

Design in the age of biology

Hugh Dubberly — Dubberly Design Office — hugh@dubberly.com

In the early twentieth century, our understanding of physics changed rapidly; now, our understanding of biology is undergoing a similar rapid change.

Freeman Dyson wrote, “It is likely that biotechnology will dominate our lives and our economic activities during the second half of the twenty-first century, just as computer technology dominated our lives and our economy during the second half of the twentieth.”¹

Recent breakthroughs in biology are largely about information—understanding how organisms encode it, store, reproduce, transmit, and express it—mapping genomes, editing DNA sequences, mapping cell-signaling pathways.

Changes in our understanding of physics, accompanied by rapid industrialization, led to profound cultural shifts—changes in our view

of the world and our place in it. In this context, modernism arose. Similarly, recent changes in our understanding of biology are poised to create new industries and may bring profound cultural shifts— new changes in our view of the world and our place in it.

Already we can see the process beginning. Where once we described computers as mechanical minds, increasingly we describe computer networks with more biological terms—bugs, viruses, attacks, communities, social capital, trust, identity.

How is design changing?

Over the last 30 years, the growing presence of electronic information technology has changed the context and practice of design.

Changes in production tools designers use (software tools, computers, networks, digital displays and printers) have altered the pace of production and the nature of specifications. But production tools have not significantly changed the way designers think about practice. In a sense, graphic designer Paul Rand was correct when he said, “The computer is just another tool, like the pencil,”² suggesting the computer would not change the fundamental nature of design.

But computer-as-production-tool is only half the story; the other half is computer-plus-network-as- media.

Changes in the media designers use (the internet and related services) have altered what designers make and how their work is distributed and consumed. New media are changing significantly the way designers think about practice. New types of jobs have emerged. For many of us, both what we design and how we design are substantially different than they were a generation ago.

What do electronic media and designing have to do with biology?

Emerging design practice is largely information based—awash in the technologies of information processing and networking. Increasingly design shares

with biology a focus on information flow, on networks of actors operating at many levels and exchanging the information needed to balance communities of systems.

Modern design practice arose alongside the industrial revolution. Design has long been tied to manufacturing—to reproduction of objects in editions or “runs.” The cost of planning and preparation (the cost of design) was small compared to the cost of tooling, materials, manufacturing, and distribution. A mistake in design multiplied thousands of times in manufacturing is difficult and expensive to fix.

The realities of manufacturing led to certain practices and in turn to a mindset or even a way of thinking. In the “modern” era, design practice adopted something of the point-of-view or even the philosophy of manufacturing—a mechanical-object ethos.

Now as software and services have become a large part of the economy, manufacturing no longer dominates. The realities of producing software and services are very different than those of manufacturing products.

The cost of software (and “content”) is almost entirely in planning, preparation, and coding (the cost of design). The cost of tooling, materials, manufacturing, and distribution is small in comparison. Delaying a piece of software to “perfect” it invites disaster. Customers have come to expect updates and accept their role as an extension of developers’ QA teams, finding “bugs” that can be fixed in the next “patch.”

Services also have a different nature than hardware products. “Services are activities or events that create an experience through an interaction—a performance co-created at point-of-delivery.”³ Services are largely

intangible, as much about process as final product. They are about a series of experiences across a range of related touch-points.

The realities of software and service development lead to certain practices and to a mindset or even a way of thinking. Emerging design practice is adopting something of the point-of-view or even the philosophy of software and service development—an organic-systems ethos.

Models of change

Several critics have commented on facets of the change from technical-object ethos to organic-systems ethos. This article brings together a series of models outlining the change and contrasting each ethos.

The models are presented in the form of an “era analysis.” Two or more eras (e.g., existing-emerging eras or specified time periods) are presented as columns in a matrix with rows representing qualities or dimensions, which may change across each era, characterizing aspects of the era.

The eras are framed as stark dichotomies to characterize the nature of changes. But experience is typically more fluid, lying along a continuum somewhere between extremes.

John Rheinfrank⁴ provides a broad summary of the change, which may serve as an introduction and an overview. He begins by describing a change in world-view, similar to the change in ethos described above.

The end of incrementalism

From (escape the past)

Mechanistic world-view
Landscape depletion
Surface novelty
Detached expert
Tangible assets
Consolidation

To (invent the future)

Ecological-evolutionary world-view
Landscape renewal
Evocative structures
Collaboration
Intangible assets
Flow

— John Rheinfrank

We may expand Rheinfrank’s model, to describe how things come to be and the role of designers and their clients in the process.

Principles of organization– adapted from Hugh Dubberly and Paul Pangaro⁵

	<i>Mechanical-object</i>	<i>Organic-system</i>
<i>Economic era</i>	Industrial age	Information age
<i>Paradigm author</i>	Newton	Darwin
<i>Metaphor</i>	Clock-works	Ecologies
<i>Values</i>	Seek simplicity	Embrace complexity
<i>Control</i>	Top-down	Bottom-up
<i>Development</i>	From outside	From inside
	Externally-assembled	Self-organizing
	Made	Grown
<i>Designer as</i>	Author	Facilitator
<i>Designer's role</i>	Deciding	Building agreement
<i>Client as</i>	Owner	Steward
<i>Relationship</i>	Request for proposal	Conversation
<i>Stopping condition</i>	Almost perfect	Good enough for now
<i>Result</i>	More deterministic	Less predictable
<i>End-state</i>	Completed	Adapting or evolving
<i>Tempo</i>	Editions	Continuous updating

A Concern for Users

Austin Henderson and Jed Harris⁶ have noted that many computer systems are constrained by a mechanistic world-view. They cite automation projects avoiding errors by drastically reducing options available to users (narrowing language or variety) but in the process crippling communication and organizational flexibility. Henderson and Harris contrast coherent systems to responsive systems. Coherent systems require consistency and predictability; responsive systems support messiness and improvisation. "In a given system, as responsiveness increases, coherence tends to decrease and vice versa—a classic tradeoff. Scaling makes this tradeoff sharper. As systems get larger, they have to work harder to maintain their coherence, and this increasingly makes them unresponsive. Conversely,

large systems that allow great local responsiveness (such as the World Wide Web) have difficulty maintaining coherence."

Henderson⁷ pointed out that consistency is an ideology, that other choices are possible, "the core ideology of computer system design is totally permeated with the assumption that computers are rule-following machines, and more generally, that all human activities can and should be described in terms of a consistent set of rules"

He argues that "feedback loops . . . actually make organizations work, and the constant negotiation that these loops entail . . . computing systems tend to break those loops . . . so people have to bear the brunt of patching them up, and usually have to fight the computer system to do it." Henderson and Harris propose a new approach, which they describe as "Pliant Computing"

Consistency versus dynamic engagement

– adapted from Austin Henderson

Coherent	Responsive
Rigid	Pliant
Fragile	Robust
Regular	Particular
Thin descriptions	Thick scenes
Designed by designers in advance of use by users enforcing a single view	Created by participants during use enabling multiple views

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At the heart of Henderson’s call for “Pliant Computing” is a deep concern for people who use computers. Henderson sees the relationship between designer and audience changing. As Rheinfrank pointed out, the designer is moving from detached expert to

collaborator. And the relationship between designer and constituent is moving from expert-patient to what Horst Rittel called, “a symmetry of ignorance (or expertise)”⁸ where the views of all constituents are equally valid in defining project goals.

Consistency versus dynamic engagement

– adapted from Austin Henderson

Follow Design FOR users	Participate Design WITH users	Lead Design BY users
Provide input Provide feedback	Combine expertise Combine values	Build on: – Scripting languages – Open systems – Construction sets

Liz Sanders⁹ presents a similar argument with slightly different eras, explicitly introducing the idea of moving beyond human-centered or user-centered design.

Relationships between designer and audience

– adapted from Liz Sanders

	<i>Past</i>	<i>Current</i>	<i>Emerging</i>
<i>Design Paradigm</i>	Expert-driven	Human-centered	Facilitated
<i>Audience Role</i>	Customer	User	Participant
<i>Activity</i>	Consume – Shop – Buy – Own	Experience – Use – Interact – Communicate	Co-create – Adapt/modify/extend – Design – Make

Co-development is also a fundamental tenet of open-source software. Eric Raymond¹⁰ wrote, “Treating your users as co-developers is your least-hassle route to rapid code improvement and debugging.” He added, “Even at a higher level of design, it can be very valuable to have lots of co-developers random walking through the design space near your product.” Raymond

famously contrasted “cathedrals carefully crafted by individual wizards or small bands of mages working in splendid isolation” to “a great babbling bazaar of differing agendas and approaches.” He suggested traditional “a priori” approaches will be bested by “self-correcting systems of selfish agents.”

The Cathedral versus the Bazaar

— adapted from Eric Raymond

Commercial	Free licenses
Proprietary	Open source
Fewer paid workers	More volunteers
Heavily managed	Loosely coupled
Hierarchical	Distributed peer review
Serial processes	Massively parallel
Longer development cycles	debugging
	More frequent releases

The Rise of Service Design

The shift from industrial age to information age mirrors, in part, a shift from manufacturing economy to service economy. In the new economy, as former WiReD editor Kevin Kelley put it, “commercial products are best treated as though they were services. It’s not what you sell a customer, it’s what you do for them. It’s not what something is, it’s what it is connected to, what it does. Flows become more important than resources. Behavior counts.”¹¹

Early on, Shelley Evenson saw the importance of service design, and she has led U.S. designers in developing the field. She has provided a framework contrasting traditional business-planning methods with service-design methods. Her framework parallels the larger change in ethos we’ve been discussing.

A Shift in Development Models

— Shelley Evenson¹²

	<i>Product</i>	<i>Service</i>
<i>Era</i>	Planned	Emergent
<i>Focus</i>	Find the right strategy	Understand customers
<i>Growth</i>	Top-down	Organic
<i>Method</i>	Sequential	Parallel
<i>Delivery</i>	Internal	Co-produced

Typically, responsibility for designing individual artifacts rests pretty much with one individual, but systems design almost by definition requires teams of people (often including many specialties of design). The need for teams of designers can be seen easily in the design of software systems and service systems, where many artifacts, touch-points, and sub-systems must be coordinated in a community of cooperating systems. For example, “web-based services” or “integrated systems of hardware, software, and networked applications” require development and management teams with many specialties.

The work of an individual designer on an individual artifact has often been characterized as “hand-craft.” In contrast, Paul Pangaro and I have proposed “service-craft” to describe “the design, management, and ongoing development of service systems.” Design practice in a hand-craft context differs markedly from design practice in a service-craft context. Having assembled a team, care must be taken to negotiate goals, set expectations, define processes, and communicate project status and changes in direction. Care must also be taken to create opportunities for new language to emerge and to create capacity for co-evolution between service and participants.

	<i>Hand-craft</i>	<i>Service-craft</i>
<i>Subject</i>	Things	Behaviors
<i>Participant(s)</i>	Individual	Team
<i>Thinking</i>	Intuitive	Reasoned
<i>Language</i>	Idiosyncratic	Shared
<i>Process</i>	Implicit	Explicit
<i>Nature of work</i>	Concrete	Abstracted
<i>Key skills</i>	Drawing	Modeling
<i>Construction</i>	Direct	Mediated

We also noted, “hand-craft has not gone away, nor is service-craft divorced from hand-craft. Hand-craft plays a role in service-craft (just as in developing software applications, coding remains a form of hand-craft). While service-craft focuses on behavior, it supports behavior with artifacts. While service-craft requires teams, teams rely on individuals. Service-craft does not replace hand-craft; rather service-craft extends or builds another layer upon hand-craft.”¹³

Characterizing Services

Robert Lusch¹⁴ wrote about changes in marketing, describing a service-dominant logic in which “value is defined by and co-created with the consumer rather than embedded in output.” The “make-and-sell” strategy of linear value chains gives way to the “sense-and-respond” strategy of self-reinforcing “value cycles.” Lusch described traditional goods-centered dominant logic as focused on “operand resources,” tangible assets with inherent value. He contrasted that logic with emerging service-centered dominant logic focused on “operant resources,” intangible assets, which create value in their use, such as skills, technologies, and knowledge. He also pointed out that service logic is not only compatible with the idea of a learning organization, but it may actually require one.

Managing operand versus operant resources

– adapted from Robert Lusch by Shelley Evenson

	<i>Traditional Goods-dominant logic</i>	<i>Emerging Service-dominant logic</i>
<i>Primary unit of exchange</i>	Goods	Service(s)
<i>Role of goods</i>	Operand resources Tangible	Transmitters of operant resources Intangible (e.g., knowledge)
<i>Role of customer</i>	Operand resource Recipient Asymmetric information Propaganda	Operant resource Co-producer Symmetric information Conversation
<i>Meaning defined by</i>	Value added before use Price	Value in use Value proposition
<i>Customer interaction</i>	Transaction	On-going relationship
<i>Source of growth</i>	Profit maximization	Financial feedback

Nicholas Negroponte has famously contrasted “atoms and bits.” The physical, tangible, here-and-now aspect of products-as-objects makes them relatively easier to evaluate than services. This characteristic is one of the things that make products easier to manage than services. A CEO can pick up a product appearance model and immediately evaluate it, compare it to

another, and decide how to proceed. Even a complex product like a car can be evaluated relatively quickly. But services are much harder to evaluate. Services cannot be apprehended all at once; they must be experienced over time. And sometimes service varies from one experience to the next.

Contrasting Goods and Services

<i>Product as object</i>	<i>Service system</i>
Possesses	Delivers
Visceral	Connected (via APIs)
Immediate	Takes longer to develop
Rapidly judged	Takes more efforts to unseat
Physical	Supporting
Node	Links
About components	About relationships
More static	More dynamic

Sustainable Design

The mechanical-object–organic-system dichotomy also appears vividly in discussions about ecology. Much of our economy still depends on “consumers” buying products, which we eventually throw “away.” William McDonough and Michael Braungart have pointed out that there is no “away,” that in nature, “waste is food.” They urged us to think in terms of “cradle-to-cradle” cycles of materials use, and they suggested manufacturers lease products and reclaim them for reuse.¹⁵ There is another important perspective on the idea of product-as-service.

Architects, too, have begun to design for disassembly and reconfiguration. Herman-Miller recently published a manifesto on programmable environments, talking about the need for “pliancy” in the built environment

and echoing the language *The Cathedral and the Bazaar* while discussing building design.¹⁶

Sustainable design is emerging as an issue of intense concern for designers, manufacturers, and the public. The same sort of systems thinking required for software and service design is also required for sustainable design. This provides further impetus for changing our approach to design education.

Stuart Walker, Professor of Environmental Design at University of Calgary, has written, “Only by fundamentally changing our approaches to deal with the new circumstances can we hope to develop new models for design and production that are more compatible with sustainable ways of living. Wrestling with existing models and trying to modify them is not an effective strategy.”

Reframing design: A comparison of key characteristics

—adapted from Stuart Walker¹⁷

<i>Conventional design</i>	<i>Sustainable design</i>
Industrial design	Design of functional objects
Product design	Creation of material culture
Specialization	Improvisation
Conventional	Uncertain, uncomfortable
Professional	Amateur, dilettante
Specific	Holistic, integrative
Instrumental	Intrinsic
Problem-solving	Experimenting
Solutions	Possibilities
A priori design	Contingent design

Early Parallels

The current shift from a mechanical-object ethos to an organic-systems ethos has been anticipated in earlier shifts.

In the mid-1960s, architects and designers began to focus on “rational” design methods, borrowing from the successes of large military-engineering projects during the war and the years following it. While these methods were effective for military projects with clear objectives, they often proved unsuccessful in the face of social problems with complex and competing objectives. For example, methods suited to building missiles were applied to large-scale construction in urban redevelopment projects, but those methods proved unsuited to addressing the underlying social problems that redevelopment projects sought to cure.

Horst Rittel⁸ proposed a second-generation of design-methods, effectively reframing the movement, casting design as conversation about “wicked problems.” His proposal came too late or too early for the design world, which had already moved on to “post-modernism” but had not yet encountered the internet.

Rittel’s work did attract attention in computer science (he was a pioneer in using computers in design planning), where “design rationale” (the process of tracking issues and arguments related to a project) continues as a field of research. More recently, Rittel’s work has attracted attention in business school publications addressing innovation and design management.^{18,19}

Reframing design: A comparison of key characteristics

— adapted from Horst Rittel by Chanpory Rith²⁰

	<i>1st-gen design-methods</i>	<i>2nd-gen design-methods</i>
<i>Approach</i>	Design as optimization Problem-solving Linear or waterfall	Design as argument Goal-framing Multi-level feedback
<i>Domain</i>	Science Design as part of science Sciences of the artificial	Design Design as its own domain Designing for evolution
<i>Stance</i>	Neutral, objective	Political, subjective
<i>Mode</i>	Descriptive “What is . . .”	Speculative “What could be . . .”
<i>Time horizon</i>	Present	Future
<i>Knowledge</i>	Factual	Instrumental

Paul Pangaro and I have also noted that Rittel’s framing of first- and second-generation design methods parallels Heinz von Foerster’s framing of first- and second-order cybernetics. Von Foerster described a

shift of focus in cybernetics from mechanism to language and from systems observed (from the outside) to systems-that- observe (observing-systems).

Cybernetics Matures

— adapted from Paul Pangaro²¹

<i>1st-order cybernetics</i>	<i>2nd-order cybernetics</i>
Single-loop Control loops Regulating in environment	Double-loop Learning loops Participating in conversation
Observed systems Observer outside frame Observer describes goal	Observing systems Observer in the frame Participants co-create goals
Assumes objectivity	Recognizes subjectivity

In 1958, von Foerster formed the Biological Computer Laboratory at the University of Illinois Urbana-Champaign. He brought in Ross Ashby as a professor and later Gordon Pask and Humberto Maturana as visiting research professors. The lab focused on problems of self-organizing systems and provided an alternative to the more mechanistic approach of AI followed at MIT by Marvin Minsky and others.²² In a way, von Foerster anticipated the shift from mechanical-object ethos to organic-systems ethos in computing, design, and perhaps the larger culture.

What do these changes mean for design education?

As design moves into the Age of Biology and shifts from a mechanical-object ethos to an organic-systems ethos, we should reflect on how best to prepare for coming changes in practice. At a recent conference on design education, Meredith Davis described, “the distance between where we are going in the practice of graphic design and longstanding assumptions about design education.”²³ (The full text of her talk is included on page 28 of the September issue of *Interactions*.)

Davis (building on Poggenpahl and Habermas) distinguished between two models of practice, “know how” and “know that,” “design as a craft and design as a discipline.” This distinction parallels the distinction between hand-craft and service-craft Pangaro and I proposed above. Davis asserted “college design curricula, and the pedagogies through which we deliver them, are based almost exclusively on the first model of practice, on know-how, and don’t acknowledge issues that drive emerging practices.”

Davis’ argument and framing are closely related to changes described in this article. Changes Davis advocates are consistent with the spirit of the new ethos and aimed at helping designers grasp the nature of organic-systems work and preparing them for practice in the Age of Biology.

Of course, not all designers welcome the coming change. Form-giving remains a large part of design practice and design education. Will some designers be able to continue to practice primarily as form-givers? That seems likely. But already a schism is developing both in design practice and design education, as individuals and institutions choose to focus on either form-giving or on planning. It remains to be seen if one person, one firm, or one school can bridge the divide and excel at both.

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