Organic Web Design

Exploring Nature as Metaphor in Responsive Web Design

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by

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Chapter I: Introduction

‘Copying nature’ is one thing and understanding nature is another. Copying nature can be simply a form of manual dexterity that does not help us to understand, for it shows us things as we are accustomed to seeing them. But studying the structures of nature, observing the evolution of forms, can give everyone a better understanding of the world we live in.

—Bruno Munari

Personal Experience

Throughout high school and into my undergraduate coursework, I spent hours upon hours hiking in the Cuyahoga Valley National Park, which lies within a 15 minute drive of Kent, Ohio. I grew up with the park in my own backyard in a sense, and always counted it as a blessing to visit a place in which time was seemingly preserved. Amidst difficult coursework and circumstances, nature provided a place of silence and of rest, but also of creative exploration—it was a new space for seeing and thinking, which I often found inspiring my design work. I was learning the process of design for the first time during my foundational years in The School of Visual Communication design, and I quickly became interested in the relationships between craft, human experience, and design. I was taking classes that introduced me to the fundamentals of form, motion, typography, color, and texture. I focused heavily throughout my coursework on classes having to do with interaction design, including HTML/CSS, User Experience Design, Interaction Design:
I also worked as an intern at a local letterpress studio. Eventually, the studio grew into a brand identity and interaction practice, where I worked among various mediums—from coding to user experience design—at any given time. I began to consider the craft of my work in new ways as I dealt with new mediums, and I owe much of what I now know about craft—it’s way of seeing and doing, whether working with code or a printing press from 1890—to Nate Mucha, who completed “The American Craftsman: A Contemporary Revival” (2012) and ran the studio. I consider him as a mentor and inspiring thought leader who is able to bridge the two seemingly detached modes of thinking and making. It is also worth mentioning that I took many philosophy classes as a minor during my coursework in design, and focused especially on aesthetics—and the nature of beauty as it’s related to art and design.

All the while I grew to love the park, and spent much time during my summers off hiking and reading Ralph Waldo Emerson, Henry David Thoreau, or John Muir. Their experiences and observation of nature directly influenced their writings and philosophies. Especially as I balanced my time between digital and physical craft, philosophy, and time in nature, my interest grew in the relations between the arts, nature, and design. This came to a peak when I first watched an online TED Talk by Janine Benyus called “Biomimicry in action”. I was fascinated by the process and idea that nature could inspire design in such a direct way, and started reading more literature on the subject. When I began considering thesis topics, my background experience in interaction design and love of nature sparked an interest in finding a path to integrate the two in an intentional way. As I dove into literature to search for graphic designers who had brought nature and design together, I found this space in literature to be largely empty—outside of engineering, industrial design, or architecture, many visual communicators hadn’t considered the implications of mimicking nature in an intentional ways, nor its potential for thinking about interaction design. In
order to focus the topic, I wanted to ground this research in my experience designing for the adaptive aspects of responsive web design, and its relation to the natural world.

**Introduction**

The rise of responsive design within the last decade has begun to shape the ways that designers consider the web as a medium. As the approach has developed, its practitioners have begun to form patterns and standardized approaches which might stifle alternative modes of thinking in the field. At the same time, criticism of this approach is still in its early stages, leaving open an opportunity for reflection, expansion, and the exploration of alternative modes of thinking and making for considering the medium. The web browser has properties which are inherently flexible, fluid, and adaptive—begging for a parallel exploration of flexible, fluid, adaptive systems as external inspiration.

Nature has been considered as a form of inspiration throughout the history of the arts and design, providing analogical and metaphorical modes of thinking that expand upon traditional approaches. More recently, biomimicry has emerged as a practice within industrial design, architecture, and engineering—yet little has been discussed within the field of visual communication design, and especially within responsive web design concerning this process. Though it could be argued that designers inherently use sources of naturalistic inspiration such as the golden ratio, this thesis investigates biomimicry as a process of its own, and its potential to be integrated into responsive design more intentionally.

This thesis investigates the relationships shared by design and the natural world through secondary research and primary research in the form of critical making, and proposes that looking to nature’s principles and forms can inform design for the web as a
medium, therefore providing an approach which builds upon and extends the capacities of responsive web design.

Methodology

This thesis presents a comprehensive literature review spanning two chapters. The first chapter discusses the use of the computer as a medium for design, the rise of responsive design to address the use of multiple screens as an ecosystem, the consideration of the web browser as a relatively new medium for design, and the need for alternative approaches to the methodology of responsive design as a response to its pattern-driven approach. The second chapter examines the role of nature as inspiration within the arts and sciences, biomimicry as an emerging design paradigm, and the use of nature as metaphor in visual communication design and its potential for growth.

Building on this literature review, the primary research conducted engages a form-driven, critical making methodology to create three prototypes. The prototypes were built to critically examine the use of naturalistic metaphors in web design, especially in relation to how it changes the design process for responsive design, and the overall approach to designing for the medium of the web. This chapter includes a detailed description of the processes used throughout each making experiment, as well as critical reflections upon the implications and findings within each prototype.

Lastly, as an evaluative method, questions on using biomimicry as an approach for responsive design were compiled into a qualitative survey, which was sent to various professionals within the fields of digital design, user experience, graphic design, and interaction design. The survey included a brief review of the prototypes created during the making processes, and asked participants to respond based on this alternative approach to
creating form on the web.

The paper concludes with implications of the critical making experiments and evaluative research, and suggests potential areas for further research.
Chapter 2: Responsive Web Design & The Medium of the Web

Any medium can be defined by its constraints. These constraints affect how a designer is able to work within the medium. To push the boundaries, you need to know where the edges are.

—Mark Boulton

Within the history of graphic design, digital technologies have given rise to more new ways of thinking and making than can be found in traditional print disciplines. This chapter reviews the user-interface—more specifically the desktop computer and the web browser—as a relatively new medium for design, and responsive design as building upon this notion for contemporary technologies. The design of user-interfaces themselves has changed dramatically over the last half-century, and continues to change rapidly with the growth of new technologies. As a response to the rise of multiple screen sizes and emerging ecosystems of devices, responsive design has arisen as a methodology for adapting the web interface to multiple screen sizes and environments. This new approach to web design considers the medium of the web in a new way—intentionally breaking away from traditional and static print based strategies for design. Yet the current approach to responsive design is limited, in that it focuses on specific technological considerations, which often leads to standardized design solutions led by user-centered approaches. These two approaches are synthesized in considering the medium of the web on a deeper conceptual level, opening a discussion about the potential for new approaches to be used in web design.
Digital Technologies in Design

The Introduction of Code to the Arts

The introduction of code and digital technologies to design has both shaped designers’ understanding of the arts and of their available tools for creation. Originally developed during wartime in the early 1940s, code was used within science and engineering as a means of designing complex weapons and running numerical calculations—the use of computers was not what we know today as “user-friendly.” Rather, using a computer and writing code was a highly specialized craft. It wasn’t until the 1950s and 1960s that code was viewed as relevant outside of these disciplines. Artists began viewing code as an opportunity for creation and exploration, ultimately leading to exhibitions such as Cybernetic Serendipity, held at the Institute of Contemporary Arts, London in 1968, Software—Information Technology: Its New Meaning for Art, held at the Jewish Museum in New York in 1970s, and Information held at the Museum of Modern Art in 1970 (Reas, 2010, pp. 21–23).

If writing code is equivalent to writing sets of instructions to perform an action, other artists during this period such as John Cage, Yoko Ono, Sol LeWitt, or LaMonte Young began experimenting with instruction based or ‘algorithmic’ conceptual processes for creating art. A contemporary focus on process itself can be seen within the manifesto for Conditional Design, as the authors state: “Our work focuses on processes rather than products: things that adapt to their environment, emphasize change and show difference” (Maurer). Consider also Sol LeWitt’s wall drawings, which listed detailed instructions and rules for the people who would ultimately produce the work. Especially with the rise of the personal desktop computer in the 1980s, the audiences for computation expanded. Languages such as Lingo or ActionScript were used by designers and artists with the rise of the World Wide Web, and literacy within code and programming increased. (Reas, 2010, pp. 21–23). Artists and
designers began to consider code as both a new conceptual approach, and the computer as a medium for creation in many regards.

Thus, although computers were originally designed for advanced mathematical problem solving, artists looked to the computer as an alternative medium for creation. As the user-interface developed, this became more accessible to designers and artists who didn’t know programming languages.

**The User-Interface**

The desktop computer caused a profound shift in the role of the computer as a highly specialized technology to a “user-friendly” tool. This began a shift in production for both users and designers. Steven Johnson (1997) provides a practical definition of a user-interface in *Interface Culture*, referring to it as the “software that shapes the interaction between user and computer. The interface serves as a kind of translator, mediating between the two parties, making one sensible to the other” (p. 14). With the birth of the user came a mediator—the user-interface—to make the computer system more easily understood. Johnson notes how the use of metaphor within the user-interface provided a means for designers to more thoroughly consider symbolism and representation:

The crucial technological breakthrough lies instead with this idea of the computer as a symbolic system, a machine that traffics in representations or signs rather than in the mechanical cause-and-effect of the cotton gin or the automobile [...] The enormous power of the modern digital computer depends on this capacity for self-representation. [...] “More often than not, this representation takes the form of a metaphor. A string of zeros and ones—itself a kind of language, though unintelligible to most humans—is replaced by a metaphor of a virtual folder residing on a virtual
desktop. These metaphors are the core idiom of the contemporary graphic interface. (Johnson, 1997, p. 15)

Thus designers now approached a new field of design, rich with metaphors and analogies, aiding as a means of abstraction. In fact, the desktop metaphor has been long debated within the field of user-interface design, as its implications for users and designers are immense. Especially on the web, where the use of metaphor is equally prevalent, both conceptually and visually. Consider how one can “bookmark” pages to save online, or how one completes a metaphorical “checkout” process when shopping for consumer goods. Yet as new technologies became available, the need for new approaches to user-interface design grows.

**The Rise of Responsive Design**

As the desktop became more ubiquitous in the home, several important technological shifts took place. Throughout the late 1990’s, web design primarily focused on the personal or ‘desktop’ computer. As mobile technology has grown, designing for desktop alone might suffice in certain contexts, but in others lead to poor user-experience.

The Pew Research Center (Fox, 2014) released a report to mark the 25th anniversary of the web. The report found that 87% of adults use the internet, and 68% of adults connect to the internet through mobile devices. Compared to an original survey taken in 2000, the number of cell phone users rose from 53% to 90% in 2014, while the ownership of smartphones increased from 35% in 2011 to 58% in 2014. The report notes how these digital technologies are viewed as increasingly essential to daily life and to being informed as a citizen. In another earlier report published by Pew Research Center titled “The Future of

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1 Pew Research Center defines the web as the service which uses the internet’s architecture—the web is not the internet itself.
Mobile News” (Mitchell, 2012), the report described how “Rather than replacing old technology, the introduction of new devices and formats is creating a new kind of ‘multi-platform’ news consumer.” There was also a shift in users using the browser for news consumption rather than in applications. Similarly, Google (2012) released a report titled “The New Multi-screen World: Understanding Cross-platform Consumer Behavior.” The summary describes the U.S. as a nation of “multi-screeners,” even “sequential” or “simultaneous screeners” driven by our own needs and contexts. In other words, users with multiple devices may browse on these devices at the same time.

When compared with the traditional graphic design practices which shaped web design during the 1990s and 2000s, these shifts in technological uses provided a clear foundation and need for new design methodologies which allow websites to adapt to multiple device contexts.

**Traditional Processes in a New Medium**

Along with the rise in the use of metaphors in web design, other technical and historical graphic design approaches have shaped web design methodologies, such as the designer’s use of the grid, traditional layouts for print, or the linear processes of designed artifacts from concept to production. These methodologies were at first implemented verbatim in the new discipline of design for the desktop and the web. With the primary interface being the home desktop—and with only a few sizes of screens available—certain metaphors and methodologies for design worked successfully at first but were soon outmoded by the needs of an upswing in the use of mobile devices. Even so, this is evidence that the web was now being considered as a new medium for design.

Ethan Marcotte, in *Responsive Web Design* (2011), gives voice to the idea of the web
as a young medium, ripe for new methods that move beyond traditional graphic
design practices:

> Some of that recycling is perfectly natural [...] and since the web is a young medium,
it’s only natural to borrow some terms from what we know: graphic design provides
us with a rich history that spans centuries, and we’d be remiss not to use its language
to help shape our industry. (Marcotte, 2011, pp. 2–3).

He continues, noting how graphic designers, when faced with this new medium of the web,
borrowed the concept of the canvas from print design. This analogy from traditional design
practice propagates a design approach based on a fixed size: the canvas implies a set height
and width which is unchanging. Bringing this process into design for the web, designers
used pixels and fixed-width layouts to mimic the pica and the page. Similarly, the concept of
the grid was implemented through the use of tables. These approaches created static, defined
site layouts, even as the browser itself could change size or implement other settings chosen
by the user, such as selecting a different font size.

Marcotte notes how relying on minimum screen resolutions, rather than a responsive
system, can lead to problems for both clients and users. He cites the original New York Times
website, which, when the browser is resized, remains the same width, hiding the ‘register’
button from view for users.

![New York Times](image)

**FIGURE 1. THE NEW YORK TIMES WEBSITE (MARCOTTE, 2011).**
As seen in FIGURE 1, the web browser itself acts as a window into the web, and is flexible by nature. Fixed approaches technically work within the medium of the browser, but they don’t fully respond to it as it changes. In the same way, fixed methodologies, inherited from print, limit the development, or effective use, of the browser as a medium. In addition, a non-adaptive web interface can affect user-experience in a negative way, depending on the context of the design and its user base. Marcotte recognized this as an opportunity to create a new approach: as the potential to cause a fundamental shift in considering the flexibility of the web browser as a characteristic of this a new medium.

Along with the increasing use of mobile technologies, these factors revealed a new problem: user-interface designers were forced to accommodate the seemingly infinite development of new devices and types of hardware. The argument could be made that our culture has grown so mobile savvy, that not designing responsively is not only a missed opportunity, but also an irresponsible approach to user-experience design. Thus, a shift in thinking was needed: from a static, print based approach, to a more flexible approach, based on the innate properties of the web.

**The Language of Responsive Web Design**

Marcotte originally coined the term “responsive web design” in his article “Responsive Web Design” (2010) published on A List Apart. This term provided a clearer vision and approach to the problem of designing for many screens. It’s important to note that the technologies used in responsive web design already existed. Marcotte only provided a clearer strategy for how these technologies could be used to enhance user-experience (Keith, 2011). For example, the experimentation with the use of percentages for flexible
images, rather than fixed pixels, had previously been conducted by Richard Rutter. At its root, responsive design is a strategy that uses the technologies embedded in front-end web development to help a design continually adapt to the browser size—regardless of the device. Thus, the design of the website itself becomes device “agnostic.”

Marcotte organized a way to take what was already being done in front-end development, and specified a language and approach for web design based primarily on three front-end development technologies:

**A flexible, grid-based layout.** Taking the modernist notion of the grid as a starting point for design, the flexible grid expands upon a fixed grid, making it flexible to the browser. Rather than using a pixel based fixed width, such as 960px, flexible grids utilize percentages within CSS code—retaining a fluid proportion of the grid and making it responsive to the browser. By using simple mathematical equations, column widths and typography scales within the grid can be interpolated. (Marcotte, 2011, pp. 13–41)

**Flexible images and media.** As previously noted, flexible images were first “discovered” by Richard Rutter. Similarly to producing a proportional and fluid grid which adapts to the browser width, flexible images and media can be set to percentages or ems instead of a fixed pixel width. (Marcotte, 2011, pp. 42–63)

**Media queries, a module from the CSS3 specification.** Media queries were introduced in CSS3 to identify the type of media (such as a screen) in addition to “inspecting the physical characteristics of the devices and browsers that render our content” (Marcotte, 2011, p. 74). Because media queries recognize device heights and widths, they can be used to automatically determine “breakpoints” for flexible grids and media. Breakpoints would occur when a column within a flexible grid, for
example, becomes too narrow to read. Defining a breakpoint will allow the column to shift vertically, stacking underneath another column, and thus forming a new row within the grid. (Marcotte, 2011, pp. 64–105)

Through the development of responsive design as a practice, designers and developers can begin to consider the web more fully as a medium in its own right in a way that is beneficial to user-experience. Marcotte and others have since begun developing responsive design into a methodology of various principles and patterns for use in an open-source fashion. Yet several aspects of this approach can constrain how designers consider design for the medium.

**On Standardization in Responsive Design**

As responsive design has developed further over the last decade, designers and developers have sought to produce patterns and principles for the practice in order that design and development might become more consistent and efficient. In a more recently published book *Responsive Design: Principles and Patterns* (Marcotte, 2015) discusses the abstract qualities of responsive design, and the idea that it is too focused on columns, rows, and available technologies. Instead, he argues designers ought to start focusing their attention on developing new approaches, or, in a sense, new languages, patterns, and concepts, for approaching responsive design while it is still in its infancy:

Over the past few years, we’ve been learning how to adapt our layouts to the infinite canvas of the web. Our sites can be viewed on any size screen, at any time, and responsive design is one approach that lets us accommodate the web’s variable shape. But with all of the challenges we’re facing and those yet to come, we need to begin
building not just patterns, but principles for responsive design—principles that will allow us to focus not just on layout, but on the quality of our work.” [...] In other words, how do we move beyond thinking in terms of columns and rows, and start talking about the quality of our responsive designs? And what would frameworks to support that look like? (Marcotte, 2015, p. 126).

Marcotte’s discussion focuses on expanding beyond the basic premise of responsive design—its technicalities—into searching for deeper concepts to drive thinking around it. This pursuit has helped to develop a consistent language, and Marcotte outlines navigational patterns such as hamburger menus or drawers, methods for creating flexible images, managing advertisements, in addition to forming responsive grid and column structures. Other contemporary examples employing this mode of thinking are evident in websites such as “Responsive Design Is” (Avery), which provides standardized patterns for various column layouts. Others such as Brad Frost have already provided extensive collections of various types of patterns through the website Responsive Patterns covering layout, navigation, images, media and data, text, and modules. While these frameworks provide a starting point for approaching responsive design, they might severely limit creative thinking around possibilities for the relationship between form and content.

In the FastCompany article “Thinking Beyond the Interface,” (Woods, 2017) Paul Woods critiques approaches to designing interfaces with pre-formed templates and patterns, and asks if traditional art direction and content creation has been left behind:

Instead of thinking, “We need to commission art and direct a photo shoot where the photographer accounts for clear space on the right-hand side of the image for the text placement,” what frequently happens is: “Let’s put a white box over the image so the text is legible at any breakpoint.”
Indeed, responsive design is still in its infancy—while patterns and processes may be efficient for prototyping, they cannot serve as an end in themselves. Further, while responsive design patterns take advantage of the medium of the web, they have the capacity to limit creative thinking about its potential as a medium. What other metaphors, analogies, or other creative thinking methodologies might continue pushing the boundaries of the web as a creative medium?

**A Discussion of Pros and Cons of Responsive Design**

As discussed throughout this chapter, responsive design is not fit for all contexts, but provides a foundation for adapting to the browser as a medium in itself. In this section, the pros and cons of responsive web design are discussed.

**Pros.** Responsive design carries several key benefits. First, it has the potential to improve user-experience across several areas of design through adapting to various device widths. This can make content more accessible to a wide array of users on a diverse range of devices. Through the use of media queries, responsive design also introduces the potential for shifting the hierarchy of a website and its content to adapt to various user needs at various sizes as determined by the designer. In other words, all of the content of a website may be available on a desktop version, while mobile versions may offer a curated, smaller portion of that content. Second, responsive design opens new possibilities for designing frameworks, principles, and patterns. Front-end development for the web is largely recognized as an open source discipline—take for example GitHub, W3SC, or Google Chrome’s “inspection” feature. Lastly, responsive design takes advantage of the web as a medium itself, and can help designers to plan their designs to be flexible and adaptive.
Responsive design has several limitations. First, as a technological approach which offers efficient patterns for development, formal design often follows suit with such patterns as modular “cards,” or hamburger navigation “drawers” (Marcotte 2015). In one sense, these standardized forms offer a glimpse of the web as a medium, complete with a “grain” of sorts. In the same way wood is shaped in similar ways between many carpenters, designers often mimic one another, creating similar designs within the web browser. Yet this presumably makes content appear redundantly across many types of content, and can stifle creativity. Second, responsive design offers a strategy for thinking about web design in terms of patterns or frameworks, but this abstract, underlying strategy, doesn’t provide catalytic ways to reconsider designing for web. Instead, concepts and ideas must be introduced separately or on top of the foundation of responsive design. Lastly, it could be noted that the standardization in responsive design is underscored by its focus on users’ devices; it attempts to make a design accessible in the best way possible to as many different users as possible. This provides a limitation in the sense that it narrows focus for designers to functional and technological issues. What other aspects of aesthetics or experience might be missing from responsive design? How might responsive design change to help designers think about the medium in new ways?

Thus, several key benefits and limitations are brought forth by the notion of responsive design. One key benefit discussed is the idea that responsive design considers the medium of the web in a specific way. This provides a specific focus point for this thesis, in that it asks how responsive design can be built upon to better consider the web as a medium for creation.

In A Practical Guide to Designing for the Web (Boulton, 2009), the role of the graphic designer in approaching web design is discussed in relation to medium. In considering some
of the most basic assumptions of a designer thinking about the web for the first time, Boulton discusses outright the medium of the web:

Any medium can be defined by its constraints. These constraints affect how a designer is able to work within the medium. To push the boundaries, you need to know where the edges are. (Boulton, 2009, p. 3)

Overall, responsive design considers the formal properties and qualities of the web as a medium in an intuitive way that does not work against it. Following Boulton’s thought, a discussion of the browser as a medium could be opened up in order to consider whether responsive design can be expanded upon further. In what ways might designers begin to push beyond current limitations of responsive design, and ultimately to push the boundaries of the web as a medium?

**The Web as a Medium**

Considering the web as a new medium presents an opportunity for introducing new approaches to responsive design. Continuing the earlier discussion set forth by Marcotte, the browser is fundamentally more flexible and variable than traditional static materials. In print, designers work within the constraints of the fixed dimensions of a page—the content is printed and remains static and unchanged unless designed intentionally otherwise. With an understanding of responsive design and its limitations and opportunities, it is pertinent to consider what the browser is and is not capable of. Better yet, what should or should not be done with this medium? What are its properties apart from the strategies and approaches found in current responsive design approaches and front-end development, and how might this shape our understanding of responsive design at a deeper level?
Two Conceptual Perspectives on the Web as a Medium

If we view the web as a medium for growth and change, what new methodologies or approaches might be appropriate when considering design for responsive environments? This section looks to broader conceptual approaches to reshape our view of the web as a medium, and ultimately as an opportunity for an alternative approach to designing for it. Two contemporary practitioners and authors have provided a broader consideration of the web as a medium: John Allsopp in his article “A Dao of Web Design” (2000), and Frank Chimero in “The Web’s Grain” (2015).

Allsopp offers important insights into the web as a “same old new medium.” First, when new mediums appear, it is common for designers to repurpose familiar strategies to make sense of the new medium, but can often lead to a “ritual” use of old techniques which don’t fully fit the new medium. This is an example of what Marcotte discusses, when we borrow the fixed width ideals of a piece of paper, and apply them to an inherently flexible browser. In contrast to the finite and definite printed page, the viewport of the web is constantly in flux, always shifting; forcing the typography and imagery any which way, compromising space and motion. Allsopp uses Daoism as a metaphor:

[The Sage]
... accepts the ebb and flow of things,
Nurtures them, but does not own them
—Tao Te Ching; 2 Abstraction

Second—and as alluded to in the quotation above—the nature of the web necessitates a relinquishment of control on the part of the designer. One important question to consider
is whether designers ought to have full control. Within print, this may be necessary. But in
the context of an interactive space, users account for a portion of how the design appears.

Third, Allsopp’s ideas can be summarized as “make pages which are adaptable.”
While there is inherent flexibility and new constraints of the medium of the web, designers
should seek to understand as much of these constraints as possible, in ways that benefit the
end user and the accessibility of the website being built.

Chimero takes a similar approach, but is more critical of the way designers approach
designing form in a web-based context, and discusses the many conventions which arise as a
product of the “grain” of the web. Chimero argues that we can see the grain of the web most
clearly through the artifacts we produce within it. He offers new thinking about the
potential for designers to expand on this notion. For example, many designers were trained
first in print design—it can be difficult to unlearn this process if our instinct is to create
boundaries, edges, and definitions. Chimero recognizes this, discussing how designers begin
the sketching process for web design:

1) Draw a box
2) Fill in said box with the page’s elements

For a canvas or a set page size, this process is adequate enough. But why do we do this within
a medium in which the “box” is always changing its size? He discusses David Hockney, who,
fed up with the constraints of a single picture frame, decided to take several pictures at
various angles to recreate environments in a more fractured way, creating assemblages of
the pieces together at the end. These images become an exploration of space and time, rather
than a fixed moment in 2D space.
This begins to let us think in a more modular manner about designing for a flexible medium. Chimero also discusses the “edglessess” of the web. In contrast to a page, the canvas of the web goes on infinitely. Users can scroll in any direction for as long as desired. Even the nature of the web itself is edgeless and continually expanding. Consider Chimero’s description of web design in contrast to print design:

An edgeless surface of unknown proportions comprised of small, individual, and variable elements from multiple vantages assembled into a readable whole that documents a moment. (Chimero, 2015)

Thus, the web introduces a new type of constraint for designers to deal with: fluidity and adaptability. The designer can no longer simply design a static layout. Instead, they must design a system which is able to constantly adapt, bend, morph, change, modify, alter, and evolve.

Chimero, Allsopp, and Marcotte each consider responsive web design within the
constraints of front-end code and usability. Chimero notes the simplicity of using code and how the changes in the viewport size define the “canvas” or “grain” of the web. Allsopp discusses style sheets at length as they pertain to accessibility. Marcotte echoes the idea that responsive design aids usability. Still, code is often provided as an entry point which defines the constraints of the medium. After those constraints are noted, the medium is better understood, and design is made to fit within it. This is a common approach—in order to paint, the painter must understand how the canvas will stretch and absorb the paint. The designer must know the weight and texture of the paper to understand which typefaces and colors will print best. In the same way, web designers ought to know about code. In a sense, by using code within the browser as a starting point, the the designer of the interface can begin to better understand the browser’s constructedness. At the same time, what other entry points might exist? What if designers started with formal exploration first? Would it cause the exploration of new code or algorithms? Would it shift the way designers see the web as a medium?

More importantly, Chimero begins to consider more designerly approaches to the web as medium. Rather than ending at technologies available, there is a shift in thinking more about how we make for the medium. How will we shape new artifacts in a responsive, flexible environment? What other new modes of thinking can be engaged to help us to consider this further?

**Looking For New Approaches**

If one is to consider responsive design critically, it is important to note that responsive design is not only a technological strategy (as it relates to devices) in its current state, but is highly standardized. Indeed, Marcotte’s recently published book *Responsive*
Design: Principles and Patterns (2015) lays out common use cases for responsive design, such as development patterns for hamburger menus or ‘drawer’ navigation, reusable column structures, or flexible image layouts. It could be argued that the many patterns or standard approaches noted above could be a result of the lack of alternative perspectives within the field.

It is worth asking whether a focus on designing reusable, open-source patterns within responsive design has over-powered other considerations such as aesthetic potentials, art-direction, conceptual, or experiential qualities. Similarly, in many cases within user-centered design processes, form is derived from intended functionality through sketching and wireframes without expanding further on aesthetic potentials (Jung, 2012). This can help to provide consistent patterns for interaction, but can also limit exploration of the medium. Within the broader scope of literature on user-interface design, however, multiple perspectives are often drawn from the humanities, cultural studies, the sciences, aesthetic theory, philosophy, or even fashion as a means of introducing new modes of thinking to the field (Bardzell, 2009; Dourish, 2004). Indeed, the broader practice of Human Computer Interaction (HCI) itself is increasingly interdisciplinary, which has the potential to broaden fundamental ideas of what HCI is as both a practice and a discipline. Carrying this idea into user-interface design, and more specifically responsive design—looking for alternative ways of describing website functionality, behavior and appearance might help to provide a new understanding of the potential for responsive web design.

Consideration of the web browser as a medium in itself provides an alternative to the standardization of design forms which has occurred in responsive web design. It showcases a need within responsive design to move beyond the abstract language of columns, rows, and CSS technologies, and to consider new approaches. Marcotte is echoed in a different way—in a discussion of users and functionality—by Steven Johnson (1997) in discussing medium of
the web.

In *Interface Culture*, Johnson opened an important conversation which still resonates within this discussion. He argues that designers can sometimes become so embedded within a historical context of technology that “blind spots” are formed. Thus, our notions of what the interface is, or what it can do, relies on our “generic” understanding of it as a tool for aiding a user in tasks—thus, we reduce the interface to something which merely serves up functionality. As discussed at the beginning of this chapter, the computer was originally used to aid in mathematical calculations during wartime. It wasn’t until artists began looking to the computer as a tool for *creation* that it moved beyond those boundaries. Still today, many discussions about designing an interface are often reduced to its functionality and ability to accomplish a task at hand. Johnson states:

> All these developments suggest a widening of the interface audience, but the medium itself still belongs to the world of functionality and increased convenience. [. . .] The most profound change will lie with our generic expectations about the interface itself. We will come to think of interface design as a kind of art form—perhaps the art form of the next century.” [. . .] The problem with the interface medium at present—and this is one reason that we have trouble taking it seriously as a medium—is that we don’t have a language like this to describe it. For the most part, our evaluative criteria reduce to the bottom-dollar question: is it easy to use or not? There’s invariably a bonus round for the cyber-slackers—is it cool?—but that’s where the critique usually comes to a grinding halt. (Johnson, 1997, pp. 213, 216–217)

Marcotte and Johnson both offer the notion of considering design for interfaces, especially responsive design, as ripe for new approaches that look beyond technologies available, and beyond pure usability. This thesis postulates that there are many shared characteristics between the web as a medium and forms, systems, and processes in the natural world.
Chapter 3: Nature and Design

Nature has been the inspiration for the Arts throughout the history of man—
cave paintings, structures, buildings...one can always turn to it as a source
for ideas and inventions.

—Edna Lawrence

What other disciplines or subjects might open up alternative ways of thinking beyond the use of patterns and templates in responsive design? In visual communication design, as well as in many other disciplines, analogical thinking has acted as a creative catalyst in addressing complex, interdisciplinary problems, while also opening conversations about new modes of thinking and ways of seeing. It could be argued that nature has always been used as inspiration in design, but this chapter also considers biomimicry as an emerging design methodology which is relatively new—bridging design and biology in an interdisciplinary fashion—in addition to shaping new ideas about the process of design, and its role as an analogous mode of thinking. This thesis argues that this methodology has the potential to open new modes of thinking about responsive design through three discussions: 1) the historical and contemporary relationships between the arts and sciences, and the ways in which this has provided a foundation for the emergence of biomimicry as a defined process; 2) the development of biomimicry as a process and its relation to the design of metaphor in user-interface design, as well as its successful use in other disciplines; and 3) the use of biomimicry in visual communication and user-interface design.
Relations Between the Arts & Sciences

Inspiration, Self-reflection, and Critical Thinking

When we consider the web as a medium for design, and as we look into new approaches for responsive design, one could argue that the natural world has always been a strong influence in the life and work of artists, designers, inventors, and makers throughout history. As a few brief examples, consider the work of the following artists and inventors:

- Leonardo Da Vinci, circa 1488, studied the anatomy of birds and designed many sketches for “flying machines” which resembled them, but which were never produced. (Vincent, 2006)

- The Wright Brothers studied pigeons in flight as inspiration for the design of the first airplane to fly in 1903. (Vierra, 2016)

- Ellsworth Kelly studied plants through careful observation in his plant drawings, which could be considered as a “gateway to abstraction” later influencing his more well known abstract modernist works. (Rosenberg, 2017)

- Georgia O’Keeffe pushed the limits of art classifications throughout her seven decades of work, as she committed to the careful observation of nature which was abstracted heavily in her paintings of flowers and landscapes. (“Georgia O’Keefe,” n.d.)

- Bruno Munari discusses the notion of spontaneous forms in industrial design in his book *Design as Art* published in 1966, noting how “nature in face creates her forms according to a particular material, function, environment, and set of needs.” (Munari, 1966, p. 114)
Peter Pearce, in his book *Structure in Nature as a Strategy for Design*, published in 1978, argues the ways in which geometry and structure in nature can influence architecture in innovative ways through the notion of minimum inventory, maximum diversity. (Pearce, 1978, pp. xii–xvii)

Alan Turing, the “godfather of modern computing” studied morphogenesis, or the ways in which processes in nature produce form and shape:

Fascinated by the presence of Fibonacci numbers in the leaf arrangements of plants and the color patterns of animals, he developed some of the earliest mathematical models of how biological shapes emerge—a pioneering effort to crack the algorithmic code of nature, correctly predicting the diffusion of chemical signals that determine the patterns of shape-development. (Popova, 2016)

In each case, natural references provide a way of expanding on existing ideas in a way that was novel and influential. As a method of study and contemplation, referencing nature provided an alternative mode of thinking. Today a multitude of theories such as the fibonacci sequence, the golden ratio, or fractals permeate visual forms in art and design, and are taught within contemporary design education. Each attempts to affect how designers think about design on a fundamental level. Whether or not designers notice, it could be argued that nature influences each and every aesthetic decision one makes, whether it be in symmetry, color, texture, or pattern. In discussing the play of symmetry in the balance of life and design, Adrienne Matei comments on our emulation of nature:

Mirror balance and algorithmic precision may sound like human fabrications, but taking a closer look at the circular swirl of a sunflower or the intricate Fibonacci sequence of a pinecone shows that nature is the original master of symmetry.
Whether we’re conscious of it or not, the designs we create often emulate the precise patterns we perceive in the natural world. (Matei, 2016)

Going a step deeper, aesthetic philosophers such as Denis Dutton provide a Darwinian philosophy of aesthetics, arguing that our understanding of beauty and aesthetics are evolutionary in origin—in that we have evolved to love art because it helps us to survive. In essence, Dutton believes that art is a deeply human need, and that “our aesthetic perceptions are much more influenced by evolution than by culture.” This idea is echoed by E.O. Wilson, a biologist and conservationist, in *Biophilia* (1984). The theory outlined by Wilson explores “the notion that humans have an innate affinity for life and life-like processes” (Overstrom, 2013, pp. 204–205). Similarly, in *Biomimicry: Innovation Inspired by Nature* (1997), Janine Benyus discusses our species as being imitators from the beginning, looking to natural habitats as inspiration for survival:

> We are self-reflective, and therefore uniquely positioned to seek nature’s counsel, to learn, to echo, and to give thanks for the wisdom we acquire. [...] The first artists were also practicing mimics, re-presenting the natural world in painting, song, and dance. (Benyus, 1997, pp. 295–296)

These examples provide insight into the ways nature has inspired art and design throughout history, as well as a picture of nature’s influence on human thought—perhaps as an evolutionary trait. This thesis builds on the work of contemporary biomimicry studies, arguing that nature still has a great potential to inform artists and designers today, especially within the contemporary relationships between the arts and sciences.
The RISD Nature Lab: A Contemporary Example

The Nature Lab at the Rhode Island School of Design (RISD) exists as an example of an innovative approach to design education which pushes students to see nature as inspiration for design and the arts. The lab, which was opened in the early 20th century by Edna Lawrence, sits within RISD’s Waterman Building, and facilitates easy access to natural history resources, scientific tools for examination, and spaces within which to push the boundaries of design:

In the early 20th century, RISD faculty member Edna Lawrence founded the Nature Lab to open students’ eyes to the marvels of beauty in nature—of forms, space, color, texture, design and structure [. . .] Today the Lab still offers unmediated access to authentic natural history specimens, while also fostering creative inquiry into biomimetics, biophilic design, ecology and climate change. (“Home,” n.d.)

The Nature Lab’s purpose is to expose students to new modes of critical thinking in design and the arts, the inherent “subjectivity of natural orders,” the potential for biology to influence art and design, and the connections between science and art, and nature and people. Especially alongside the rise of biomimicry, the lab has helped spark an important conversation about tapping into 3.8 billion years of evolution as it relates to design. In other words, what might designers learn from nature, the longest living designer?

Neal Overstrom, in an essay titled “The Nature Imperative,” (2013) discusses the impact of the Nature Lab on students, looking to the relations between science and art, and the importance of developing “personal taxonomies” as they relate to identifying and creating new schemes for the organization of natural materials and organisms—whether by size, texture, color, or symmetry. This provides ways for students to overcome existing knowledge about the visual arts and design in new ways—by introducing nature as a catalyst
for thinking. For artists and designers, why must natural history objects always be organized by species, genus, or kingdom. Overstrom notes:

Comparison, juxtaposition, and composition—all integral aspects of art and design—help students see myriad potential systems, a process that mirrors the way cognitive scientists believe the human brain organizes information and conceptualizes the world. (Overstrom, 2013, p. 196)

In this way, the Nature Lab provides a sort of avant-garde way of approaching art and design by facilitating the cross-pollination of ideas from other fields, while expanding on designerly ways of knowing and understanding. In an MFA thesis published by Olivia Verdugo (a student of the Nature Lab) and quoted by Overstrom, this idea is reiterated in a new way:

There is a compositional grammar and an order underlying every aspect of the natural world, shaped by forces which act upon great and small alike. I am fascinated by the patterns that emerge from this grammar…rich surface designs emerge from microscopic studies of a common pigeon’s feather; the behavior of particles in fluid dictates the framework for a generative computer applet; the study of symbiosis spawns a new form of book. (Overstrom, 2013, p. 198)

In this sense, nature is able to inspire designers at multiple visual and conceptual levels. Whether the form of a book, the repetition of a pattern, or the design of surfaces, nature can inspire new ways of thinking about old formats, techniques, or modes of thought.

A case study which provides a greater context for the similarities between the sciences and the arts is demonstrated in a project conducted by RISD students Mengzhuo Li, BFA, and Eliza Squibb, BFA, and funded by the National Science Foundation. The project asked teachers to observe microscopic specimens, sketch what they felt was significant, share their sketches with a group, and then organize those sketches into their own visual
taxonomies. The project offered insight into the relations between the arts and sciences, and especially to look at how visualization is similarly practiced in both fields. The biggest insight gained was that the visual taxonomies which emerged—such as “contour,” “symmetry,” or “texture”—highly resembled J.H. Mathewson’s “Master Images” compiled in his paper The visual core of science: definitions and applications to education (Overstrom, 2013).

Mathewson expounds on the way in which science can be seen as a highly visual field of study. He lays out a set of “master images,” such as “coils,” “strata,” “flow,” “packing,” and “gradients,” and provides a glossary with rich examples of where these images appear in the sciences (Mathewson, 2005).

Mathewson notes that scientists are not necessarily experiencing a lack of images, but instead their “readiness to understand and use these images critically and constructively.”
In a similar way that designers and artists use metaphors and analogies, Mathewson argues that scientists, too, have used analogies for creative thought, and as a way to better understand complex ideas about nature and science (Mathewson, 2005). Thus, metaphor acts as a common connector between the arts and sciences. Overstrom continues by discussing how the two students who hosted the workshop above described their teachers’ “ability to organize and express information through themes, metaphors, and analogies” (Overstrom, 2013). In these ways, science and the arts have the ability to inform one another in new ways—each field can benefit from the cross-pollination.

Thus, the relationships that are developed between the arts and sciences can act as an interdisciplinary bridge for new modes of thinking—bringing together outside sources of inspiration to inspire new thought patterns and connections. The relations between the two fields has significantly shaped designers, educators, and inventor’s views of design in a new way. In a sense, this inspiration by nature throughout history has provided a foundation upon which biomimicry as a defined design methodology has grown over the last 70 years.

**Biomimicry as an Emerging Design Paradigm**

**A Brief History of Biomimicry**

Biomimicry as a term was initially coined by Otto Schmitt during the 1950s. Previously, Jack Steele of the US Airforce had coined the term bionics to refer to “the science of systems which have some function copied from nature, or which represent characteristics of natural systems or their analogues.” In 1969, Schmitt used the word biomimetics in the title of a paper, and the term appeared finally in 1974 in the Webster’s dictionary (Vincent et al., 2006).
Although nature has been a source of inspiration for several thousand years, biomimicry as a defined practice is a relatively new discipline which merges multiple others, uniting a diverse range of fields such as chemistry, physics, engineering, electronics, sustainability, pharmacology, business, architecture, industrial design, sociology, computing, design, and biology. As noted in “Biologically Inspired Design: Process and Products”, biomimicry is inherently interdisciplinary, and is “based on cross-domain analogies requiring expertise across two disparate domains” (Helms, Vattam, & Goel, 2009).

The approach today remains much the same as when Schmitt coined the term, referring to the practice of looking to nature as inspiration for ideas. Published as a “seed-bank of best practices” the Biomimicry Resource Handbook (2013), edited by Danya Baumeister, Ph.D., defines biomimicry as “learning from and then emulating natural forms, processes, and ecosystems to create more sustainable designs.” Rather than simply copying nature, the practice of biomimicry attempts to extract the most important aspects or principles of a biological form, process, or ecosystem, and then integrate those into a design in a new way.

Perhaps more importantly, biomimicry offers a new way of thinking about existing disciplines. As an interdisciplinary practice, it brings analogical modes of thinking into the fields of design, engineering, architecture, and others. While the principle idea of biomimicry today is centered around looking to more sustainable methodologies for design, it is important to note that Schmitt’s original definition offered biomimicry for other purposes, but “especially for the purpose of synthesizing similar products by artificial mechanisms which mimic natural ones.” In other words, while sustainability is indeed a noble goal, it need not be an end-all-be-all. There still exists the opportunity to mimic nature for other purposes, such as igniting interdisciplinary collaboration, enhancing product novelty, creating biophilic spaces and designs, or using new analogies as an
alternative mode of thinking for idea generation. Within biomimicry, there generally exists three modes of emulating nature in design.

1) *Mimicking a natural form.* Looking to natural forms in nature to inspire patterns, visuals, textures, or shape.

2) *Mimicking a natural process.* Looking to natural processes to understand how something is made.

3) *Mimicking a natural ecosystem.* Understanding how both form and process fit within a larger ecosystem or biosphere.

As an emerging field, biomimicry often exists as an ad hoc approach. A certain problem is identified, and then approached by looking to natural sources in varying ways. Many attempts have been made to create normative processes, including methods for production, emulation, or design. In “Biologically Inspired Design: Processes and Products” (2009), the authors state:

> While designers have used biology as an inspiration for thousands of years, no normative process exists specific to the practice of biologically inspired design. (Helms, Vattam, & Goel, 2009)

Especially within the field of engineering and industrial design, biomimicry as a process has led to mixed results. Janine Benyus praises the many 'biomimics' who are consulting nature for industrial design, engineering, and architecture, leading to breakthroughs in sustainable design. Benyus begins only to scratch the surface for the potential of biomimicry in providing an innovative way to approach design in our contemporary dilemma of unsustainable products, increasing global population, and misuse of resources, arguing that biomimicry will be the next paradigm for design:

> In a biomimetic world, we would manufacture the way animals and plants do, using
sun and simple compounds to produce totally biodegradable fibers, ceramics, plastics, and chemicals. Our farms, modeled on prairies, would be self-fertilizing and pest-resistant. To find new drugs or crops, we would consult animals and insects that have used plants for millions of years to keep themselves healthy and nourished. Even computing would take its cue from nature, with software that "evolves" solutions, and hardware that uses the lock-and-key paradigm to compute by touch.

(Benyus, 1997)

Biomimicry has emerged largely as a practice for sustainability, and many tools and resources have emerged as a result of Benyus’ work, including the Biomimicry Institute, AskNature.org, the Biomimicry Toolbox, and others. These not only provide ways of looking at case studies of other designers’ work and incorporation of biomimicry, but how success might be measured. The practice of biomimicry has produced a substantial amount of research in two particular areas: process and outcome.

The Process of Biomimicry

The process of using biomimicry has been studied extensively within engineering design (Goel, McAdams, & Stone, 2014; Bar-Cohen, 2006). Typically within biomimicry, the process for emulation has four components: scope, discovery, creation, and evaluation. These components exist as a radial set of relationships (see figure 4), and can be combined or applied in varying degrees of complexity based on a designer’s specific needs. As described at length in the Biomimicry Resource Handbook (Baumeister, 2013), the four components include:
1) Scoping: identifying a problem at hand—including the problem’s context, criteria, and constraints.

2) Discovering: looking for inspiration and ideas in nature.

3) Creating: inventing, or putting things together in a new way.

4) Evaluating: assessing the appropriateness and viability of the design.

This process provides an access point for responsive web-design processes, as the discovery and creation phases of the process involve looking to ideas and inspiration in the natural world as something to emulate in the creative phase of design. A large part of biomimicry includes the foundational idea provided by Schmitt—looking to an analogous system of nature for design.

Biomimicry as a methodology is built on a foundation of forming metaphors. For both biomimetic metaphors and user-interface metaphors, common ground is shared by using a metaphorical approach. Especially within the field of user-interface design, and more
specifically responsive design, metaphors are commonly used by designers to create recognizable conventions such as ‘shopping carts’ when paying online, or ‘drawers’ when designing a navigation menu for the user to open. Further, metaphor is a continually expanding field of research with a rich history. At its core, a metaphor helps to map an unfamiliar domain in terms of a familiar domain. George Lakoff and Mark Johnson published *Metaphors We Live By* in 1980, and their theory of metaphor has heavily influenced how designers, especially within the field of Human Computer Interaction (HCI) view metaphor (Blackwell, 2006, p. 499). They provide the idea that there is a “source” and a “target” (although these are as Alan Blackwell calls them, “philosophically inexact”).

The overarching—albeit overly simplified—theory is that metaphor helps us to map one domain in terms of another. Regardless of the amount of literature published on the subject, metaphor is extremely difficult to pin down and define, as its root is philosophical in nature. Even within the field of HCI, it has a “troubled history”, and is continually debated even today.

Alan Blackwell discusses metaphor’s emergence in his article “The Reification of Metaphor as a Design Tool” (2006). Perhaps one of the best examples, and one that Blackwell traces throughout his article, is Apple’s Desktop metaphor. The underlying historical aspect of note is that ‘the desktop’ as a metaphor was not intentional at first. In fact, Apple’s ‘desktop’ metaphor for the Lisa computer in 1983 was quite counter-intuitive at the time—users found it “extremely confusing.” Instead, metaphor gradually emerged as a seemingly successful construct over a long period of time:

...the desktop metaphor was not directly motivated by any coherent theoretical stance regarding metaphor, but was chiefly a product of technical evolution and historical contingency. (Blackwell, 498)

Although this metaphor was initially a failure, through the use of and familiarization with
this metaphor by user-interface designers and their audiences throughout the last 30 years, it has become a mainstream technique by which to make complex computational systems more accessible. Often drawing on cultural symbols which are highly familiar to users, metaphors have the ability to make systems feel familiar.

At the same time, metaphors can often limit the potential of a system, as well as its understanding by users, as Donald Norman discusses at length in *The Design of Everyday Things*. Indeed, the design of metaphors themselves can be considered as a complex process in practice. The process for designing metaphors can be seen as parallel to the process of biomimicry, in that alternative references—whether visual, conceptual, linguistic, or haptic—are explored in order to inform the design of something in an analogically parallel way.

In the article “Metaphor and User Interfaces” (1998), Aaron Marcus also holds the notion outlined above that metaphors aid in understanding by connecting two separate domains: “Metaphors are mappings from one domain to another. The designer first must identify targets, i.e., those objects, structures, or processes, that seem confusing, unrelated, or inappropriate.” Within user interface design, he describes the metaphor design process which exists as both linear and iterative:

1) Identify items among the data or the functions of the interface which should be targets for metaphors.

2) Identity multiple sources of metaphorical reference.

3) Generate as many metaphors as possible for the data and functions necessary.

4) Identify and evaluate matches and mismatches within the metaphors generated.

5) Revise metaphors to strengthen effective matches and reduce harmful or confusing mismatches.

This iterative metaphorical approach is shared by biomimetic practice, but is slightly altered.
In “Biologically Inspired Design: Processes and Products” (2009), the authors sought to conduct a study which would provide insight into biomimicry “as a type of design activity.” Through observation, they outline a process which resembles the formation of a metaphorical approach:

1) Problem definition
2) Reframing the problem, or “biologizing^2 the problem”
3) Searching for biological Solution
4) Defining the biological solution
5) Principle extraction
6) Principle application

In a sense, the two processes outlined above are nearly identical. The primary difference between biomimicry and the traditional use of metaphor lies in where a source is explored. In the case of biomimicry, the specific focus of the discovery phase lies in looking to natural sources of inspiration, rather than cultural metaphors. Because metaphor is already practiced heavily within the design of user-interfaces, the similarities between these processes provide further support for integrating biomimicry into responsive web design.

^2 To “biologize” a design problem is to reframe a problem in biological terms (The Biomimicry Institute). The authors here provide an example of a biologizing a design problem of damage caused by a bullet: “instead of ‘stopping a bullet,’ the biologized version of this function was ‘What characteristics do organisms have that enable them to prevent, withstand and heal damage?’” (Helms et al. 2009)
Novelty as an Outcome of Biomimicry

One of the the most notable outcomes which has been published in various ways is increased novelty among studies which incorporate biological analogies in the design process. In cognitive study on engineering design in 2009, the authors of “The effects of biological examples in idea generation” suggest the ways that “exposure to biological examples in idea generation can increase the novelty of design ideas generated after exposure without inhibiting the variety of the design ideas generated, unlike human-engineered examples which resulted in decreased variety” (Wilson et al., 2009). In another similar study from 2006, “Using descriptions of biological phenomena for idea generation,” the authors suggest that a focus on very specific aspects of nature as analogy can provide novelty for a detail of design, while “generalness” can also be useful for concept generation (Mak & Shu, 2008). In a third study from 2016 measuring the effect of AskNature.org, “Enhancing novelty with knowledge-based support for Biologically-Inspired Design,” the authors argue that the functional classes organized on AskNature.org are highly likely to lead to “out-of-the-box” solutions during an ideation stage (Vandevenne, Peters, & Duflou, 2016). Especially within the context of this thesis, these research studies suggest the potential for biomimicry to inform new approaches to responsive design.

Thus, the processes and outcomes of biomimicry provide clear considerations for approaching responsive web design in a new way, both within process and outcome. The next section discusses three examples of the use of natural metaphors in visual communications, in order to look to specific instances of these processes and outcomes as support for the primary research conducted in this thesis.
Bruno Munari, an Italian designer, artist, industrial designer, and inventor, was a pioneer who often referenced natural systems as inspiration for design and process. Munari offers no particular process of his own, but insists on direct observation of nature—as it relates to craft, process, materials, and form itself. The concept that “form follows function” is highly regarded within the practice of design. In *Design as Art* (Munari, 1966), Munari discusses the ways in which this principle itself has its origin in nature:

...we have formal coherence, rather as we see it in nature. A leaf has the form it has because it belongs to a certain tree and fulfills a certain function; its structure is determined by the veins which carry the sap, and the skeleton that supports it might have been worked out by mathematics. Even so, there are many kinds of leaf, and the leaves of any single tree differ slightly among themselves. But if we saw a fig-leaf on a weeping-willow we would have the feeling that all was not well. It would lack coherence. A leaf is beautiful not because it is stylish but because it is natural, created in its exact form by its exact function. A designer tries to make an object as naturally as a tree puts forth a leaf. He does not smother his object with his own personal taste but tries to be objective. He helps the object, if I may so put it, to make itself by its own proper means... (Munari, 1966, pp. 30–31)

Munari introduces two important concepts. First, that the simple act of designing form to convey function has always been at the heart of design—and that this concept arises from nature itself. Looking to a leaf provides an analogy for designers to follow. In some ways, we do this instinctively as we become more proficient in our design process. Second, Munari talks about “making an object as naturally as a tree puts forth a leaf...” In a sense, he’s talking about medium—we use forms that feel natural in a particular context to
reveal function.

Continuing this discussion on research practices in design, Munari (1966) opens the question of where designers ought to look for inspiration, and how they can go about doing so. He turns especially to the evolution of form in nature, such as in plants, minerals, or other structures, and notes that form is always dictated by external forces. He notes that in theory, all leaves should be the same, as they have the same function. Yet each leaf grows within a set of conditions—it is not outside of its own ecosystem’s variations. All natural forms continually undergo transformation in some form or another. This is especially noted by Peter Pearce in Structure in Nature is a Strategy for Design, as he discusses internal and external forces which dictate forms in nature. In fact, Pearce’s ideas stem from a deeper mathematical and biological text by D’Arcy Wentworth Thompson, *On Growth and Form*, first published in 1917. Munari understands this on a deeper level, stating that the designer ought to study not only the form itself, but the evolution of a form over time.

For Munari, looking to nature as inspiration for design is more than simple observation, but more of an understanding of a form or a system. He notes a distinct difference between copying and emulating:

‘Copying nature’ is one thing and understanding nature is another. Copying nature can be simply a form of manual dexterity that does not help us to understand, for it shows us things as we are accustomed to seeing them. But studying the structures of nature, observing the evolution of forms, can give everyone a better understanding of the world we live in. (Munari, 1966, p. 158)

Although Munari was writing in 1966, his definition of emulating nature closely resembles a definition for biomimicry, which will be discussed in the next section.

Moving from aesthetics and functions in industrial design into visualization design, this approach of looking to nature can also be used to form new frameworks and structures
for the visualization of complex data sets. In the paper “Aesthetics and Inspiration for Visualization Design: Bridging the Gap between Art and Science” (2004), Greg Judelman presents a diverse range of projects and examples which can be considered as new visualization metaphors, arguing that many organic systems such as trees, rivers, flowers, mountains, or stars can provide a new way to think about visualizing data, stating that “The most complex, dynamic, and adaptive system, of course, is nature herself, and many ideas can be drawn from the ecological principles and visual characteristics of nature.” Judelman points out principles of nature developed by Benyus (1997), citing rules such as “gathering and using energy efficiently, running on information, and using materials sparingly,” among others. Many of these principles run in parallel with the way the web is described as a “grain” by both Chimero and Allsopp, as discussed in the last section. For the web, light code optimizes display time, flexible materials like flat color or SVG’s mold and adapt to various viewport sizes, and shape can be used to determine functionality.

The discovery of underlying properties can provide clearer insight into how design for digital mediums might be expanded upon. In a thesis titled “Organic Information Design” (2000), Ben Fry discusses the ways that information design can use simulated organic properties found in nature to handle large amounts of dynamic, complex, quantitative data. He argues that methods used to visualize static information ultimately fail when dynamic information is considered. To address this problem, Fry presents the idea of studying and analyzing decentralized and adaptive systems, particularly the traits of simple organisms. He outlines nine properties of biological systems—structure, appearance, metabolism, growth, homeostasis, responsiveness, adaptation, movement, and reproduction—and the ways in which each can influence new ways of visualizing dynamic data.

Thus, through the use of metaphor, natural systems have the potential to be explored
and more deeply understood as a process for inspiration, and have the potential to provide a new way of thinking about visual communication design. The consideration of biomimicry and metaphor, both as processes, leaves the question open of how the two might come together within user interface design, and more specifically, responsive web design.

**Natural Metaphors in User-Interface Design**

In the thesis “The Role of Metaphor in Interaction Design” (2005), Dan Saffer lays out a short history and context of metaphor. He notes that in a broad sense, metaphor in the design process can be used as a research tool to explore relevant subject matter, as inspiration or juxtaposition to trigger new ways of thinking about solution to a design problem, or as a communication device—to convey concepts to stakeholders, for example. He also discusses how metaphors can also take several forms in design, whether a conceptual framework, defining spaces and structures, orienting users (i.e. a digital “shopping cart” in an online “store”), operations, or even personification. Saffer cites two examples of metaphor which are used as conceptual frameworks, both of which reference natural phenomena. Each provides a brief case study of how natural metaphors might be used to inspire new modes of thinking about interface design.

“Ryukyu **alive**” (2004), a project by Akira Wakita and Fumio Matsumoto, creates an information visualization system that uses the metaphor of an information space or galaxy to organize the Okinawa Digital Archives. Icons for projects, which provide access to a web page, were reimagined as stars. The metaphor also includes the flow of time, with stars flowing towards the center of the galaxy, and uses the concepts of gravity and anti-gravity to display which pages have been visited by users.
Additionally, the metaphor includes other functions such as a constellation view, to show or hide the contents of a specific category within the galactic archive. By the use of the galaxy metaphor, the interface becomes interactive and engaging in new ways, and the large scale metaphor of the galaxy lends itself to sub-metaphors that fall within that galaxy, providing a new domain—or a new context—for users to experience the content within.

In a second project titled “Artifacts of the Presence Area” (2003) created by the MIT Media Lab in 2003, an interface uses the metaphor data is geology. As part of a digital installation at the Boston Institute of Contemporary Art, the piece captures video and audio, and compiles the data into an interactive visualization which uses a geological metaphor.
As data is recorded, layers of audio and video, or “sediment,” build up vertically over time, forming an archive resembling a cross-cut of a mountain. In describing the metaphor, the authors describe the ways in which a metaphor allowed for a new interpretation of the collected data:

In trying to convey a sense of historical buildup over time, it made sense to look at natural examples of accretion for inspiration. The geological layers in sedimentary rocks and their function as record keepers provided us with such an example. The accumulation of geological layers over time transforms temporal change into legible and appealing visual patterns that can, with care and attention, be interpreted as history. (Viégas et al., 2003)
Additionally, rather than allowing users to browse the media in a conventional way, the installation allows them to instead become archeologists “excavating” the layers of rock.

Both of the user-interface metaphors above utilize a naturalistic metaphor in order to map one domain—in these cases, some form of data or archive—to another, namely, an interactive system for parsing and understanding complex data and content. In addition, each is highly visual. The interfaces rely on a visual image of each system, whether sedimentary strata or a galaxy, and then mimic that image. But metaphors can also extend further as a conceptual method of application. One approach already developed in the field of responsive design takes a more systematic approach, by looking to chemistry as inspiration. This method is notably called “Atomic Web Design” (Frost, 2016). This methodology developed by Brad Frost breaks web elements—such as form fields, buttons, textual headlines, or colors—down to their fundamental components. The primary goal of atomic design is to design systems of elements which work cohesively, rather than “pages.” Individual elements are able to occupy a library of separate component parts for an entire website. These pieces can then be reassembled into larger and larger pieces in a modular fashion—building from atoms, to molecules, to organisms.

This idea resembles Chimero’s approach discussed earlier. In reference to David Hockney’s photographic approach to combining multiple photos together, Chimero presents us with a picture of an edgeless browser space, where the assembly of small, variable components into larger pieces can better fit to the grain of the web. Both Chimero and Allsopp touch on the idea that the web has certain properties—that the web is not a completely open book, and that in the same way a piece of wood has a grain and ought to be sanded or sawn in a particular fashion, so too does the web ‘grain’ to be worked with. The web is contained in a fluid viewport, simple CSS, shapes and color work because they’re easy to transform, break down, and flex, and it has a vertical and horizontal bias. The web is an
infinite space within which to work, and designers should accept its ebb and flow. Chimero describes the web as “an edgeless surface of unknown proportions comprised of small, individual, and variable elements from multiple vantages assembled into a readable whole that documents a moment.”

This modular approach to design is also highly biomimetic. Even within the field of architecture, Peter Pearce, in *Structure in Nature as a Strategy for Design* (1978), expounds upon the ways in which structures in nature are built out of small component parts, affected by both internal and external forces of nature. Consider a beehive as an example, which contains perhaps thousands of hexagons built into an entire nest. Pearce argues that architecture can build on this notion, and coined the approach of *minimum inventory, maximum diversity*. In other words, what is the smallest number of forms or structures which will, when assembled together in various ways, give rise to the most diverse number of constructed forms? In light of the Atomic Design methodology for responsive web design, the same question might be asked.

Throughout this chapter, nature has been discussed as a reference for design inspiration, whether formal or conceptual. The primary research in this thesis builds on this notion, arguing that natural metaphors can act as a catalyst for considering responsive web design and the medium of the web in an alternative way to the standardized approaches set forth in the first chapter. To better understand the ways in which biomimicry might influence responsive design in new ways, critical making was used to juxtapose biological principles and the medium of the web, in addition to creating prototypes which explore various naturalistic metaphors.
Chapter 4: Critical Making Experiments

If it is sometimes difficult to accept the artistic aspirations of the interface medium, its lack of an intelligible subculture may be at least partly to blame [...] On the Web, the latest visual metaphors can find their way into circulation for a tiny fraction of the cost, which means that more experimental forms—forms more interested in pushing the envelope than pleasing the masses—will naturally prosper in this environment.

—Steven Johnson

Throughout the previous chapters of secondary research, the underlying concept of responsive design as an approach to the medium of the web, and natural metaphors as an alternative mode of thinking have been discussed. This chapter explores the ways in which a biomimetic process can be used to intentionally explore natural systems as metaphors for responsive design prototypes. Critical making is introduced as a method to explore theory through the physical making of prototypes. In addition, the idea of exploring the web as a more responsive medium, and the exploration of this is discussed.

Research Environment

Critical Making

This thesis utilizes the process of critical making as a form-driven approach to responsive web design, primarily for the exploration of naturalistic metaphors. Critical
Making, a term originally used by Andrew Blauvelt, is an approach uniquely situated between being ‘critical’—analysis, evaluation, examination, or shifts in perspective—and ‘making’—the creative process engaged in materialization and production (Barness & Papaelias, 2015). Matt Ratto further developed the approach in “Critical Making: Conceptual and Material Studies in Technology and Social Life” (2011), defining it as a bridge between physical and conceptual modes of exploration. Ratto provides a clear purpose statement for critical making:

The use of the term critical making to describe our work signals a desire to theoretically and pragmatically connect two modes of engagement with the world that are often held separate—critical thinking, typically understood as conceptually and linguistically based, and physical “making,” goal-based material work.

(Ratto, 2011)

Ratto discusses the three main aspects of critical making: 1) reviewing relevant literature, concepts, and theories; 2) designing and building technical prototypes as a means of exploring those concepts and theories; 3) the iterative process of reconfiguration, conversation, and reflection. Thus, critical making acts as a practice-based engagement with pragmatic and theoretical issues.

Within the context of this thesis, critical making is highly valuable, in that it introduces a way of approaching theory through practice and process. Two aspects of critical making relevant to the primary research conducted in this thesis are noted by Barness and Papaelias:

It provides a means to understand and question the relationships between research, scholarship, and production. It also places emphasis on the making process itself; the findings that occur within this become the crux of the endeavor and may produce as
much knowledge as the polished, finished product. These activities are centered on human experience and continually fluctuate in ways that are practical and theoretical, rhetorical and physical.

Because critical making allows for a strong focus on making itself, it is well suited as an approach to explore biomimetic metaphors within responsive web design, while incorporating a form-driven approach, discussed further in this section. To clarify goals and strategy, a deliberate focus was placed on designerly ways of understanding, based on Nigel Cross’s *Designerly Ways of Knowing* (2007). Cross postulates that design operates within its own domain, as equal to but different from both the humanities and the sciences. In interviewing expert designers, Cross lays out characteristics of design, such as the idea that it is exploratory, emergent, opportunistic, and reflective. He states:

...design is not a search for the optimum solution to the given problem, but that design is exploratory. The creative designer interprets the design brief not as a specification for a solution, but as a kind of partial map of unknown territory (as suggested by Jones, 1970), and the designer sets off to explore, to discover something new, rather than return with yet another example of the already familiar.

(Cross, 2007, p. 52)

It is in this spirit that critical making is engaged as primary research within this thesis. Because medium, metaphor, and biomimicry have not been used intentionally within responsive design, one primary goal of this thesis is to map out a new territory—to explore in a new way what Steven Johnson discusses as the “mainstream versus the avant-garde.” Johnson points out the ways in which interface subcultures can work in opposition to what is considered mainstream:

If it is sometimes difficult to accept the artistic aspirations of the interface medium, its
lack of an intelligible subculture may be at least partly to blame [...] On the Web, the latest visual metaphors can find their way into circulation for a tiny fraction of the cost, which means that more experimental forms—forms more interested in pushing the envelope than pleasing the masses—will naturally prosper in this environment. (Johnson, 1997, pp. 216–226)

Within the context of this thesis, critical making is primarily engaged around the design of forms for responsive web design. As discussed in the first chapter, the browser can be viewed as a living medium: it is flexible, living, and adaptive. Although responsive design was primarily developed to be user-centered and pattern-driven as previously noted, this has caused a standardization of formal approaches, leaving open the opportunity for alternative approaches within the field. Thus, there is room to expand and enhance these responsive design approaches—particularly through the incorporation of biomimicry.

A Form-Driven Approach

In the paper “Digital Form and Materiality: Propositions for a New Approach to Interaction Design Research” (2012) by Heekyoung Jung and Erik Stolterman, the authors propose a form-driven approach to interaction design that is meant to invigorate current user-centered design approaches. They argue that aesthetics are often considered late within the process, and could be considered as more integral. They note how in traditional design disciplines, “…form has been an essential part of a designed artifact, directly representing its functionality, affordance of interaction, and symbolic values. Moreover, as an affective and visceral quality from an emotional standpoint, form can evoke different user responses regardless of efficiency or ease of use.” The authors discuss various perspectives of form, noting how each can be explored to determine new functionality or affordances when used
as an intentional exploratory process. Rather than the primary use of analytical user-centered methods in designing a responsive interface, perhaps designers face an opportunity for incorporating more of a designerly approach to making and exploring which considers an “understanding of material, making, and meaning of form.” They set forth a framework which considers three aspects:

*Form as experiment.* A form-driven approach which deliberately considers various physical materials, shapes, or making strategies.

*Form as intention.* Rather than a byproduct of a function, form can be considered as a means of “underscoring purposeful design intention.” In other words, perhaps form does not always need to follow function, and instead can be used to inspire new affordances, or satisfy deeper unseen human desires.

*Form as Medium.* A form-driven approach recognizes that the designers role in making is continually changing. New design tools and digital mediums “actively contribute to ongoing exploration of functional and aesthetic potential of new computational technology.”

This framework not only provides a new perspective within responsive web design which opens the idea of the web as a medium into a broader scope, but also has implications for design process and making. Throughout the design process during this primary research stage, these three aspects were reflected upon and integrated directly into the process of making and reflection.

First, form is explicitly explored above user-needs within the primary research completed. While user-needs and functional requirements are stated in each of the three prototypes, it is not discussed thoroughly, as a means of focusing on the experimentation with form.
Second, design methodologies for responsive design ought to consider an intentionally form-driven design perspective. Rather than beginning with more analytical user-centered approaches and ending at responsive design technologies, an opportunity exists to experiment with the possibilities of form within a web-based environment. How might experimentation with shape, making strategies, or materials enlighten responsive design approaches? One distinct consideration set forth by the authors is the exploration of metaphor:

...metaphor can be one strategy to couple shape and meaning, including specific approaches such as biomimicry, a strategy that mimics the body structures of living creatures or the mechanisms of their ecosystems... (Jung & Stolterman, 2012)

Especially within the context of this thesis, what biological forms might inspire new functionalities, affordances, or kinetics? What material properties do these forms exhibit which are valuable to the design of the interface? What types of strategies for design can be explored to fully integrate and understand metaphor?

Third, we can further consider the role of medium within responsive web design. Rather than stopping at the functional possibilities for form of the responsive technologies provided, we instead move towards the exploration of the aesthetic potentials and formal possibilities of the web as a medium. Not only does the use of biomimicry as a metaphor act as a catalyst for new formal exploration—it can also provide a new way to approach responsive web design. In what ways might the incorporation of naturalistic metaphors draw us to a new understanding of the medium of the web, if at all?

Thus, the following critical making experiments act as a primary research method to explore a new territory for biomimicry in responsive design—particularly through the use of a form-driven approach as outlined by Jung and Stolterman. Each experiment follows a structure based on Ratto’s model of investigating the theory set forth up to this point: 1) the
process of making and 2) critical reflection. To explore the notion of biomimicry in responsive web design, three prototypes were created, centered around the concepts of an archive, the forming of a set of organic properties, a news feed, and a blog.

**June 44: A Tidal Archive**

**Process and Making**

As an initial exploration, a tidal archive was created to explore nature as metaphor within responsive web design. To better understand the ways in which this might be done, the process of biomimicry was examined and used to create a process for forming metaphors. The process for biomimicry includes scoping, discovering, creating, and evaluating. Often, an undefined and circular organic approach can be used to move between various stages of this process.

**FIGURE 7. TIDAL ARCHIVE: BIOMIMICRY PROCESS (BAUMEISTER 2013).**
Scope. The goal of this project at the start was to structure the information as an archive that users could access. Many directions for content were explored initially, including various sets of data having to do with earth sciences, such as geology and climate. For this experiment, oceanic tidal height data at Fells Point in Baltimore, Maryland was collected. The data set was gathered from each year on June 1, ranging from 1970–2015, then visualized using RAW—a data visualization tool—in order to aid in an initial understanding of the natural process of tidal ebb and flood currents, in addition to the formal qualities of the visualization and of the process as it occurs in nature. The visualizations were then turned into content for a digital archive, which was designed by using the metaphor of archive as tidal flood and ebb current, using biomimicry as a process for emulation.

Discovery. To incorporate a natural metaphor to house this archival content, many natural metaphors were examined. The initial challenge was set forth to “biologize” the question. What forms, processes, or ecosystems in nature have the ability to preserve information? Many options were brainstormed through the use of mind-mapping, resulting in potential forms such as tree rings, geologic formations, and shell structures. One issue encountered is that the range of natural examples which exist for emulation reaches from subatomic to galactic (consider the Eames’s “Powers of Ten” film (1977)). This can provide difficulty for designers in terms of scope and range while considering analogies. Ultimately, the metaphor of the ebbing and flowing of the tides themselves were used as a means of showing change and acting as containers for compartmentalized sets of tidal data, as it acted as a direct reference with rich formal qualities.
Creating. A prototype was then created to reflect the forms created by the tides themselves as a metaphor for containing five year increments of tidal data. HTML, CSS, and Javascript were used to explore formal aspects of the design first and foremost, and best practices were used to explore iterations as the prototype was built. Scalable Vector Graphics (SVGs) were used because they are a flexible vector format and can scale infinitely within a web context. They also have the ability to be turned to simple, lightweight XML code (W3Schools). In a sense, this satisfies both
the flexibility of the web in addition to the principle of optimization in nature. Evaluation is discussed in the following reflection.

**FIGURE 10. TIDAL ARCHIVE: MODULAR DEVELOPMENT**

**FIGURE 11. TIDAL ARCHIVE: FINAL PROTOTYPE**
Reflection

This experiment suggests three takeaways. First, a particular opportunity for building on responsive web design lies within the ‘discovery’ phase of biomimicry. In order to incorporate natural metaphors, an acting catalyst for interaction design is the established metaphorical approach within user-interface design. The prototype draws on the metaphor ARCHIVE IS TIDAL CHANGE, but also uses quantitative values dictated by nature—in this instance tide heights—to create form, structure, and motion. The prototype engaged a naturalistic metaphor, and was intentionally built in a modular fashion, resembling Peter Pearce’s notion of minimum inventory, maximum diversity.

Second, it was noted that better understanding materiality and medium of the web is critical to using natural metaphors within digital design and development. In order to enact natural metaphors within a web interface, the designer must try to understand the material of the web, and to integrate the metaphor in a way that spans not only form, but also its underlying principle. For example, as SVGs were tested within the browser, careful attention was paid to their flexibility and their ability to retain an “organic” form. Not only do natural metaphors lend themselves to new structures and affordances, but they can also be used to dictate a new set of principles as a framework. Further, how might organic forms from nature be emulated using the properties and materiality of the web in the most efficient and natural way? The particular aspects engaged in this prototype involve Jung and Stolterman’s form-driven approach—shape as denoting the appearance of both functionality and materiality. Through the coupling of shape and meaning, one can engage in a sort of formal visual speculative inquiry: “The notion of design by affordance, metaphor, and embodiment can inspire the exploration of new forms and inform the critique of an artifact’s qualities” (Jung & Stolterman, 2012). In the same way, this prototype also explored the creation of “new forms or functions of digital artifacts by considering materiality at every
“phase of the design.” Throughout the design process, reflection upon the material qualities and affordances created by the waves were done within the consideration of the medium of the web.

Thirdly, this prototype revealed that further opportunity exists to use values from natural data to dictate form, structure, motion, color, and other digital interactions—in the sense that natural forms might visualize data and create new affordances at the same time. Additionally, the opportunity remained open to look at ways in which the web as a medium might relate specifically to biological properties as a whole. This is discussed in the next section.

**Forming a Set of Organic Principles**

Not only do natural metaphors lend themselves to new structures and affordances, but they can also be used to form a new set of properties as a framework for making. To better understand the medium of the web and and nature’s influence on it, an additional investigation was conducted to compare sets of biological principles and the web’s properties. Using a similar approach to Fry discussed in the previous chapter, multiple biological patterns were surveyed from various authors and texts. Comparisons were then drawn between various aspects of responsive design and the nature of the web. To begin, multiple sets of principles from various authors were cross referenced:

1) “Nature’s Unifying Patterns” (The Biomimicry Institute, 2017)


3) “Properties of Life” from *Biology* (Raven et al., 2017)


6) “The Sixteen Patterns of Biology” from *Exploring the Way Life Works* (Hoagland, Dodson, & Hauck, 2001)
Similarities were identified, then reorganized and reappropriated for the purposes of this thesis. The principles identified in each of the above sets were then “averaged out” and condensed. These helped to form a well-rounded set of nature’s principles for the purposes of this thesis work:

1) Nature optimizes its processes through the use of cyclical processes.
2) Nature is modular, and builds from the bottom-up by utilizing minimum-inventory, maximum-diversity to build complexity.
3) Nature is resilient to disturbances, and repairs itself for survival.
4) Nature gathers information from local stimuli to continually respond and adapt to its environment; it continually adjusts to both internal and external conditions.
5) Nature is reproductive.
6) Nature competes within a cooperative framework.
7) Nature uses shape and form to suit function.

These principles were then compared and contrasted with various aspects of responsive design strategies, as well as the consideration of the web as a medium. Many of the properties and considerations within responsive web design align with the above, and were gathered from “The Web’s Grain” (2015) by Frank Chimero and “A Dao of Web Design by John Allsopp” (2000), building on their conceptual approaches to the web discussed in chapter two:

1) Small, individual, variable elements
2) Assembled
3) Flexible and adaptive grids, images, typography, and other media
4) Deconstruction of designs into systems and pattern libraries

5) Edgelessness, both horizontally and vertically

6) Flexibility of the viewport or browser

7) Favors lightweight code for efficiency of use

---

**Organic Patterns & Properties in Nature, Properties of the Web**

<table>
<thead>
<tr>
<th>Nature's Principles</th>
<th>Definitions</th>
<th>Properties of the Web</th>
<th>Organic Principles for Web Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>energy, recycling, optimization, cyclic</td>
<td>nature optimizes its processes through the use of cyclical processes</td>
<td>small, individual, variable elements</td>
<td>minimum inventory, maximum diversity</td>
</tr>
<tr>
<td>minimum inventory/maximum diversity, modularity, build, grow, variation, complexity</td>
<td>nature is modular, building from the bottom-up by utilizing extensive inventory, maximum diversity and complexity</td>
<td>small, individual, variable elements</td>
<td>adaptable to the medium</td>
</tr>
<tr>
<td>reproduction</td>
<td>nature is reproductive</td>
<td>flexible grid, images, media queries; document action for responsive systems libraries; edgelessness in both horizontal and vertical (growth-oriented)</td>
<td></td>
</tr>
<tr>
<td>resilience, survival, repair</td>
<td>nature is resilient to disturbances, and repairs itself for survival</td>
<td>flexibility of viewport/browsing functions proportioned</td>
<td></td>
</tr>
<tr>
<td>information, response, adapt, locally attuned</td>
<td>nature gathers information from local stimuli to continually respond and adapt to its environment; it continually adjusts interchange/external conditions</td>
<td>flexibility of viewport/browsing functions proportioned</td>
<td></td>
</tr>
<tr>
<td>cooperative, supportive</td>
<td>nature operates within a cooperative framework</td>
<td>flexible grid, images, media queries; browser height/width; edgelessness can be responsive to ensemble environment</td>
<td></td>
</tr>
<tr>
<td>form to function</td>
<td>nature uses shape and form to suit function</td>
<td>flexibility of viewport/browsing functions proportioned</td>
<td>fits form to content and function</td>
</tr>
</tbody>
</table>

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**FIGURE 13. ORGANIC PRINCIPLES: PROPERTIES FOR WEB DESIGN**

Overall, this aided in forming a set of conceptual rules by which to design responsively. In a final comparison, the following organic principles for responsive web design were formed:

*Minimum inventory, maximum diversity.* Based on the notion of developed by Peter Pearce, this includes the recycling and building from the bottom up of design
systems; the assembly of small, variable, interdependent parts.

Adaptability of the design to the medium. The design of elements which can locally adapt to the browser; design elements which can adapt to both internal and external stimuli; design that is responsive to context or environment.

Fits form to content and function. Design fits the shape of interactive elements to their content and function in the most natural way.

These principles were then utilized within the context of the following critical making experiments, forming both a generative approach to thinking about the medium of the web as an organic medium in a clearer way, in addition to forming an evaluative framework for each responsive design.

News Feed as Stratum

Process

A second exploration was conducted to explore a specific application for a natural metaphor, while attempting to define a clearer biomimetic process. A news feed was chosen as a practical user-interface problem to address, which fits well within current cultural expectations and methods of obtaining dynamic information. The idea of a “feed” as a user-interface metaphor limits how we might think of news content and its design. A feed, by definition, is continually flowing—it acts as a supply of materials, goods—in this case, content. In this sense, it allows users to understand that as time passes, new content will be produced and released. It also provides a chronology of the content by defining the top of the web page as an orientational metaphor: the “top” of the feed. As noted by Marcus (1998) on
the concept of metaphor in user interface design, metaphors can provide limitations for designers and users. For Google’s news page, the feed metaphor only tells us that the content at the top is new. Additionally, the metaphor doesn’t provide a visualization of how old or new the content is, aside from providing metadata in a textual form.

![Google News Feed](image)

**FIGURE 14. NEWS FEED AS STRATUM: GOOGLE NEWS**

The design of a news feed requires design to be adaptive to two aspects: 1) the dynamic content itself, and 2) to the device and contexts of use. People can access the news at any given time, in any given place. Content is continually flowing, dynamic, and aging. Designers have an opportunity to not only consider the user and their context, but the content itself. How might naturalistic metaphors affect the design of the content with its varying properties? How can the content be represented effectively, while still adapting to various screens and devices? We might consider these considerations as *internal*: the design of the content’s form, and *external*: the design of conditions for the content to be previewed within.
In this experiment, the problem was biologized by asking what natural systems, forms, or structures store time or display a chronology. Even for a moment, to consider the layers of tree bark and their display of both spring and summer growth, in addition to their display of each year, provides a new way of thinking about the problem—both visually and conceptually.

Several frameworks and texts have already identified natural patterns and visual forms which occur in nature, one example being Nature.org. For the purposes of this thesis, James H. Mathewson’s “The Visual Core of Science” (2005) was utilized in order to provide a starting point for considering natural metaphors. These provided a leaping off point by addressing the problem of searching within an extended range of metaphors as noted in the previous section.

One visual aspect of nature provided by Mathewson is stratum. This is a horizontal extension in the form of a bed, coating, sheet, or zone. In essence, it is the forming of layers. This pattern occurs in many diverse ways: whether the stratosphere as a layer within Earth’s atmosphere, or in stratigraphy, which is “the study of the sequence of accumulated rock types (and ages).” Stratum provided a dynamic metaphor for the problem of designing news. First, it visualizes time in a new way. Rock layers and sediment compact as they grow older, forced by the weight and pressure above them. In other words, not every layer is equal—the type of sediment, the amount of time, or external forces in nature act on each layer and affect its form. Second, it provides a chronological analogy. In most cases, the youngest layers of rock settle on top, granted that fault shifting may bend layers, or volcanic substances may rise from below onto the surface of the earth, thereby creating new layers themselves.
FIGURE 15. NEWS FEED AS STRATUM: GEOLOGIC STRATA (UNIVERSITY OF ILLINOIS)

FIGURE 16. NEWS FEED AS STRATUM: WIREFRAMING
FIGURE 17. NEWS FEED AS STRATUM: ORGANIC PRINCIPLE EVALUATION

FIGURE 18. NEWS FEED AS STRATUM: FINAL PROTOTYPE
Reflection

Firstly, the use of an underlying set of principles and the incorporation of a naturalistic metaphor shapes a new way of considering modularity in web design. The idea of minimum inventory, maximum diversity is a concept noted by Pearce, and falls within optimization. In many ways, visual communication design already operates this way. Designers take the simplest communication forms—typography, color, image—and are able to recycle and recombine them in an infinite amount of ways. In this problem, there was a deliberate decision to simplify by recycling particular elements, both to optimize the design for web and to mimic nature. A “kit of parts” was constructed both in the visual design and code.

Elements in the design were used in a modular fashion in order to recycle and reapply them. Peter Pearce discusses the way that natural systems operate concerning internal and external forces—so consideration was given to the “nesting” of various elements. In a web based context, the external might be considered as the browser, device context, or ambient conditions. These would then affect the internal structures, such as nested elements in HTML/CSS and their margins, padding, or media-query breakpoints. When building from the bottom up in a modular fashion, the ways in which these elements respond to one another can be deliberately controlled.

Secondly, the principles of biomimicry provide a way of considering more deeply the medium of the browser itself, as they work coherently with it, rather than against it. In the same way a woodworker ought to work with wood in a way which suits the grain of the wood, so designers can work with the web in a way which suits grain of the web by using naturalistic metaphors. Bruno Munari puts it succinctly:

...the study of natural and spontaneous forms is of the highest importance to the
designer, whose habit is to use materials according to their nature and their technical characteristics. He does not use iron where wood would suit better, or glass when the logical thing would be plastic. (Munari, 1966, p. 114)

Similarly, Saffer points out in “The Role of Metaphor in Interaction Design,” that designers can “Use metaphor to uncover otherwise hidden aspects of the material.” This experiment demonstrates how this can occur, especially through modularity.

Thirdly, the application of Stratum as a natural metaphor to content comes with limitations, as any metaphors do. In stratigraphy, layers of geologic strata do not necessarily compact only at the bottom. Depending on the makeup of the sediment, the time in which that sediment accumulates, or other internal and external forces which affect each layer, there may be variation in thicknesses moving from top to bottom. In this prototype, three primary ideas were borrowed, and adapted to the problem of forming a new type of news feed: 1) the idea of stratum as “layers” of content, 2) the idea that geologic stratigraphy “stores time,” and 3) the notion that geologic layers compact under pressure and over a certain amount of time.

Fourthly, perhaps the most significant discovery through this critical making prototype is that the incorporation of a naturalistic metaphor helped to visualize the content in a new way. In other words, a natural metaphor not only helps to remind the designer to fit form to function, but also form to content. This new organic approach offers a new way to consider content. Inherent in the idea of identifying functions within a web context is identifying analogous functions and properties in biological systems. This experiment reveals that these properties can transfer to both the medium, context, and the content, rather than only the medium and context. For example, the idea of “time” being stored in geologic stratum offers a way to consider the content of a feed itself. In this case, articles are not all equal, but instead the forms of each article, or metaphoric layer, adapt to a specific value of
the content—in this case its relative age. The relative chronology of each article determines its size as well as its placement. In a sense, this provides both a responsive framework for adapting to the device based on the biomimetic principles incorporated, while also visualizing the content in an organic way. This making experiment demonstrates the idea that there is potential to consider new ways of designing organic systems for the web to adapt both to the device and to the content in an aesthetic way.

Blog as an Alluvial River

Process

The final critical making experiment created builds on the first two experiments, but explicitly seeks to apply a metaphor in a less conventional manner. In many ways, the stratum metaphor lead to a somewhat conventional form often seen as a standardized grid structure used in responsive design. This prototype sought to be more experimental in nature, focusing highly on medium and form over user-centeredness.

Using the fictional content of a music blog as a design challenge, multiple directions were initially pursued to explore the possibilities of many metaphors and the best application. These were again based on J.H. Mathewson’s Master Images of Science as a starting point.

1) Flow. “The transporting of matter in deformable media,” such as streams, tides, or currents.

2) Gradients. For example, the “change in the value of a variable over spatial coordinates,” or the color of the sky during sunrise or sunset.

3) Cycles. “Regular shifts between minimum and maximum values over time” such
as solar, lunar, tidal, circadian cycles.

These “master images” are general by nature, so specific examples of each were researched in order to provide more specific metaphors for use. Ultimately, from the concept of “flow,” a river metaphor, was selected to use in considering the content of a blog. The goal of this experiment was to use the metaphor to a fuller potential to influence the whole of the design, rather than any specific individual part of a river. More specifically, alluvial rivers were examined. In discovering characteristics of alluvial rivers, several key characteristics were found:

- Rivers flow towards areas of least resistance, and will always follow gravity
- An alluvial river is a classification which flows, carries, and deposits sediment downstream (alluvium, referring to loose sediment)
- Types of alluvial rivers include straight, meandering, braided, and anastomosing

These characteristics provided a point at which to compare the metaphor to the functionality of a fictional music blog:

<table>
<thead>
<tr>
<th>BLOG FUNCTIONS &amp; NEEDS</th>
<th>RIVER METAPHOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Display a constant flow of new multimedia content (writing, video, audio, etc)</td>
<td>Loose sediment settles on the inside of river banks, where there is less pressure/force</td>
</tr>
<tr>
<td>Lock/anchor specific topics which are featured</td>
<td>Heavy sediments settle at the bottom of the river</td>
</tr>
<tr>
<td>Distinguish between various topics of content</td>
<td>High flow leads to erosion, low flow leads to settling sediment</td>
</tr>
<tr>
<td></td>
<td>Rivers follow a path of least resistance</td>
</tr>
<tr>
<td></td>
<td>Adjust and change shape over time</td>
</tr>
<tr>
<td></td>
<td>Follow gravitational pull</td>
</tr>
<tr>
<td></td>
<td>Straight, Meandering, Braided, or Anastomosing</td>
</tr>
<tr>
<td></td>
<td>Classifications form “channels” as they flow</td>
</tr>
</tbody>
</table>
This juxtaposition and the use of the initial metaphor provided a group of metaphors by which to use in a responsive design: BLOG IS AN ALLUVIAL RIVER; CONTENT IS SEDIMENT; TOPICS ARE RIVER CHANNELS; VIEWPORT IS RIVER DEPTH.

This group of metaphors helped by providing a new vocabulary by which to design responsively. Sketching was then used throughout the process both to visualize natural river patterns, and to relate this back to web-based blog content. This process of sketching aided in making the metaphor visual, and assigning functions and values to the metaphor’s usage.

The prototype was developed using HTML, CSS, and Javascript. Parallax was used as an open-source framework to create the visual and kinetic motion of the flow of a river.
Specifically, the CSS translate property (z) was used to add depth and scaling to background elements, which creates the illusion of depth and flow speed. Two “layers” were designed and coded in order to separate old content from new content, and older layers “sink” to the bottom of the river as they accumulate time. Because the two layers of sediment operate independently of one another, a media query was added for mobile devices to bring them to the same layer below 700px, so that the float property would fit the content to the device—this was a relatively simple way to make the website traditionally “responsive” to the device—although the metaphor itself, being modular in nature, aided in the simplicity of the code.

**FIGURE 20. ALLUVIAL BLOG: CONTENT IS A LIQUID**
The first prototype obscured content in a subversive manner, hiding text and layering content. In a sense, this refers to Johnson’s discussion on avant-garde, artistic approaches to design. Initially, it is easy to criticize the prototype for its lack of usability—at the same time, it challenges ideas about what formal qualities are acceptable within a web based environment. The form of the blog follows the metaphor of flow, as each piece of content itself acts as sediment, yet the content isn’t visualized in any specific or deliberate way as in the first two prototypes. Other methods were explored to reveal typography and content in dynamic ways to users, (keeping with the metaphor of flowing water) in the same way that reflections on flowing water can change one’s visual perception of the rocks, stones, or sediment underneath. In exploring the concept of water more closely, an opportunity emerged to consider content as a substance itself. Substances are able blend and merge in various ways, opening up possible interpretations about how the content might be related, such as through color, shape, viscosity, size, or motion. Thus, many techniques were
explored in HTML, CSS, and Javascript to form the illusion of content as a viscous substance.

**Reflection**

First, it was found that natural metaphors transfer modular properties from nature to responsive web design. The metaphors themselves being from nature—modular, dynamic, and adaptable—provided a flexible framework for design. In other words, those qualities which make nature responsive are transferred, in a sense, to the web and make the design responsive.

Second, it was found that natural metaphors work well with dynamic, changing content—nature itself is never fixed. Samuel Moon, in a poem titled “The Shape of Space” (1965), offers an artistic sensibility to the constant motion of nature, stating that “nothing in space and time is still.” In the same way, the content of the blog will continually change. Yet an Alluvial River as a metaphor provides a system which is designed to grow and adapt through time: whether into more channels, more sediment, or more depth—just as a river is able to change its shape and path as time goes on. This idea of modularity is discussed at length in Marcotte’s book *Responsive Design: Principles and Patterns* (2015). He notes that use of modular patterns make it possible to consider a multitude of devices, in addition to aiding the design process: individual components can be combined and recombined in many ways for many purposes—thus continually growing and changing.

Lastly, using natural metaphors provided a shift in language when approaching this responsive design problem. Marcotte describes how at its base, responsive design is a series of strategies for approaching web design in a flexible manner. Yet he discusses the need for new frameworks and approaches for using responsive design effectively:

Over the past few years, we’ve been learning how to adapt our layouts to the infinite
canvas of the web. Our sites can be viewed on any size screen, at any time, and responsive design is one approach that lets us accommodate the web’s variable shape. But with all of the challenges we’re facing and those yet to come, we need to begin building not just patterns, but principles for responsive design—principles that will allow us to focus not just on layout, but on the quality of our work. (Marcotte, 2015)

In other words, beginning with a set of principles for a grid is only an abstract starting point devoid of concept or meaning. The grid is underlying responsive design as a starting point. With these experiments, it was attempted to move towards a way of approaching responsive design in a new manner—moving away from language which only revolves around grids and layout, and instead moves into a more conceptual and metaphoric approach—building on the approaches already developed within responsive design. In this prototype, an Alluvial River provided a rich set of metaphors to inform design while also providing a responsive framework.
Chapter 5: Evaluative Questionnaire

Evaluation Process

In A Designer’s Research Manual, (2009) the authors describe the ways in which summative research can be conducted in order to better understand outcomes of an investigative process. For this thesis, a questionnaire was designed to qualitatively engage professional responses and attitudes towards the potential of the critical making prototypes described in the previous chapter. Steve Mulder, in The User Is Always Right: A Practical Guide to Creating and Using Personas for the Web (2007), describes how user interviews can be incorporated into the design process to validate insights gained. Especially within the context of this thesis, understanding goals and attitudes, or “what people said,” was used as a summative research method to gain insights into the success of the process and prototypes created.

Questions were written to be intentionally open-ended, and a short demonstration video was produced to explain the process of making the prototypes and their use in motion. Overall, six participants responded to an email for taking the questionnaire. Participants had a broad range of experience levels, from 1–15 years of experience in their respective fields, and their ages also ranged widely, from 18–40 years. The professional positions held included two UI/UX designers, one “graphic designer,” one “designer,” one assistant professor, and one Director of UX Instruction.

Insights and Findings

Three primary insights gained aided in validating findings gained throughout the critical making process, while others critiqued the process. These are described in the
Following sections.

Firstly, many participants hadn’t used natural inspiration deliberately, except perhaps on a surface level, such as describing motion, color palettes, or textures. They were mostly aware of metaphor in design, however. For example, one participant noted: “I guess in a metaphorical and visual way I have used nature as a design metaphor but never put a name to it.” Another participant stated “I can’t say that I’ve ever deliberately used it. Perhaps a bit in conceptualizing a design direction, but not in actual design/implementation.”

Secondly, several participants responded that the process of biomimicry in responsive design would not be fit for every project, and that its use should depend upon the specific user needs and goals of the project. Two participants noted that metaphors might be too laborious to create in a professional practice. The first participant noted: “While I have used the basic frameworks mentioned prior, I have stopped using them in place of my own custom patterns. While these can be more unique, they are also time consuming to create, especially within a set budget.” The second participant stated: “The labor of developing and deploying these metaphors weighed against the impacts/outcomes of simply deploying the content and getting it into people’s hands and employing existing models of understanding/display/interaction often weighs out in favor of the latter.” Other participants believed that it was important not to forget about usability and goals: “I feel like it has a time and a place to be used; I would want its visually engaging results to be used deliberately and not in all contexts;” “It depends upon the goal of the project [...] This is the problem with metaphor; it is difficult to consider all of the dimension and systematic connections of a given thing and to consider how those connections and dimensions impact the decision to mimic.” Another participant felt that biomimicry could be another tool for use in design, but should not necessarily be used in every context: “I think it’s great to have another tool in the toolbox.”
Thirdly, some participants noted the potential for biomimicry as a process to challenge assumptions or provide more unique, custom solutions to responsive design. One UX designer validated an underlying argument of this thesis, noting that natural adherence to predictable patterns can be less interesting, or hinder the design of content: “...because nature does not always follow standard and predictable linear patterns. Our adherence to predictable patterns in today’s web design (including my own) has made information less interesting and engaging. We already know that people have become numb to the written word and skim through information on the web. By following design patterns such as this, we might be able to provide more depth about its significance.” Another participant noted that it was important to challenge conventions and assumptions: “I think it’s always a good idea to challenge our thinking / assumptions. Conventions exist to help communicate ideas effectively but it can also be useful to shift those conventions and see what might develop.” Lastly, two participants believed the framework would work well for inspiration, exploration, and experimentation: “I would consider using a framework like this especially as an initial brainstorming tool for web design;” The second participant stated: “However I believe it will produce different results [...] I see Biomimicry As a Great opportunity for inspiration and exploration.”
Chapter 6: Implications

Organic Web Design

Throughout this thesis, the relationships shared by responsive web design and the natural world have been investigated through secondary research and primary research in the form of critical making. This thesis argues that looking to nature’s principles and forms can indeed inform design for the web as a medium, while providing an approach which extends the capacities of responsive web design and moves beyond the patternization which has become so prevalent within the field.

Several implications can be drawn from this investigation. Firstly, by using biomimicry as a process within responsive web design, form has the ability to fit not only to function (such as a “button”), but also to content itself, by providing a visualization of a piece of content through a natural metaphor. Secondly, biomimicry can indeed provide a new language for considering responsive web design. As noted by Marcotte, this metaphoric language moves beyond columns, rows, CSS3 technologies, and patterns by building an analogical approach on top of it. Thirdly, metaphor is not without its boundaries. In many cases, naturalistic metaphors would need to be user tested with a wide range of audiences, and further refined afterwards. Natural metaphors may not be suitable for every responsive web design occasion, and could hinder understanding or mask the importance of content in some situations. If used in practice, how might this approach be scaled to fit various budgets, project scopes, or user needs? Careful attention and further research could be done to understand real users’ responses to natural metaphors, rather than professional responses to the process itself. Does content visualization aid understanding? Is the content perceived correctly? On a similar note, how might it change aesthetic, cognitive, or physiological experiences of interfaces, thus building on the theory of biophilia? Lastly, it is shown
through this thesis that natural metaphors can be formed into a more defined approach within responsive web design, and could be considered as a tool for other designers to use as a catalyst for thinking and making. This process should still be refined more thoroughly, as this thesis seeks only to spark new conversation and exploration of the topic. In what other ways might natural metaphors continue to push the boundaries of responsive web design? Are there particular natural metaphors which might more deeply reveal the larger constructedness of the browser, or provide new forms of knowledge about web design which is evolutionary and adaptive in origin?
Appendices
Appendix:

Participant Survey
Appendix

Participant Survey

The following survey, titled “Biomimicry in Responsive Web Design” was created using Typeform, an online survey tool, and was sent to various professionals involved in design, user-experience design, web design, design educators, and other related fields. The intent of the survey was to better understand various interpretations and perspectives on the prototypes created in this thesis using critical making as primary research. The questions serve as an evaluative research method focused on gaining qualitative insight into the overall framework of using biomimicry within responsive web design. Six respondents answered the survey after being sent a personal email request to participate.

Participant Survey

1) What is your professional title? (i.e. visual designer, UX designer, digital producer, etc)

2) What is your age?
   a) 18–24
   b) 24–30
   c) 30–35
   d) 35–40
   e) 40+

3) How long have you been working in your field?
   a) 1–3 years
b) 3–5 years
c) 5–15 years
d) 15–25 years
e) 25+ years

4) Have you ever used a framework for web design? This might be conceptual or visual. (i.e. bootstrap, responsive design)

5) Have you ever used or designed a visual or conceptual metaphor on a web design project? (i.e. a “shopping cart,” or a “dashboard”). If yes, please explain the project and its context.

6) Have you ever used nature as inspiration or as a metaphor for a design project? If yes, explain the project and context.

Informational Description: Biomimicry is the conscious emulation of nature as a design methodology. The process can be used to solve problems and spark creative thinking, especially by using analogies found in nature for design. For example—the Wright Brothers originally designed an airplane based on their study of flying birds.

7) Are you aware of biomimicry? If yes, have you ever used it on a project? If no, have you ever considered it?

Informational Description: To better understand the following questions, please watch this short video about the specific investigation of this thesis work (this video link is listed in Appendix B).

8) Do you think that biomimicry makes sense as a framework for creating metaphors web design? Please explain.
9) Would you consider using a framework like this for creating natural metaphors in web design? Please explain.

10) Does this biomimetic approach change the way you think about designing for web? Please explain.

11) Do you have any additional thoughts or comments?
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