Network-centric Biomedicine:
toward a learning healthcare system

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Biomedical Knowledge Cloud:
A Network to Transform Healthcare
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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
Determining 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

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
  – Resources
  – 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)
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

The glue that binds parts together is metadata infrastructure

Shape of boundary is defined in APIs
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

- Special function applications accessible from code repositories, app stores, etc
- Exposed application programming interfaces (APIs) that support connecting components
- Various digital capabilities on multiple platforms

Hardware platform

Defined API

Data resource

Mobile devices, Personal computers, Servers
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

hardware platform
browser
Web api
Web api
data resource
Escalating complexity facilitating Biomedical Research Data Liquidity
Escalating complexity facilitating Biomedical Research Data Liquidity

- hardware platform
- browser
- Web api
- security
- data resource
- security
- analytic resource

Complex Adaptive Systems Initiative
Escalating complexity facilitating Biomedical Research Data Liquidity

- hardware platform
- browser
- Web api
- MetaData Repository (data elements)
  - Web api
  - data resource
  - security

- Web api
  - data resource
  - security

- Web api
  - analytic resource
  - security
Escalating complexity facilitating Biomedical Research Data Liquidity

hardware platform

browser

Web api

MetaData Repository (ontologies, data elements)

security

Web api

data resource

Web api

data resource

Web api

analytic resource
Escalating complexity facilitating
Biomedical Research Data Liquidity

hardware platform

browser

Web api

security

security

security

MetaData Repository
(ontologies, data elements, models)

Web api

data resource

Web api

data resource

Web api

analytic resource
Escalating complexity facilitating Biomedical Research Data Liquidity

- MetaData Repository (ontologies, data elements, models)
- Web api
- data resource
- security
- Web api
- data resource
- security
- Web api
- analytic resource
- security

- hardware platform
- browser
- Web api

Resource Registry
Workflow Management
Escalating complexity facilitating Biomedical Research Data Liquidity

hardware platform

browser

Web api

security

adapter

Web api

data resource

Web api

data resource

Web api

analytic resource

Resource Registry

Workflow Management

MetaData Repository (ontologies, data elements, models)
Escalating complexity facilitating Biomedical Research Data Liquidity

hardware platform

browser

Web api

MetaData Repository (ontologies, data elements, models)

security

adapter

Web api

data resource

security

Web api

data resource

security

Web api

analytic resource

Resource Registry

Workflow Management

Community Grouper
Biomedical Knowledge Cloud
(Services Infrastructure)
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.