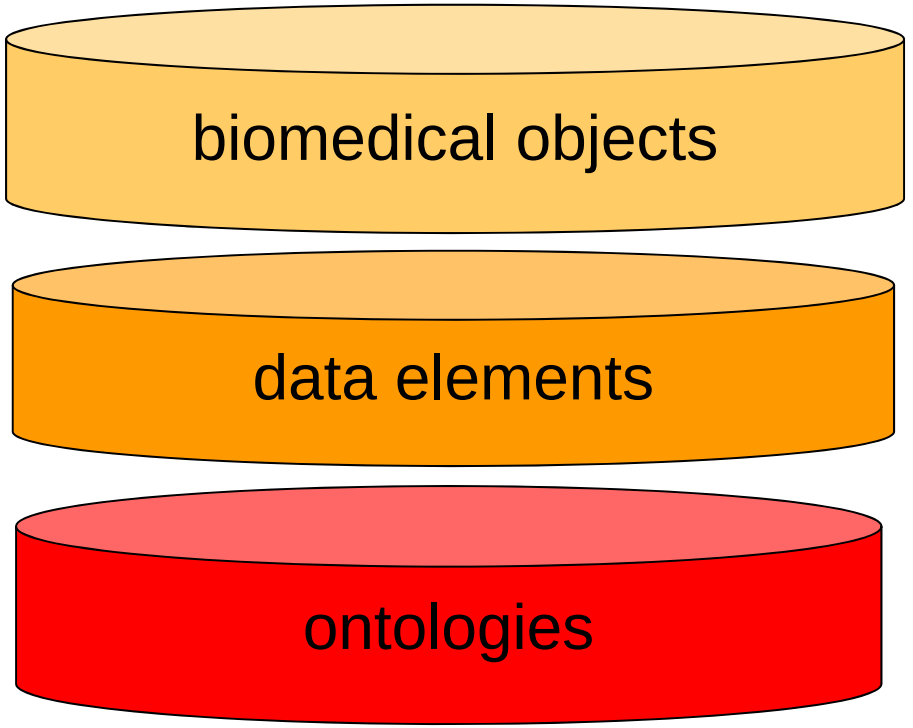
# Application Programming Interfaces

- Can be heterogeneous
- Can restrict access
- Can be commodity (proprietary) components that connect at (open) defined interfaces

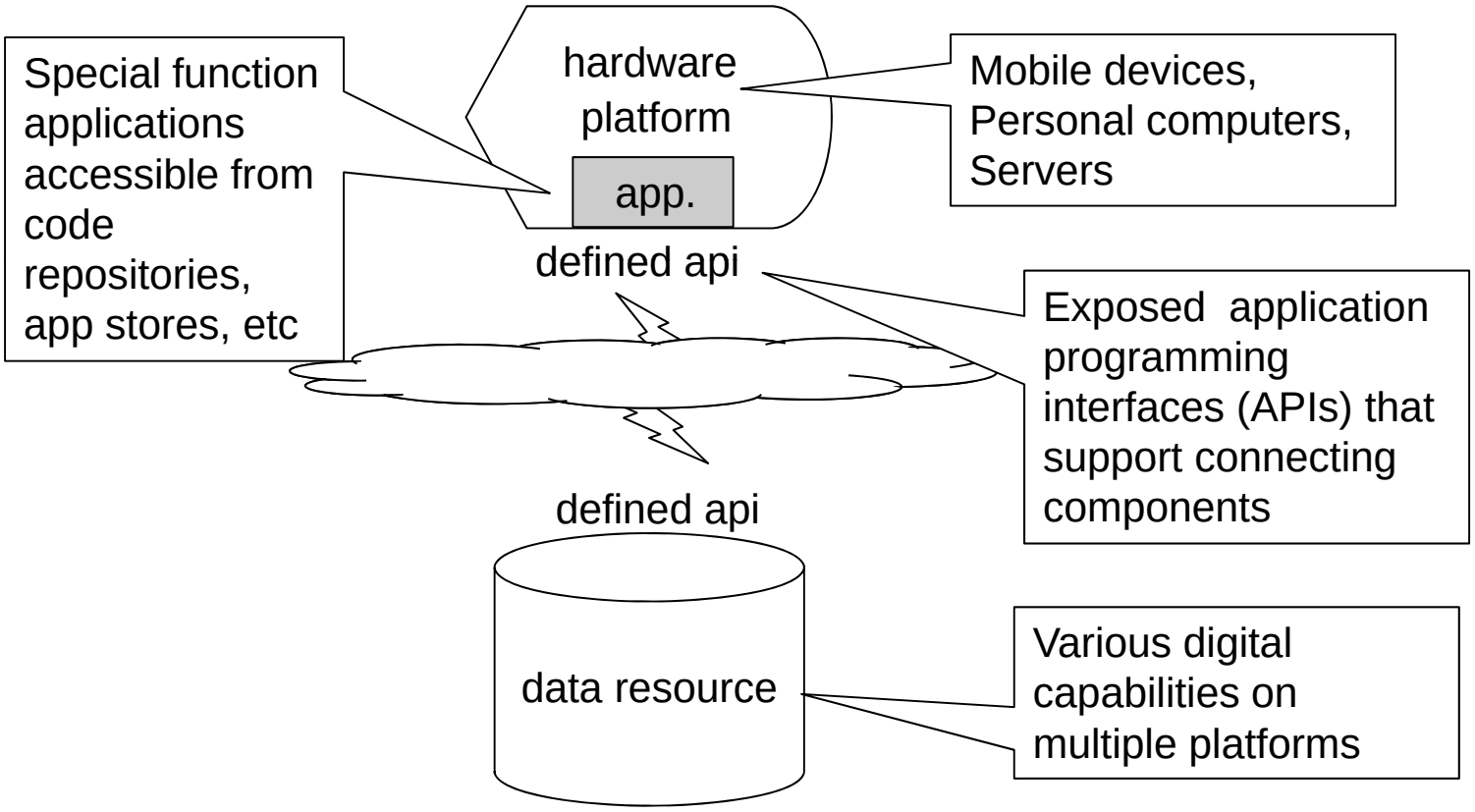


# Interoperability through Metadata-based "Knowledge Stack"

- Componentized knowledge representation
- Permits information to be "pivoted"
- Based on international standards



# Idealized Modular “Framework” supporting Biomedical Research Data Liquidity



# Complicating Considerations

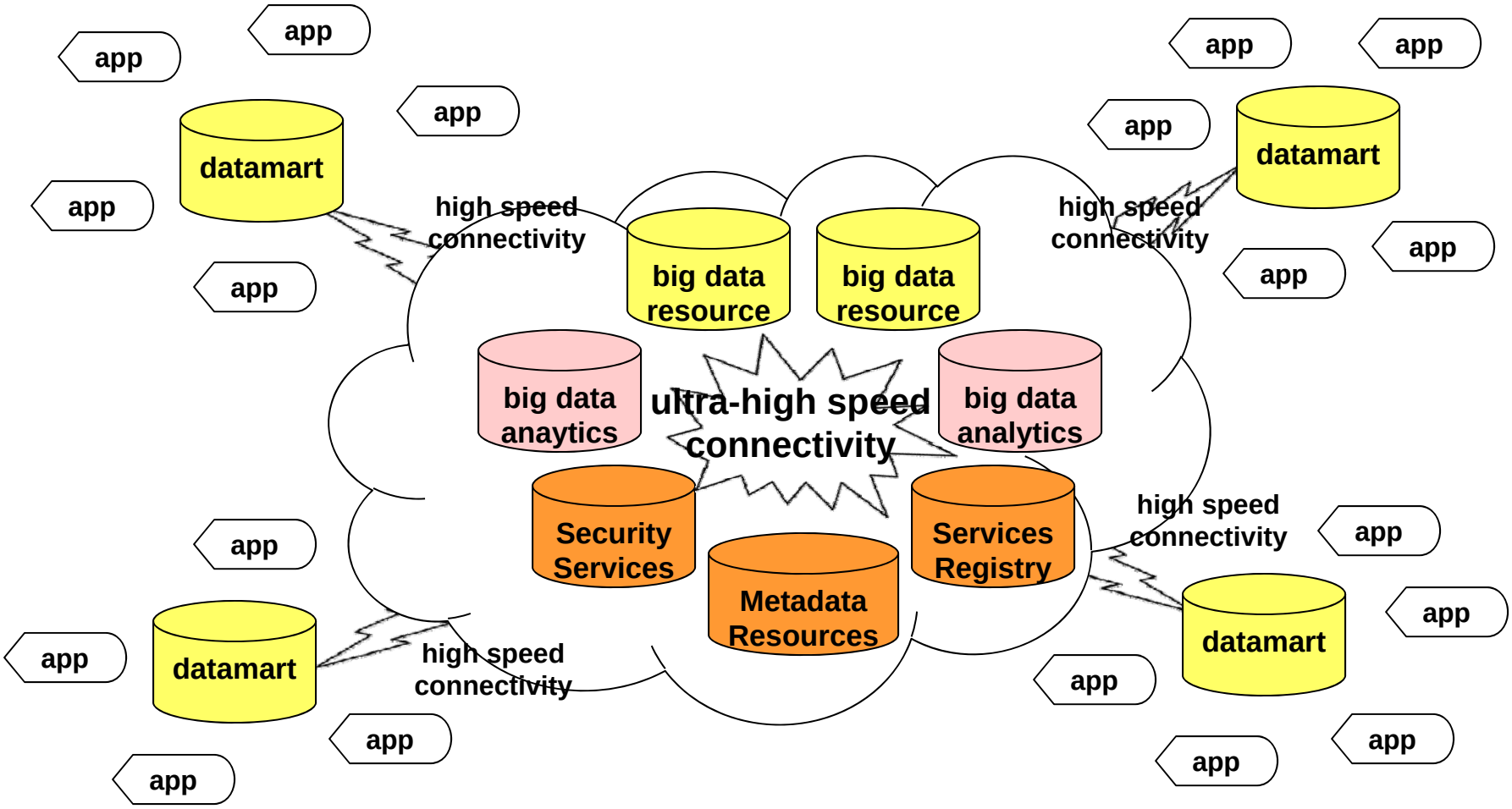
- **Nature of Data**
  - "Data Validity": Garbage In- Garbage Out
  - Human Subjects Protections
  - Intellectual Property
- **Technical**
  - Secure access
  - Volume/Magnitude
  - Need for integration
    - Diverse Data
    - Multiple Source
  - Need for choreography
- **One size does not fit all**
  - Nature of the data to be accessed
  - The question one wants to answer

**Continuum of need mediates the need for adding layers of complexity**

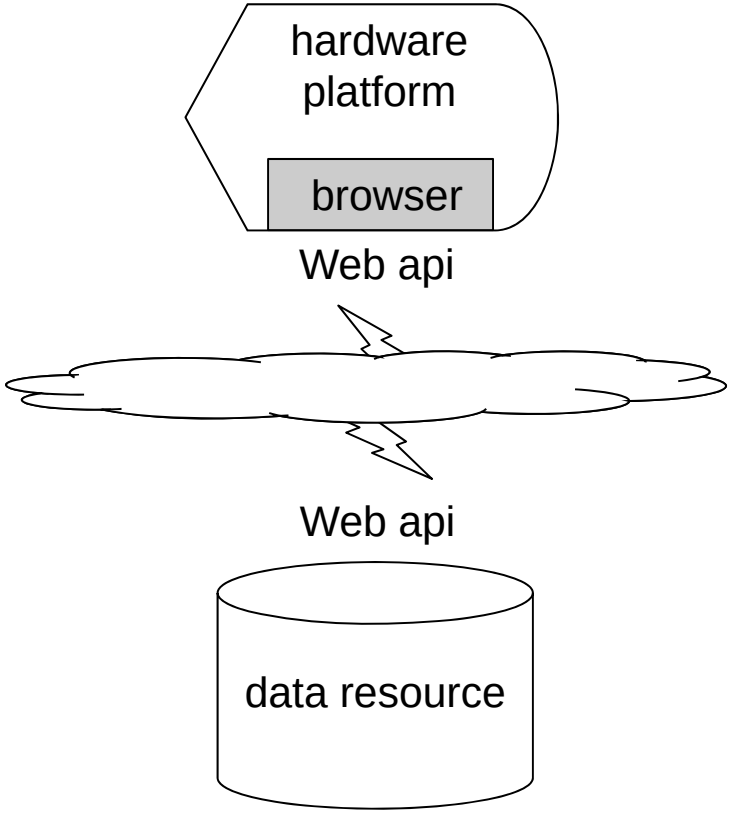
# Strategies for Addressing Complexity

- Diversity of APIs that support paradigms within given communities (expose multiple “flavors” where possible)
- Adding modules to address issues ONLY when necessary
- Federating Access: Data control remains local
- Escalating introduction of standards-based metadata
- Analytics go to the data/co-reside with the data
- Virtual Communities where access to individual level data is needed

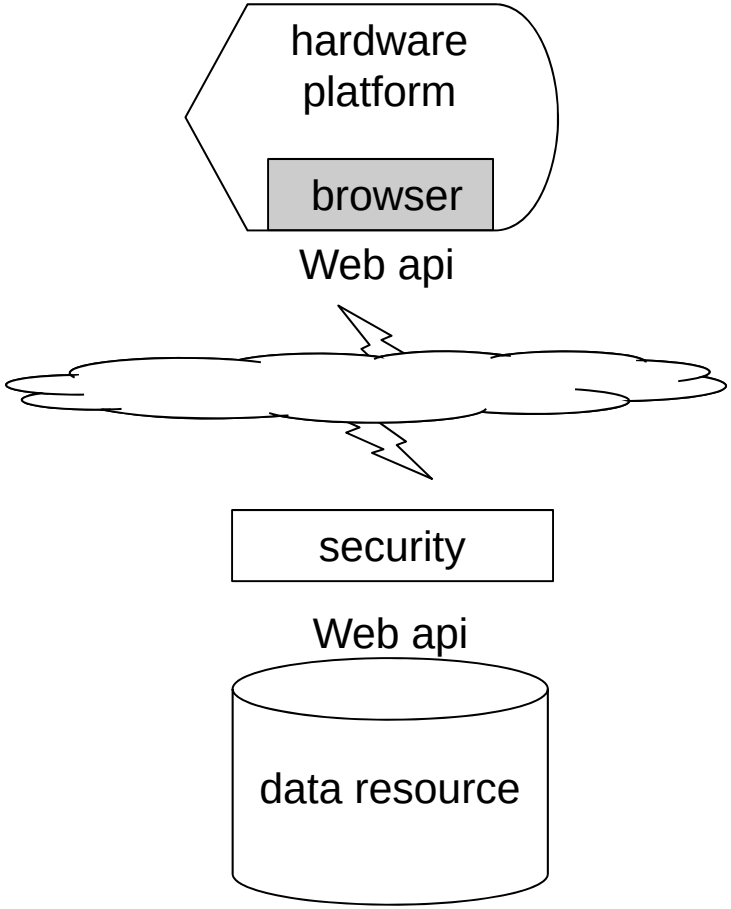
# A Biomedical Informatics Ecosystem



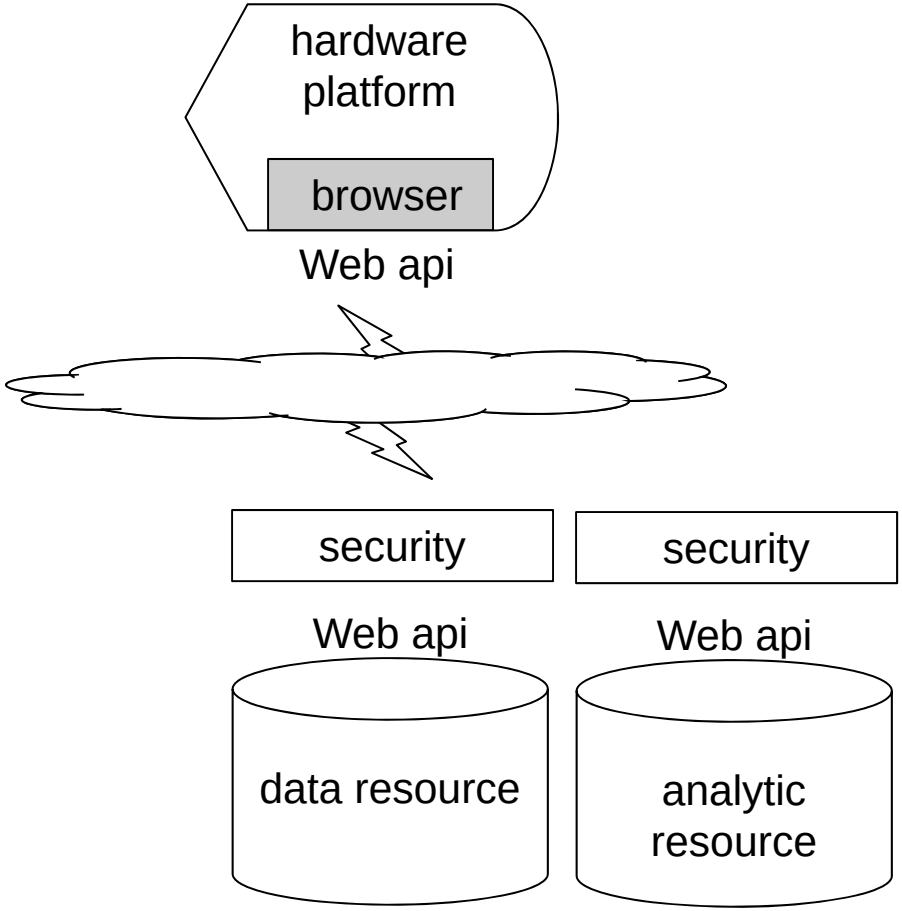
# Escalating complexity facilitating Biomedical Research Data Liquidity



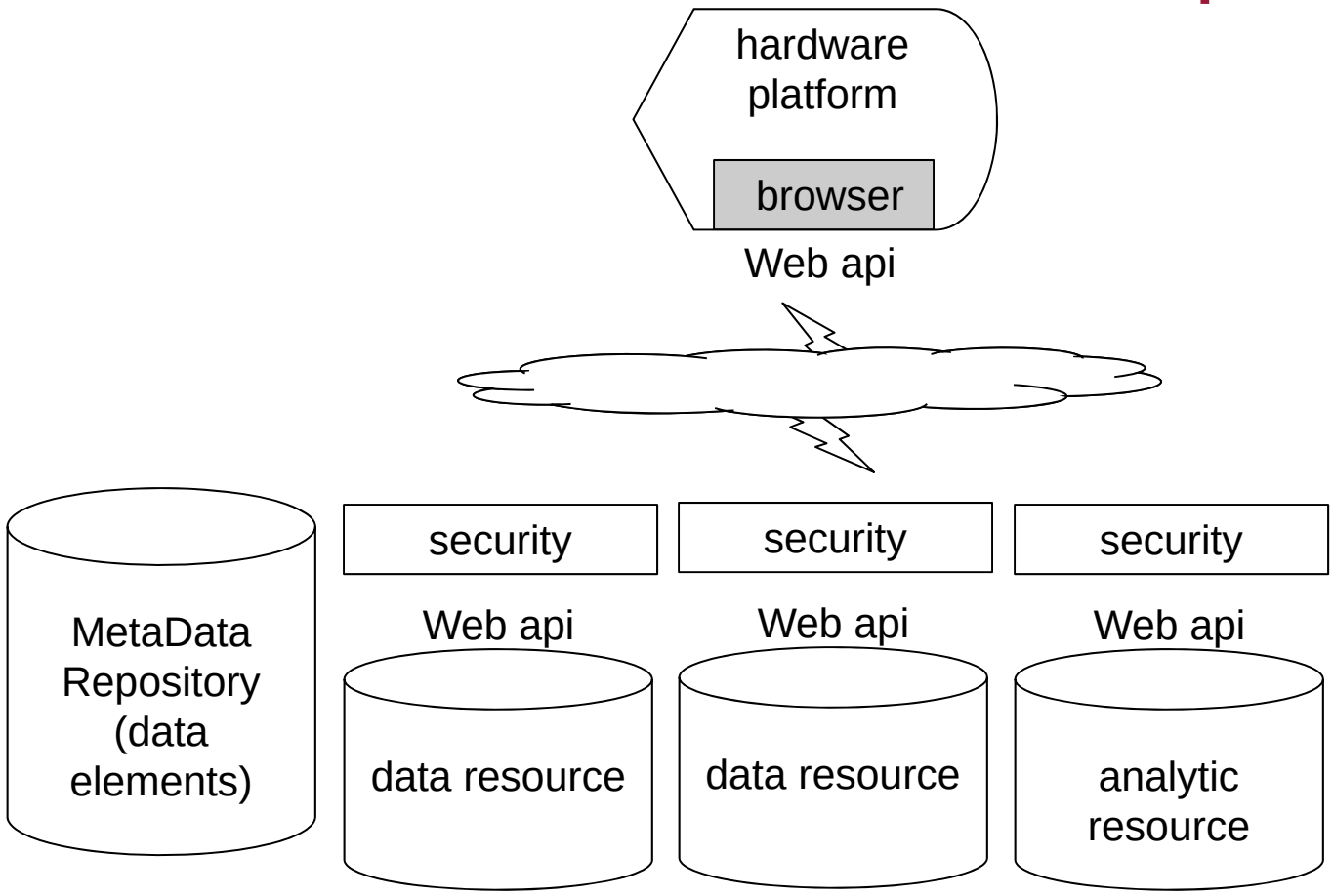
# Escalating complexity facilitating Biomedical Research Data Liquidity



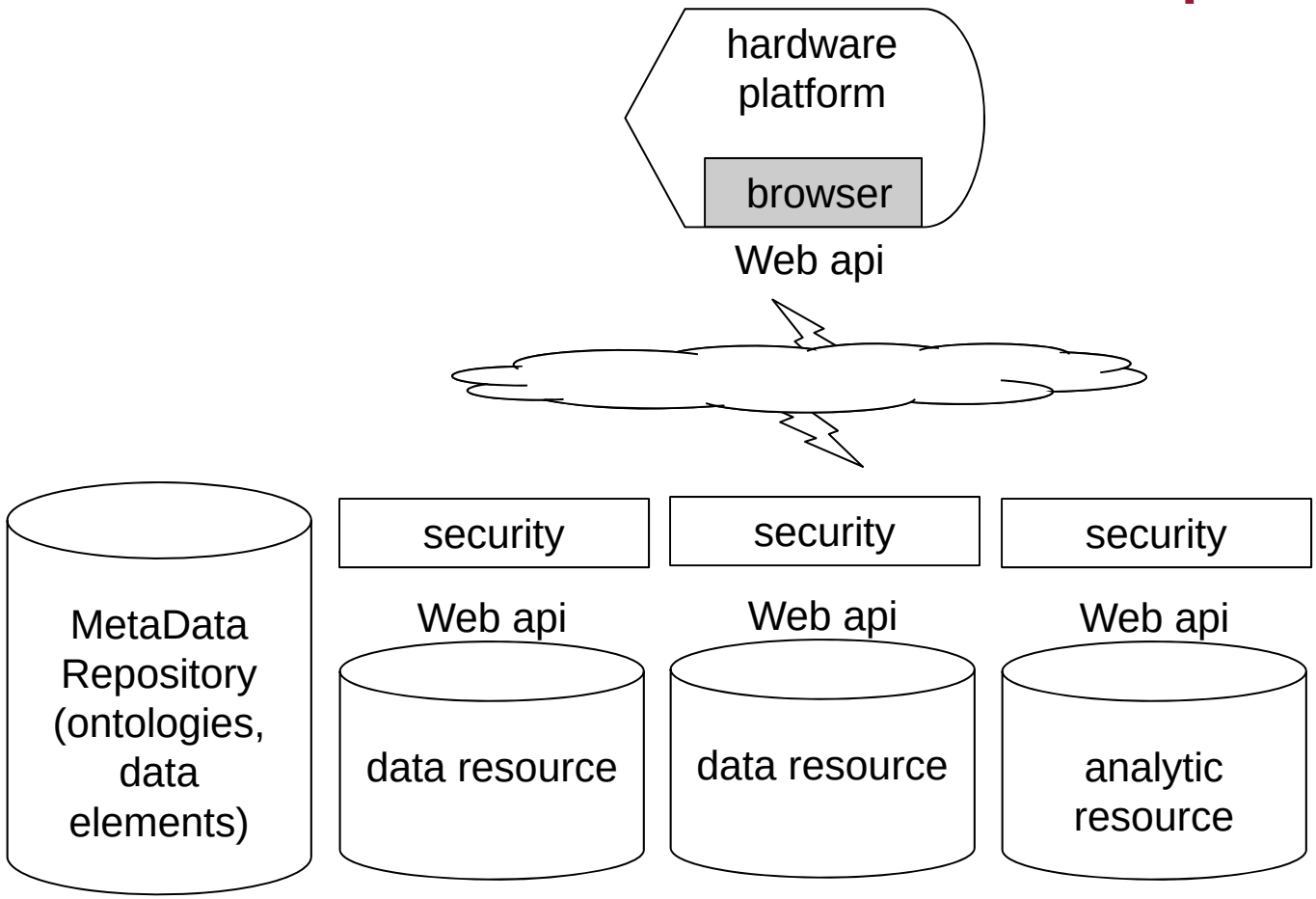
# Escalating complexity facilitating Biomedical Research Data Liquidity



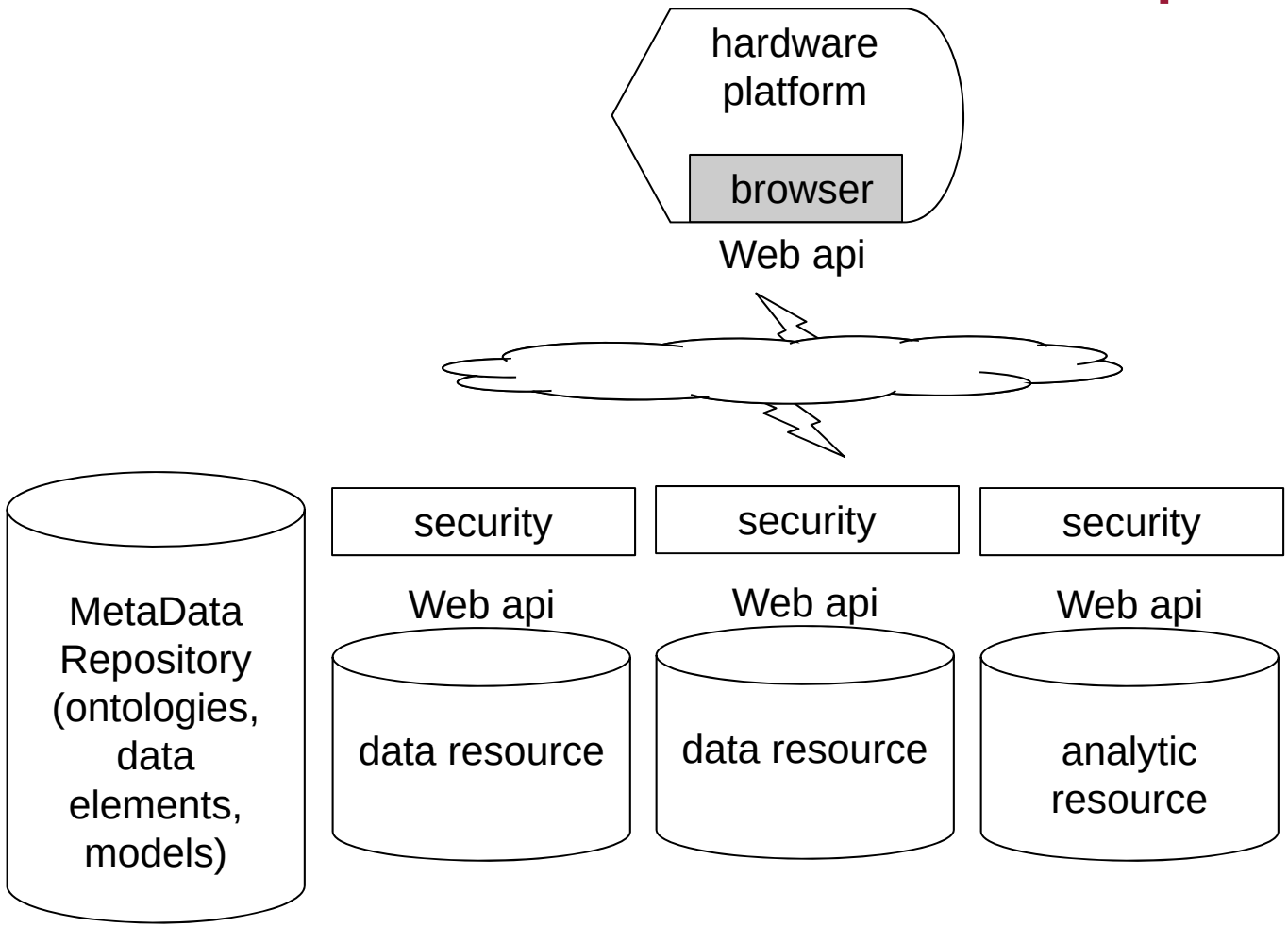
# Escalating complexity facilitating Biomedical Research Data Liquidity



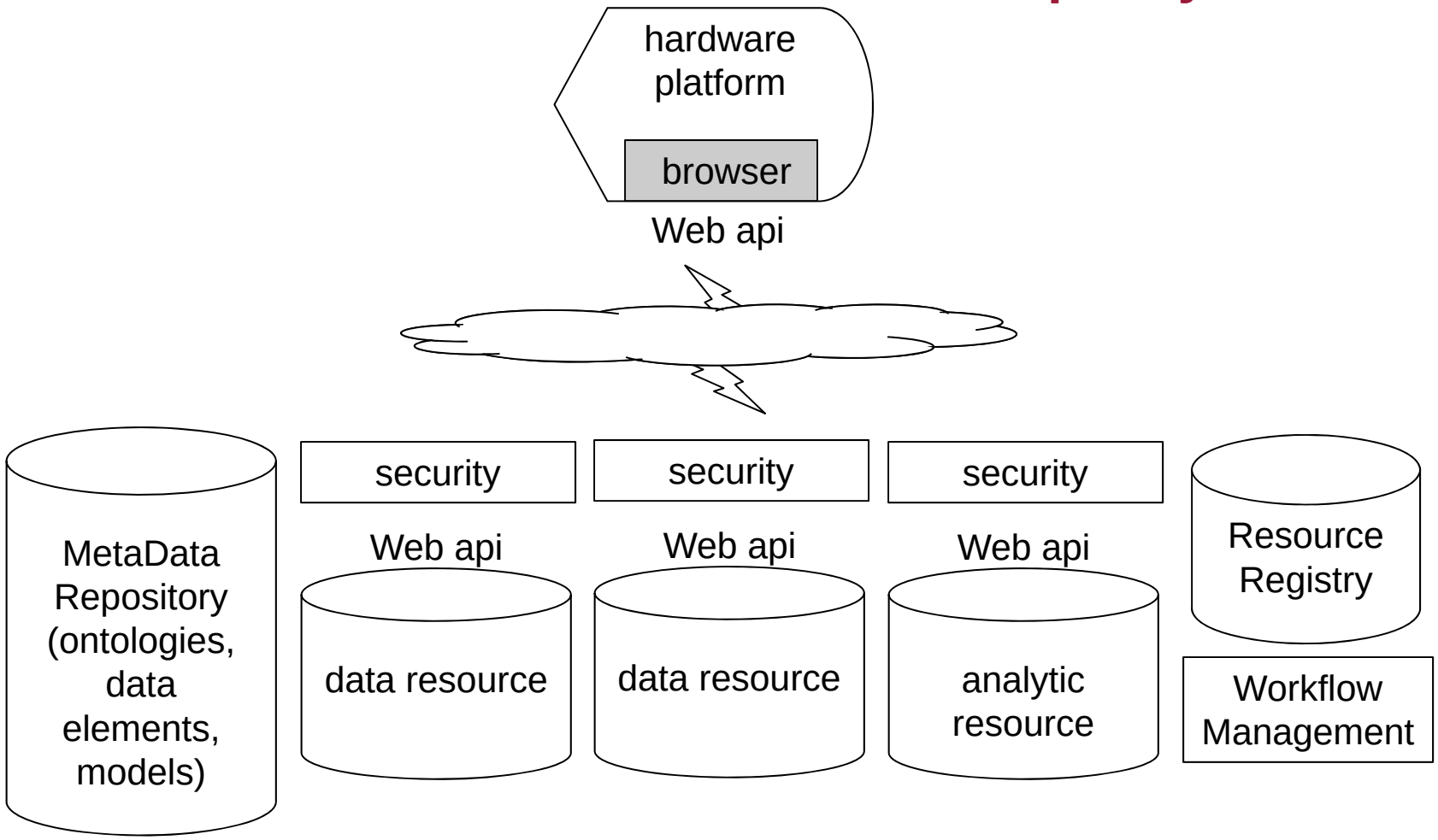
# Escalating complexity facilitating Biomedical Research Data Liquidity



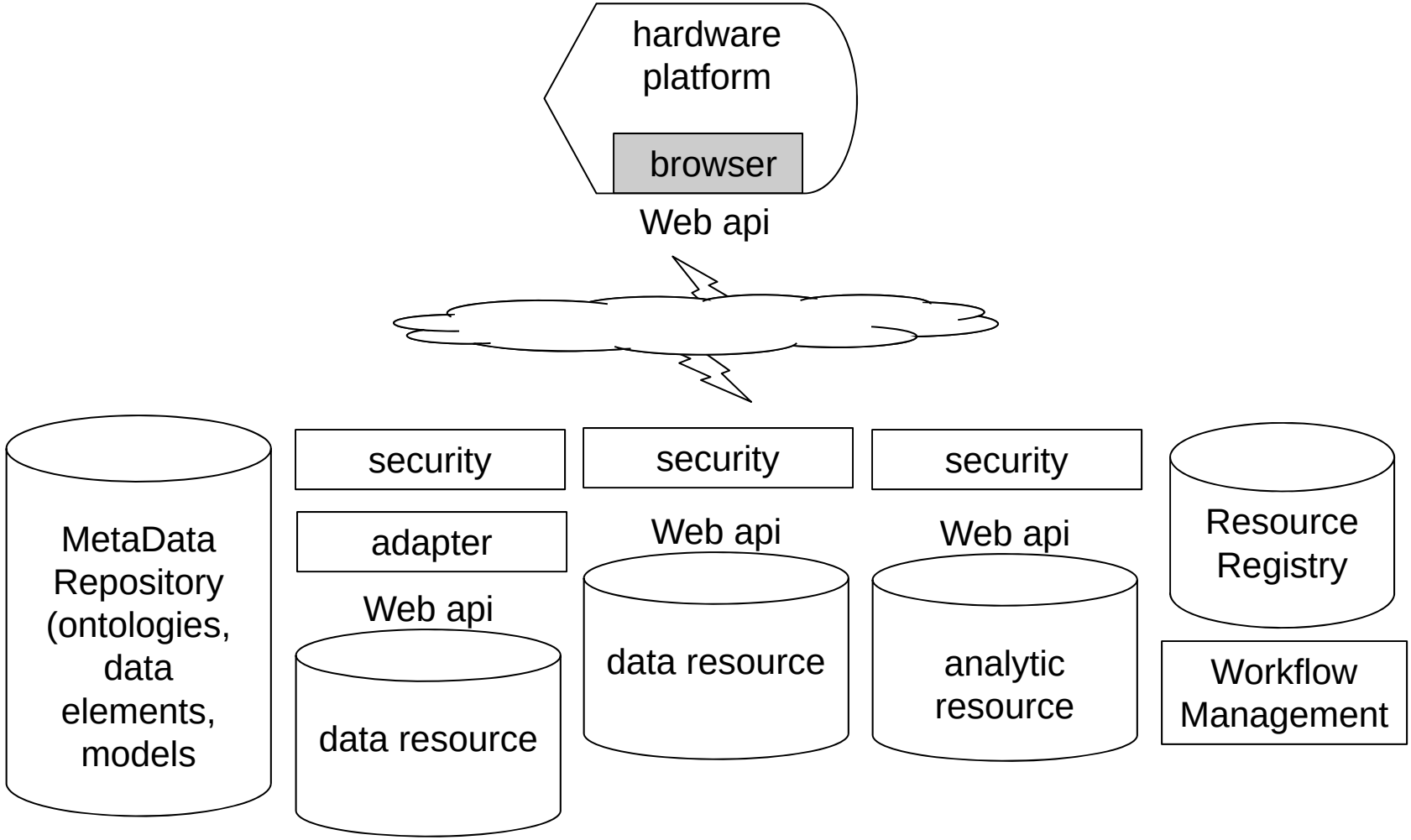
# Escalating complexity facilitating Biomedical Research Data Liquidity



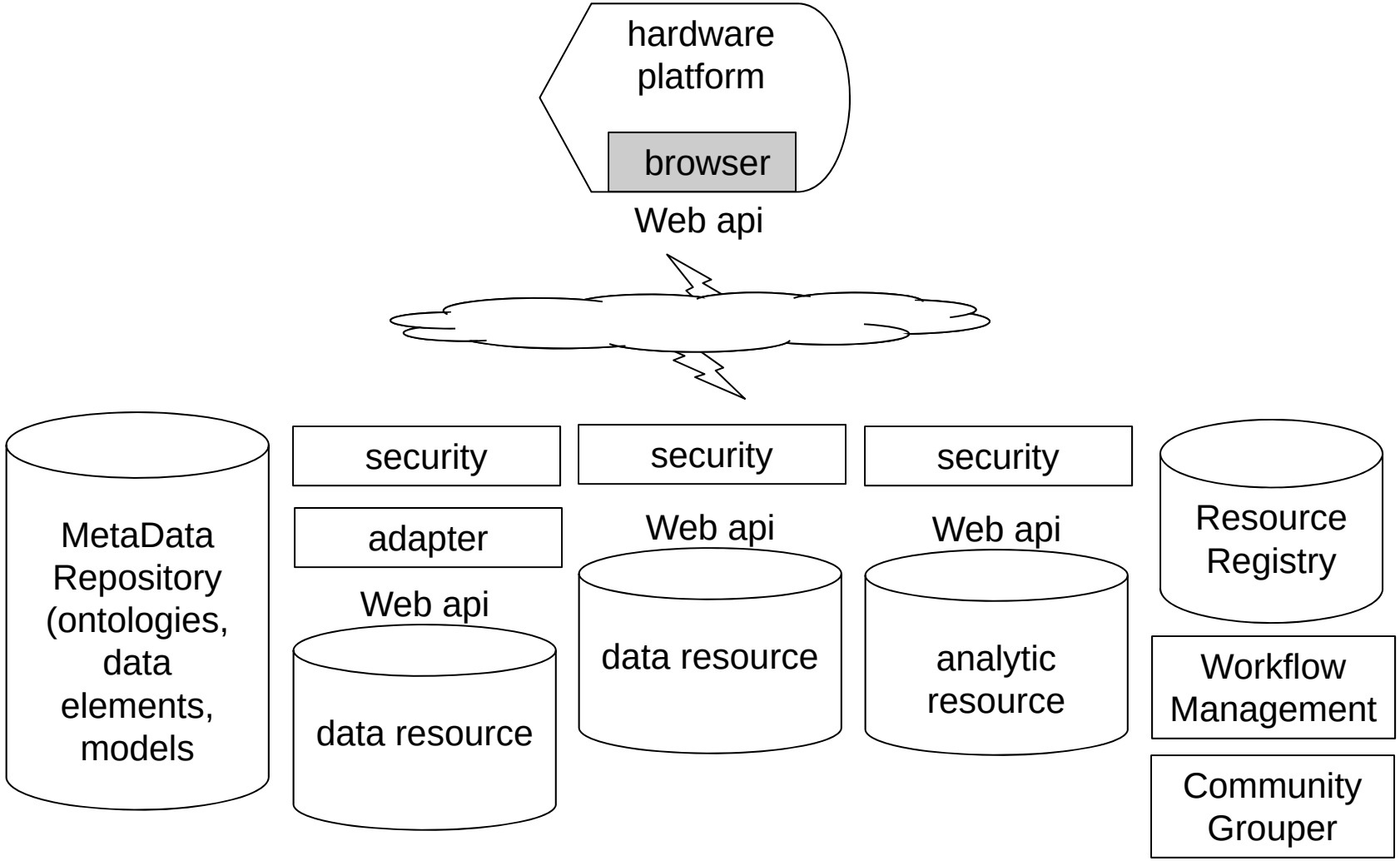
# Escalating complexity facilitating Biomedical Research Data Liquidity

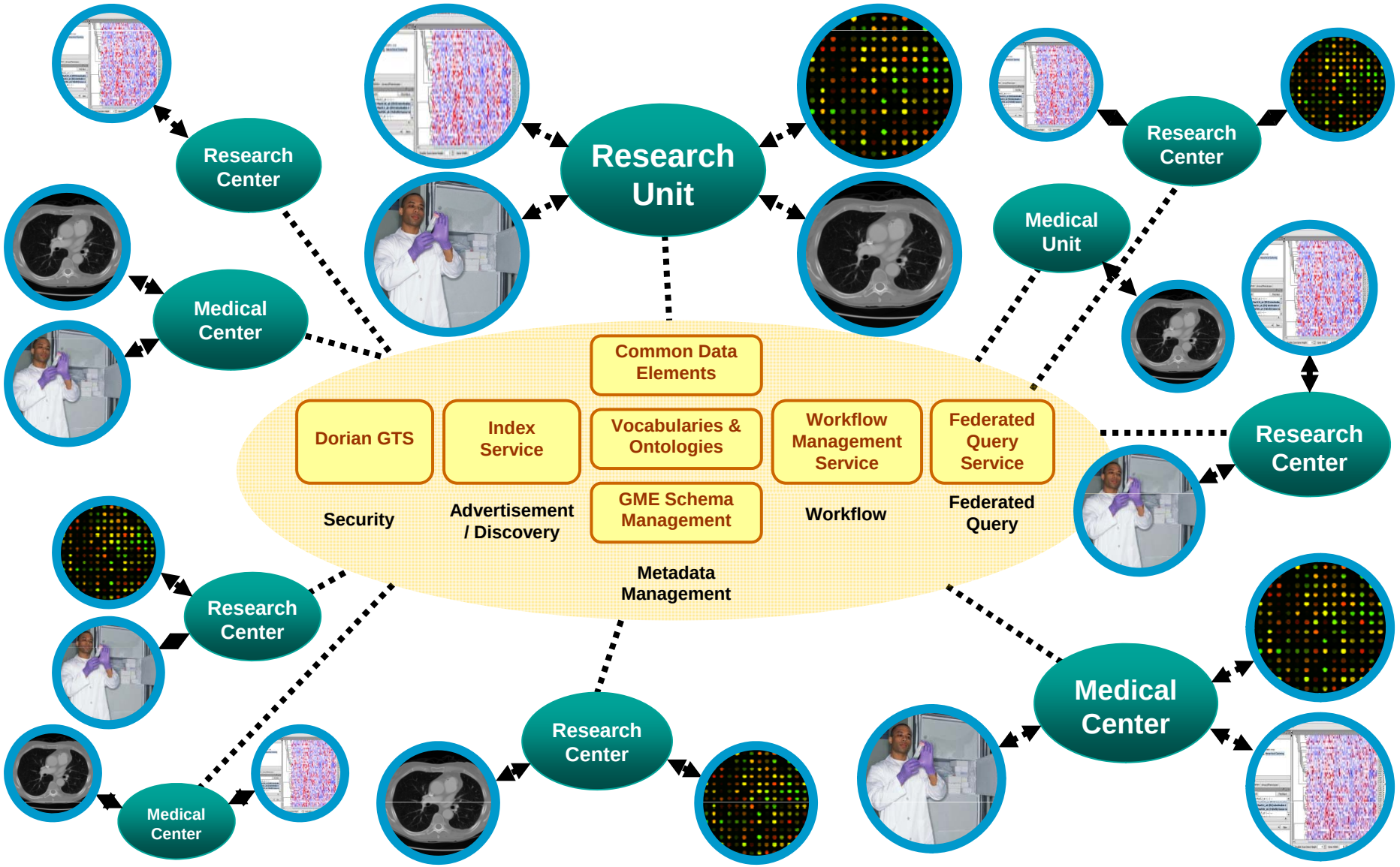


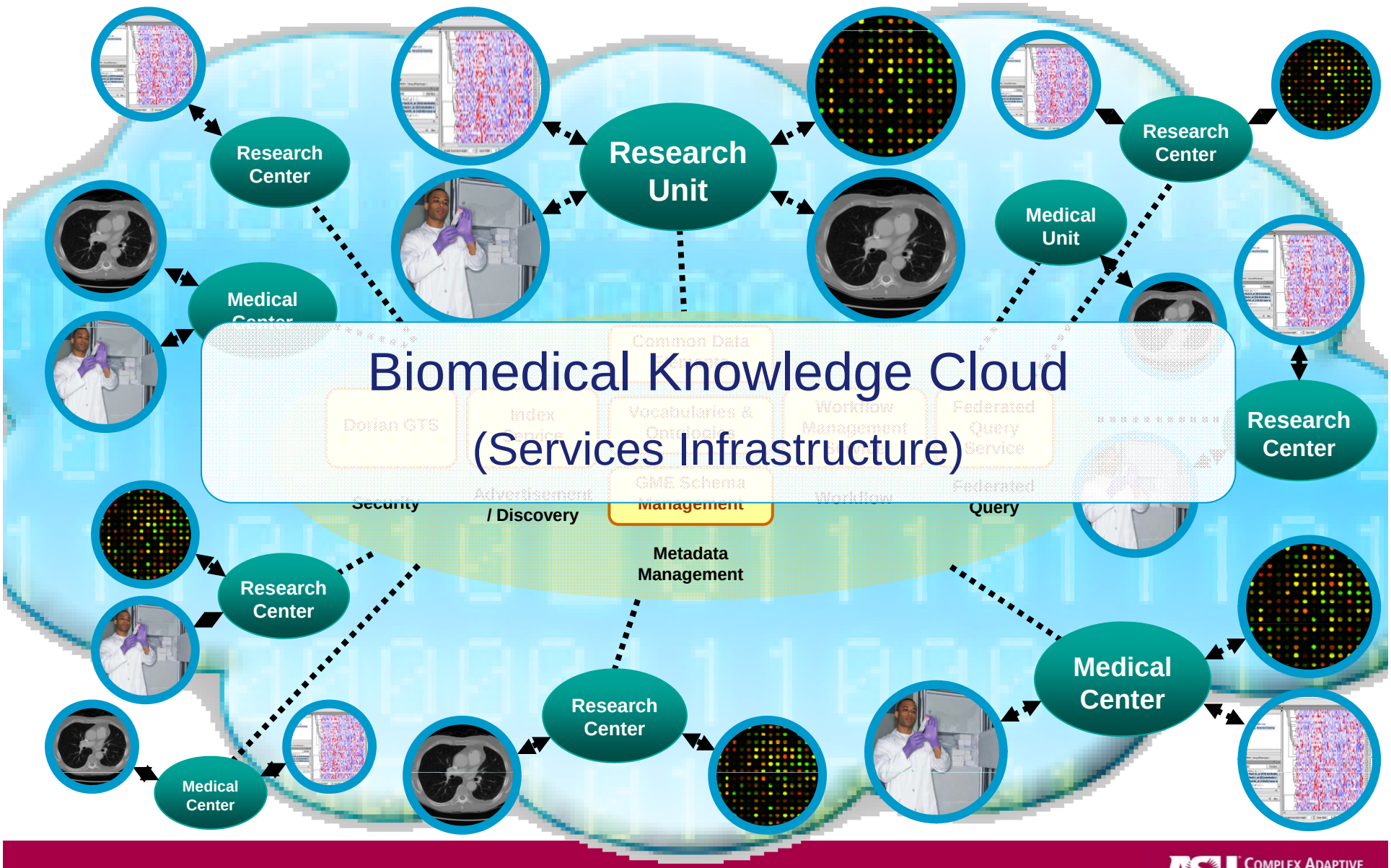
# Escalating complexity facilitating Biomedical Research Data Liquidity

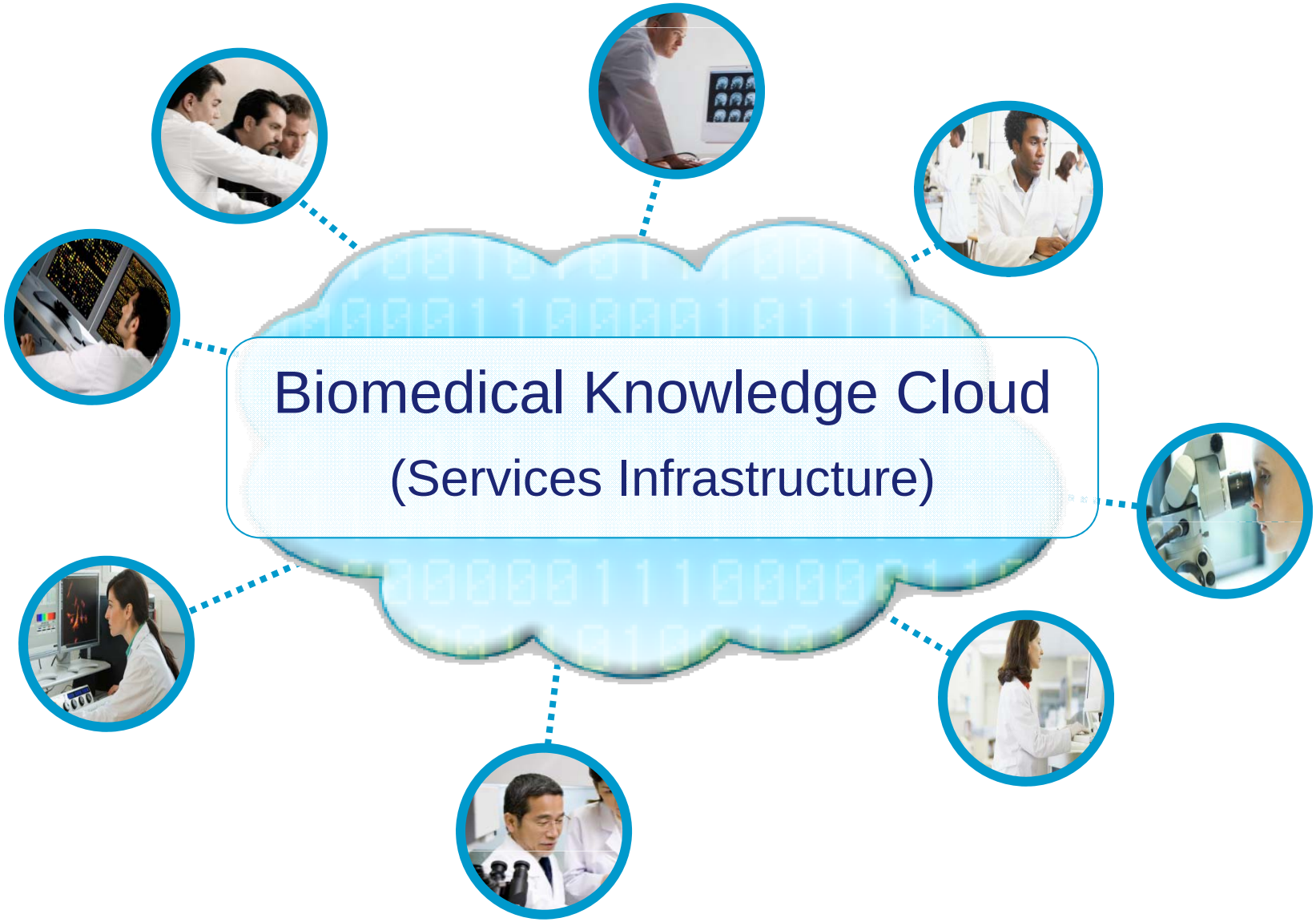


# Escalating complexity facilitating Biomedical Research Data Liquidity




Research Unit
Research Center
Medical Center
Medical Unit
Research Center
Research Center
Medical Center
Research Center
Research Center
Medical Center
Common Data Elements
Dorian GTS
Index Service
Vocabularies & Ontologies
Workflow Management Service
Federated Query Service
GME Schema Management
Security
Advertisement / Discovery
Workflow
Federated Query
Metadata Management


Research Center
Research Unit
Research Center
Medical Unit
Medical Center
Research Center
Biomedical Knowledge Cloud
(Services Infrastructure)
Dorian GTS
Common Data
Vocabularies &
Workflow Management
Federated Query Service
GME Schema Management
Security
/ Discovery
Query
Metadata Management
Research Center
Research Center
Medical Center
Medical Center


Biomedical Knowledge Cloud
(Services Infrastructure)

# How do we get there from here?

- Approach as **Ultra Large Scale Systems** problem
  - "**City planning**" as opposed to "**building architecture**"
    - "**Building codes**"
    - Over-arching **framework**
  - **Incremental**, problem-directed, implementation
  - Bias toward "**working code**"
- **Coalition of the Willing**
- **Policy** to address **regulated environment** and **cultural barriers**

# Summary

- Approaching **Biomedicine as a Complex Adaptive System** may help address some of the challenges it currently faces
- **Information**, and as such Information Technology can serve as the glue to **connect the Ecosystem**
- It is **technically feasible** to create and deploy technology to exchange information within and between members of the ecosystem
- A **multi-stakeholder, multidimensional community** will be necessary to create a sustainable ecosystem