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The Four Waves of Systems Thinking

Derek Cabrera[a,b,@], Laura Cabrera[a,b], and Gerald Midgley[c,d,e,f,g]
a: Cornell University, USA
b: Cabrera Research Lab, USA
c: Centre for Systems Studies, University of Hull, UK
d: Birmingham Leadership Institute, University of Birmingham, UK
e: Department of Informatics, Linnaeus University, Sweden
f: School of Innovation, Design and Engineering, Mälardalen University, Sweden
g: Schumacher Institute, Bristol, UK
@: dac66@cornell.edu

The Origins of this Handbook[1]

This *Handbook* is about the past, present, and future of systems thinking. It captures the history of systems thinking over its first three 'waves,' which are thought of as significant paradigmatic time periods in the history of the field. It then introduces a (possible) emerging *fourth* wave. Herein, we review the first three waves, as they have been written about in depth before, and dedicate more space to describing the fourth wave, as this is likely to be new to many readers. We cover all four waves as an entree to the many chapters, which were both recommended by an International Advisory Board (listed and thanked in the description of this special issue) and written by esteemed invited authors. These chapters aptly describe the various frameworks[2] that characterize the different waves, and notably include how those frameworks have continued to evolve since their origin.

It has been over thirty years since the third wave washed onto the beach of systems practice, bringing with it (amongst other things) a healthy focus on methodological pluralism [1,2]. This focus represents a significant aspect of the context for editing this book, and is the reason why such a diverse variety of approaches and methodologies could be represented in it. We describe the focus on methodological pluralism as 'healthy' because, in the early 1980s (just before the start of the third wave), the systems research community was involved in a paradigmatic war [3,4] between first wave thinkers, who advocated a focus on objective analysis and optimization (usually using quantitative modeling methods to derive expert recommendations to hand over to decision makers), and second wave practitioners who advocated the participative exploration of stakeholder perspectives, and the use of qualitative modeling methods to enable better mutual understanding and agreements on action to be taken. In contrast, third wave authors argued that both types of systems approach were useful for different purposes and in different contexts [5–13]. This advocacy for methodological pluralism struck a chord with pragmatic practitioners, many of whom already mixed methods from different paradigmatic sources—systems

[1] This paper was originally written in 2019 and is Chapter 1 of the *Handbook of Systems Thinking*. The references and some examples in the text have been updated in places to reflect new contributions between 2020 and 2024, but the bulk of the narrative remains the same as in 2019.
[2] To reduce excess verbiage and decrease the repetitive use of the same 'list of things,' which we will be referring to often, we use the term 'frameworks' as an all-inclusive term to refer to approaches, concepts, models, methods, methodologies, theories, and the like (i.e., any and all intellectual ideas).

methodology was aligning with what many people intuitively saw as best practice. That was in the second half of the 1980s and early 1990s, and for the most part, it ended the paradigm war between first and second wave systems thinkers. A new valuing of diversity flourished, and as a result, more and more methodological innovations were proposed.

Over the next thirty years we witnessed, not only the growth of theoretical, methodological and practical diversity, but also the proliferation of separate systems research communities, all pursuing their own ideas, and all with their own understandings of 'systems,' phrased using different specialist terminologies. Some people, it seemed, were not even aware of the existence of systems traditions other than their own.

The diversity of methodological ideas was a great boon for practice, although this boon also had its price, not the least of which was that it became almost impossible to tell a newcomer what 'systems thinking' is, while still being inclusive of ideas from multiple systems approaches. If you take only one methodology as being the whole of systems thinking, then explaining it in a two-minute 'elevator pitch' is relatively straight-forward, but that means failing to even mention the other ideas that make up 95% or more of the resources available to the practitioner. Conversely, staying faithful to the value of the diversity of approaches means explaining that there are many (sometimes contradictory) ideas about what our field involves. If you need to study for a Masters degree just to begin to understand what systems thinking is, then this is a huge barrier to adoption. The systems research community has found itself in what Bateson [14] calls a 'double bind:' we are damned if we do, and damned if we don't respect the variety of approaches. If we over-simplify what systems thinking is, it will mislead newcomers to our field; but if we attempt to tell a fuller story, we risk the listener becoming baffled by the complexity of the explanation and daunted by the work it will take to understand the variety of approaches.

Long before the idea for the *Handbook*, Gerald Midgley had already given talks at the Australian National University and Cornell University [15,16], proposing that Cabrera's DSRP theory [17–27] looked like the best available candidate to resolve the double-bind—it was easy enough for a newcomer to understand [18,21,25,28], sophisticated enough for an expert in systems thinking to use as a primary tool, and it had the potential to help practitioners better understand the capabilities, strengths and weaknesses of other methodologies, methods and tools. Therefore, it could be a 'gateway' to, and organizer of, the wider set of approaches.

While DSRP theory proposes some systems thinking universals, it should be noted that Midgley's view on its potential role wasn't coming from someone who wanted to unify the systems enterprise behind a single methodology or common language, but from an advocate of methodological pluralism who had been writing on the topic since 1988 [29]. Midgley had previously pointed out the dangers of taking a 'foundational' or 'universality' approach [30], and had explicitly warned against excluding or marginalizing methods, methodologies, and the people associated with them [11,31,32]. What the Cabreras were proposing with DSRP theory explicitly eschewed an either-or proposition—universality *at the expense* of diversity. DSRP is an *both/and* theory, so much so that it actually accounts for both either/or and both/and in its structure. It is comparable to ideas about evolution, where universal processes (e.g., evolution, DNA, etc.) bring about a rich diversity of species and organisms. This was not a position that was being taken lightly, or a conclusion Midgley had come to quickly. In fact, Midgley was originally suspicious of the claims made by DSRP theory [33] (mostly, at the time, due to a superficial

understanding of DSRP). He reached this new understanding of the importance of DSRP because of the dual pressing needs to (a) communicate systems thinking to newcomers to our field in a way that enables an 'elevator pitch' that can later lead onto (2) learning DSRP at progressively deeper levels that help one to understand the variety of systems approaches.

Conversations continued when Gerald visited Derek and Laura Cabrera at Cornell University in Ithaca, New York, for in-depth discussions on the potential for collaboration. They discussed where research on systems thinking needed to go next, and the potential for synergies between the work undertaken by Derek and Laura on defining the structures that universally underlie systems thinking [18,20–22,34] and Gerald's approach to methodological pluralism, which involves mixing diverse methods (and designing new ones when existing methods are not appropriate) in response to a critical-systemic exploration of the purposes and context of an intervention [35]. We shared a common perspective on the history of systems thinking: that there have been three 'waves' (or paradigms) of systems thinking so far [35], as well as the possibility that the Cabreras' work on universality, used to underpin methodological pluralism, could usher in a fourth wave that resolves some of the 'double bind' problems of the third wave.

There are, however, dangers in emphasizing universality, and it is important to recognize that there have been justified and legitimate concerns expressed in the literature: primarily, that future innovations in the diversity of approaches could be constrained by the 'imposition' of a universal framework to 'govern' the variety of systems thinking methodologies [30,36,37]. What is more, deep suspicions have been expressed about any kind of claim to universality on the grounds that this hides the local and contextual features of what we are looking at [38–40]. Also, if the search for universals becomes part of a dominant paradigm, this can empower its advocates to marginalize researchers with different ideas on the grounds that they are not conducting 'proper' (i.e., universal) research [41]. These last two criticisms have not been specifically aimed at universality in systems thinking, but stem from concerns about a previous generation of mid-20th Century, neo-positivist universal theories that were presented as 'grand narratives.' The validity (or truth value) of these theories was seen as independent from their utility in the scientific and/or practitioner communities who might put them to use (i.e., the theories were presented a-contextually). Actually, theories of universals *do* involve truth claims, but from our perspective, universal theories also always have *contexts*, whether these involve practical use to achieve some social purpose, or deployment by an academic community to make a difference in a debate to yield scientific understanding. The context for introducing a universal systems theory at the present time, as we have seen, is the proliferation of systems approaches and the fragmentation of our research community. Once we acknowledge context, it brings a degree of humility to a proposal of universality. In our case, it also provides a rationale for protecting against the reduction of methodological diversity: if we are aware that both universals *and* diversity are necessary in the current context, then we need to make it explicit that a theory of universals is being introduced for use by practitioners to aid the exploration of the capabilities, strengths and weaknesses in their methodological ideas, but this does *not* require those ideas to be denuded of their own specialist concepts and methods, or be rephrased using the language of the universal theory. This is *not* about homogenizing the landscape of systems practice. It *is* about explaining the common underlying properties of diverse systems approaches to aid the communication of our ideas.

Around the same time as our discussions, Jacqueline Curthoys, a publisher at Routledge, approached Gerald Midgley about the idea of an edited *Handbook of Systems Thinking*. Routledge had already

established some of the boundaries of what should be included. It would be part of their series of Management Handbooks, marketed to an academic audience for purchase primarily by university libraries. As such, it would focus on 'management and policy' applications (e.g., it would not include other topics that systems thinking or systems science has influenced, such as family therapy, the nature of living systems, thermodynamics, and understanding the whole Earth as a system), and it would balance 'theory and practice' by targeting 'scholarly practitioners.' We would strike a balance between the theory and practical domains because, as Lewin [42] famously said, "There is nothing more practical than a good theory." He meant two things by this: that *a good theory creates new understandings with significant practical consequences*, and *practice should never be regarded as theory-free,* as there are always assumptions underpinning it, and making them explicit through theory opens them to critique and improvement. Indeed, theory and practice are two sides of the same coin. Thus, we welcomed the focus on *applied* systems thinking (in the domains of management and policy) that Routledge proposed. We therefore responded with three criteria that every chapter (other than this introductory one) would have to meet. Authors would need to ensure that their chapter:

1. Spelled out in sufficient detail the methodology or approach, with proper citations for further reading.
2. Met basic standards of scholarship that would normally be expected in academic writings (e.g., appropriate referencing, explaining the main history of ideas, describing significant disagreements, etc.)
3. Provided a case study or tangible *applied* examples of the methodology or approach in action[3].

Jacqueline approached Gerald, and he immediately thought of bringing on Derek and Laura as co-editors. This opportunity was not only exciting, but it also came at an opportune moment, with a sense of serendipity. Faced with the 'double bind' problem brought about by the diversification of systems ideas (especially in the third wave), and having a growing sense that there was a 'both/and solution,' all three of us agreed that there was a need for a collection of writings (this *Handbook*) that would serve newcomers and old-timers alike in framing the existing three waves of systems thinking, plus the wave we all suspected might emerge—a fourth wave. In other words, the *Handbook* should have stand-alone value, but if somebody wanted to go further in their learning, it should help them understand what the different methodological approaches are useful for, and the universal patterns of thought that we propose underlie them, despite their surface-level differences. If a practitioner or scholar worked predominantly in one area or used one framework of systems thinking (say, systems engineering, system dynamics, soft systems methodology or critical systems heuristics) the *Handbook* should provide a review of their own area, but also illustrate that they are part of a 'big tent' of characters. This would perhaps encourage them to 'reach out' and incorporate new methods or approaches into their tool kit—seeing that there is a 'pattern that connects them all,' creating a sense that the different methodologies are 'birds of a feather,' or that there is a unity that they all share, in addition to having their own different characteristics and uses. Essentially, this is about the *unity of systems thinking* underlying the methodological diversity.

It was clear to all of us that, while DSRP theory could provide a simple, accessible entry point to systems thinking, and even be thought of as 'four simple systems thinking skills' that anyone can use in their

[3] In this regard, we agree with [43] that we need to raise the bar for publishing methodological contributions and always insist that their potential for impact is illustrated with real examples, not just hypotheticals. Ultimately, the demonstrated value of systems thinking to practice is important for take-up by newcomers and impact on management and policy making.

everyday life and work, it was also being used by expert problem solvers to navigate complex and technical systems, challenges, and problems. Of great discussion at the time was the fact that the simplicity of DSRP is deceptive because the four core systems thinking universals can be combined and recombined recursively, in a fractal way, into a near-infinite number of combinations and permutations in the context of practice. Indeed, this is what makes DSRP useful to both novice and expert alike! Nevertheless, the basic idea of DSRP *is* communicable in an elevator pitch. There was some excitement that it might be possible to not only make the field of systems thinking more approachable, but also to help the field mature in its ability to increase the precision and specificity of its processes of analysis and synthesis: understanding what makes methodologies systemic, and identifying their capabilities, strengths and weaknesses as an aid to use in practice.

During Gerald's visits to the Cabreras at Cornell University, they explicated the other ideas and principles that could provide the thrust for what might be a fourth wave of systems thinking: e.g., the need for systems thinking to act as a bridge between both the physical and cognitive worlds [18,19] and to learn from recent advances in the cognitive sciences to inform systems methodology [44–50]. This is so we do not make dubious assumptions—for instance, that thinking (cognition) always involves a tremendous amount of bias [20–22], that metacognition is a kind of 'holy grail,' uncovering these biases and increasing success in all realms [20–23,26,51,52], and that systemic practice involves rational analysis that is somehow separated from the ethical and emotional [22] commitments that make us care about, and give us the tenacity to address, complex ecological, social and organizational issues (for critiques of this separation, which is implicit in many earlier systems thinking approaches, see [53–57]). Likewise, we saw the opportunity, discussed by Rajagopalan and Midgley [58] and Rajagopalan [57,59], of welcoming frameworks from traditions, such as systems theater [50,51], that are not entrenched in a traditional form of rational analysis. As Cabrera [21] points out, DSRP theory's multivalent logic provides a theoretical basis and language that makes it clear that these traditions have a *different* approach to rational analysis, and are not 'irrational' or deficient in rationality.

More and more, albeit cautiously, it began to dawn on us that we might be talking about something more than just an extension of the third wave of systems thinking—this could even be the swellings of a fourth wave! The *possibility* that we may be working on ideas with this potential was exhilarating and clearly worth pursuing, and we discussed the prospect of writing a second, jointly-authored book in addition to the *Handbook* (this is currently at the very early stages of being written).

After another meeting at Cornell, and with the help of our International Advisory Board who provided recommendations on chapters and authors, an initial, provisional list of *Handbook* contents was produced. The rest, as they say, is history—except that we did not publish with Routledge in the end, for reasons that we will not go into here. We decided instead to publish the *Handbook* in the *Journal of Systems Thinking*. This has significant advantages over a book priced for purchase by university libraries, as it will be made open access, free of charge.

Of course, even with recommendations from a diverse International Advisory Board, no selection of chapters can be comprehensive. In Francois's *International Encyclopedia of Systems and Cybernetics* [60], there are 3800 entries, which include big ideas, frameworks, and theorists, all of which are part of the 'big tent' of systems thinking, and all of which could have provided the basis for additional chapters.

So, we have certainly left out some important ideas or frameworks. But, we have exerted a mighty effort to be inclusive of the *predominant* frameworks in the first three waves, with the caveat that there is much more out there. Because the fourth wave, if it is indeed a fourth wave, is relatively new, we offer a bit more writing in both this introductory chapter as well as in the *Handbook* section on the fourth wave, to provide readers with a deeper understanding of how we have experienced and conceptualized it. We also explain some of the effects it has already had.

The Four Waves of Systems Thinking

As mentioned earlier, scholars in the field of systems thinking often use the metaphor of waves as a way to capture the history and development of systems thinking. The wave metaphor has some problems, and caveats need to be added before we use it. Generally speaking, it is useful in clarifying the major developments in our field. Prior to use of the wave metaphor, the main historical narrative in our research community was of a series of paradigm breaks [2,6,61], and it was Midgley [35,62,63] who overlaid the idea of the 'waves' onto this, such that each wave is synonymous with a new paradigm.

There are three reasons why describing the history of systems thinking in terms of 'waves' is more useful than talking about 'paradigms.' The first is simply aesthetic: it is a more evocative metaphor, and is accessible to almost everyone, regardless of what they specialized in at school or university (not everyone uses the language of paradigms). The second reason is that paradigms manifest very differently in different disciplines: when Kuhn [64] first coined the word, he was referring almost exclusively to the natural sciences, and he observed that paradigms come one after another in a series over time, with periods of conflict in between as the new paradigm struggles for dominance over the old. In contrast, Burrell and Morgan [65,66] argue that the social and organizational sciences manifest multiple paradigms *in parallel*. We would add that, for the most part, natural scientists agree on basic philosophical and methodological assumptions, so paradigm differences usually stem from the challenging of *theoretical* assumptions. This is in contrast to the social sciences, where there are much more likely to be philosophical or methodological disagreements (e.g., arguments about whether language does or does not reflect a real world, and whether quantitative measurements of the world or qualitative analyses of stakeholder perspectives are the proper focus of inquiry). Hence, it is apparent that the term 'paradigm' means different things to different people, depending on the disciplines in which they have been educated, so using the term can cause confusion and misunderstandings. The third and final reason why it is preferable to talk about waves rather than paradigms is that the wave metaphor can be usefully extended: Midgley [67] discusses how each wave of systems thinking deposits debris on the beach (theories, methodologies and methods of use to the systems practitioner), and when the next wave hits, it not only deposits new materials, but also rearranges what is already there, sweeping some of the less well-anchored pieces of debris back into the sea. Thus, each episode in which the fundamentals of systems thinking are rethought involves the *reinterpretation* or *repatterning* of old theories, methodologies and methods as well as the addition of new ones, enabling significant innovations in our systemic practices.

The four waves are summarized in the following table, with more explication afterwards:

Wave & Origin point	People and Frameworks	Thrust, Assumptions about the World	Evolution
The First Wave: 1950s	Prominent methodologies include: system dynamics [68], systems analysis [69], systems engineering [70], and the viable systems model [71].	The structure and function of real-world systems can be known (quantified). While some interpretation is involved, we can control bias and achieve a reasonable level of objectivity.	Started in reaction to inadequacies in traditional, reductionist science. Continues to evolve to this day.
The Second Wave: late 1970s	Methodologies include: soft systems methodology [72], interactive planning [73], strategic assumption surfacing and testing [74], interpretive structural modeling [75], and Churchman's [76] whole systems approach.	Critical of the first wave. Includes qualitative modeling & participatory practice; accounts for human and non-technical factors; emphasizes multiple perspectives and intersubjective construction of meaning/action.	Started in reaction to identified weaknesses of the first wave, and continues to evolve to this day
The Third Wave: late 1980s	Approaches and methodologies include: critical systems heuristics [77], critical systems thinking [1,2], boundary critique [18,24,78], systemic intervention [35]; and theories of power [79], conflict [80–82], and marginalization [22,83,84].	Critical of the first and second waves for an inadequate approach to power, and for clashing in a paradigm war. Focuses on dealing critically with power relations, and embraces methodological pluralism. Influenced by critical social theory.	Started in reaction to identified weaknesses in the first and second waves, and continues to evolve to this day.
The Fourth Wave: Early 2000s	DSRP/systems thinking [18,21,34], VMCL/systems leadership [85]. It is possible that competitors or complementors could appear as the fourth wave grows.	Universality in mind and nature: (1) the search for universality (universals or "consilience"), (2) systems thinking bridges physical/ cognitive complexity), and (3) facilitates approachability and maturation of the field.	Started in reaction to the first three waves and "Cambrian explosion" [18] of frameworks. We are arguably at the end of the beginning of this wave....

Table 1: Summary of the Four Waves of Systems Thinking

While Table 1 provides a summary of the four waves of systems thinking, we will explore them in much greater detail after we review some of the caveats that need to be stated when using the waves metaphor.

Caveats of the Waves

This characterization of the history of the field of systems thinking in waves is a useful heuristic. Of great importance, however, are caveats that require explication when analyzing the field of systems thinking:

1. The boundaries of systems thinking that are drawn, both in time and scope, matter to the field;
2. The inherent bias in establishing historical periods in any given field (i.e., periodization[4] bias);
3. The identification of the *origin point* of the field of systems thinking, and the distinction between explicit and formal versus implicit and informal attempts[5] at systems thinking;
4. That many historical artifacts are lost to 'extinction' (usually quite a few more than remain today)[6]; and
5. One must distinguish between the *thrust* of the wave and its continued *evolution*.

With these caveats in mind as context, it is important to understand that the frameworks associated with each wave *did not stop evolving when new waves occurred*. For example, system dynamics [68,87] and the Viable System Model [71,88], both first wave approaches initially, were thoroughly reconceptualized in the second wave. This resulted in a bifurcation: new second-wave practices emerging to sit alongside the evolution of practices that continued to make first-wave assumptions.

Figure 1 illustrates these caveats that provide a wider context for the waves of systems thinking.

[4] Periodization refers to the tendency (especially in historical analysis) to group or categorize time periods thematically. Often this categorization involves an implicit perspective that causes past events to be grouped into discrete, often quantified units of time. Periodization has both strengths and weaknesses. Its major strength is pedagogical/andragogical: it facilitates the understanding and analysis of historical events (especially complex ones). The danger of periodization is that it always introduces a degree of bias. Periodization provides convenient terms and discrete abstractions that can be used to understand history, but these discrete benefits are often based on fuzzy, loose, or arbitrary distinctions. History is, by its nature, fluid and continuous, with webs of causality and sprinklings of randomness. Yet, without making distinctions between grouped periods, it becomes unwieldy to understand. In other words, no matter who we are (individuals, groups, cultures, subcultures, nations, etc.) we are prone to some level of periodization bias. And, it is likely that multiple perspectives on periodization overlap, conflict, and leave gaps as well as requiring refinement, editing, and change. In short, periodization is something we do, but we should be cautious when we are doing it and try to avoid the most costly biases inherent in its use.

[5] In [18] Cabrera writes, "The development of knowledge-about-systems began nearly 2,600 years ago with Lao Tsu, who in the *Tao Te Ching* wrote what is perhaps the first formal description (albeit in verse) of a system when he described the forces of yin and yang." The system described is a coupled oscillator. The starting point of systems thinking is widely debated. Some say in the 1950s with Bertalanffy or Forrester, others say with Prigogine, others say Bogdanov [86], still others go as far back as Lao Tsu [18].

[6] The extinction caveat is not of paramount importance to the casual user of the waves metaphor, but to the historian of systems thinking, it will be. As a general caveat, one should consider the [biological] evolutionary reality that 99.9% of all organisms that have existed have already gone extinct. Similarly, in the history of systems thinking, a great many frameworks (concepts, theories, efforts, methods, etc.) are not mentioned, primarily because they have gone extinct or unused. Of course, a great many of these ideas were in some way influential at the time or transitional between one idea and another. Thus, even a rigorous listing, for example with the tens of thousands of people and ideas in the Midgley-Francois-Schwarz (MFS) Universe, is never a full accounting. The 'MFS Universe' is a phrase coined by Cabrera [23] because those three authors have produced some of the most widely respected compilations of systems ideas, so combining them gives an approximation of the whole territory of systems thinking, but even this is inevitably incomplete.

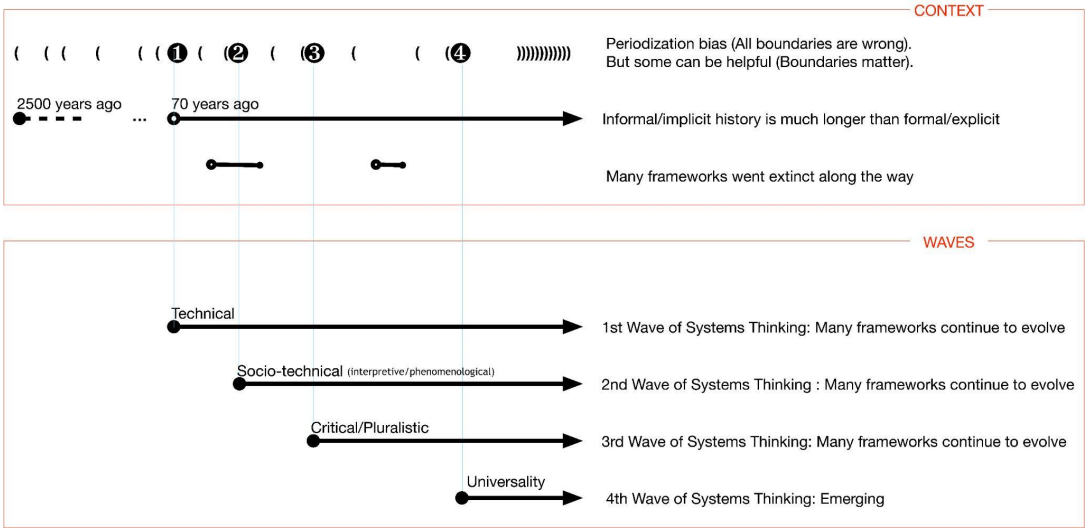

Figure 1: The History of Systems Thinking and Its Caveats.

It is important to remember that, although the waves are associated with time periods and were born out of certain contexts, they also continue to evolve (as do the methods and models within each wave) to the current day. *They are not static, but dynamically evolving.* Thus, we should distinguish between two aspects of the waves as shown in Figure 2: 1) the 'thrust' of a wave, or the energy and purpose that drove the wave to form in the first place; and 2) the continued 'evolution' of the wave, the ongoing dynamical interaction and changes made as a result of the times and the influence of new waves.

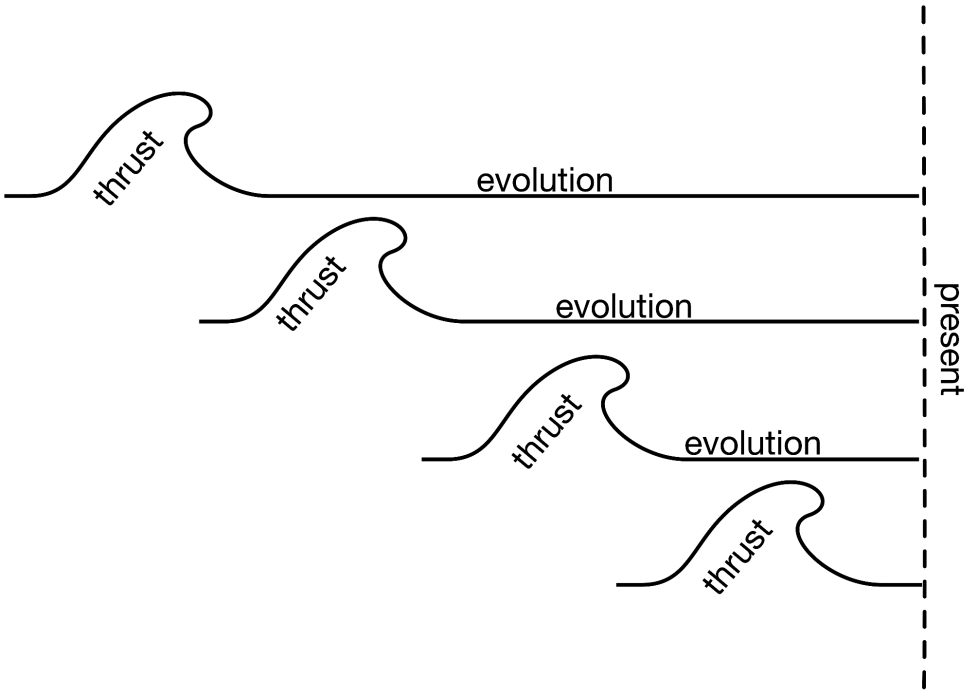

Figure 2: The Thrust and Evolution of Systems Thinking Waves.

Figure 2 shows that the waves do not remain in their static, originating form, but adapt to changing times. In this way, an approach that appeared and was dominant in the first wave, such as systems engineering, continued to evolve as the thrust of the second wave influenced it, causing some systems engineers [89] to consider their biases and mental models, and to take on new philosophical ideas, like phenomenology, and/or think through socio-technical problems. Likewise, as the thrust of the third wave occurred, some systems engineers altered their discipline to adapt to the new wave, by critically considering methodological pluralism, political power, equity, opportunity, and disadvantaged perspectives [90]. In the fourth wave, the same systems engineering discipline has already begun to see universality across domains, and now realizes that very different types of problems and phenomena can be similarly structured (as seen in [91,92]).

The wave metaphor suggests that the first three waves came and went. But they did not. They still exist today. In other words, this metaphor suggests that the subsequent wave 'replaces' the one before it. Rather, each subsequent wave *expands* upon the prior wave and reconstructs some of its ideas. Although scholars who write about the waves generally accept that the waves do not replace each other, the metaphor itself miscommunicates this. Most notably, people new to the field assume (based on the metaphor) that the latest wave represents the current state of the field in all parts of our research community, as if the latter was homogenous. This is problematic, as it is not how the field sees itself, nor how things play out in reality. We must see that what we perceive as 'new' waves are not replacements of their predecessors, but additions and paradigmatic shifts that also coexist with the older ideas in the present time. This means that the important work that came before is subsumed into the new wave, rather than being rejected, ignored, supplanted, or 'washed away.' Also, some practitioners will not agree with the subsumptions and reinterpretations and will continue with their old ideas, unchanged. The reader should keep this in mind as they continue through this special issue, as it is broken down into the four sections corresponding to the four waves, yet authors of each individual model have been asked to reflect, not only on the origins and history of the model, method, or framework that they have written about, but also to discuss where things stand today. More often than not, much evolution has occurred in between the origin of a wave and the present day.

Keeping the above caveats in mind, we believe we can legitimately talk about three successive waves of systems thinking that have crashed onto the shore of systems practice, and we will argue that there is a case for the current swelling of a fourth wave.

The First Wave

The first wave is sometimes known as 'hard systems thinking' [72]: it is characterized by expert analysis, striving for objectivity, and primarily relies on quantitative modeling. It began in the 1950s and flowed into the 1960s, but with some advocates continuing to develop their ideas after new waves had already started. The first wave involved a structural-functionalist approach to systems [93]: i.e., assuming that we live within coherently-structured societal systems, and our roles are functional in terms of maintaining and evolving those systems. Almost all the methodologies in that era placed an emphasis on expert, quantitative modeling, mostly done by engineers and operations researchers. Systems were seen as primarily physical (actually in the world, rather than constructed in the mind as a way of understanding

the world), and a computational metaphor undergirded most approaches. The first wave of systems thinking was like a tidal wave. It was new and exciting, and challenged some of the places where more traditional applied science was failing due to an overly reductionist approach: analyzing systems by breaking them down into more easily-studied parts, thereby failing to see that some of the most important properties of systems couldn't be traced back to any one single part, but instead emerged from the *interactions between* all the parts (i.e., they were emergent properties of whole systems) [94]. Systems thinking was largely a critique of the way science was being done (importantly, it described itself *as* science during the first wave): it had become absurdly reductionistic, trying to explain things by decomposing systems into their smallest possible parts, as if causality lay in the parts of the system rather than in their collective interrelationships. It often missed the larger, containing system, so lacked context; and it focused too much on overly-simplified, linear causalities. Early on, systems thinking carried over one critically important bias of scientific practice: an emphasis on pure objectivity, as if systems are not always seen from a perspective [94]. Interestingly, the underlying ideas of this first wave remain prominent in the fields of systems engineering and operations research today, although there are sub-communities in both fields that challenge them. This remained the dominant paradigm throughout the 1950s and 1960s, but in the 1970s and 1980s, it came under sustained attack from second-wave systems thinkers as well as planners and social scientists [95–97]. While new ideas were to be developed in the second wave, some authors (especially in systems engineering, systems analysis and to a lesser extent system dynamics) continued to develop first-wave-style thinking.

The Second Wave

The second wave is sometimes known as 'soft systems thinking' [72], and is characterized by qualitative modeling and participatory practice. It became the dominant paradigm in the early 1980s in response to critiques of the first wave. This resulted in an explosion of new methodological developments. An emphasis was placed on always seeking to account for the human and non-technical aspects of interventions into systems. Additionally, there was an emphasis on exploring multiple perspectives and the intersubjective construction of agreements on how to take coordinated action. The 'systems idea' came to be seen as a *useful conceptual device* for interpreting complex situations: some commentators pointed out that everything we take as reality is mediated through our perceptions and interpretations [98], so we cannot know for certain whether systems actually exist in the wider world—but *seeing things in terms of systems* is certainly useful. Methodologies associated with the second wave included soft systems methodology [72], interactive planning [73], and strategic assumption surfacing and testing [74].

In this wave, an interpretive approach to systems [99,100] was advocated, in which the observer (or more accurately, the *participant*-observer, as there is no external vantage point from which to view the world) was brought back into the picture after having been hidden during the first wave in the name of objectivity: understandings of the world were subjectively and inter-subjectively constructed, and there were inevitably different perspectives [72]. Values came to the fore—both stakeholder values, and the values of the systems practitioner who decides what to research in dialogue with those stakeholders [101]. The second wave shifted attention to qualitative modeling in the context of participative practice. Second order cybernetics (the cybernetic partner to soft systems thinking, in which the idea of observer-dependence was thoroughly explored) proposed a radical shift away from a purely physical and objective perspective of systems thinking [102]. Along with recognition of the social context in which any

technical systems thinking occurred, this was a significant epistemological shift in systems thinking that meant that social context and second-order effects (the effects of the observer, both in terms of taking a perspective on systems and changing them through action) could never again be excusably ignored. This therefore forced us to not only be systemic about our practices, in the sense of applying theory to an external world of systems (first wave), but also to consider the psycho-social context of these practices (second wave). This epistemological shift led to a change in emphasis from systems existing in the real world to *perspectives on action being systemic* and *methodologies as systemic processes of inquiry* [72].

It was also at this time that an emphasis on dialogue, shared understanding, mutual appreciation, and an exploration of assumptions through participatory dialogue began. Reality came to be seen as an intersubjective construct rather than something that could be taken for granted as external and objective [103]. However, note that the emphasis was on *inter*subjectivity rather than pure subjectivity because of a pressing concern for facilitating coordinated human action [104].

Despite the scale of the epistemological shift, this stance was nevertheless critiqued in the mid-to-late 80s for failing to account sufficiently well for power relations, and for starting a paradigm war with first-wave systems thinkers, threatening to fragment the systems research community [105]. Jackson and Keys [3] made a sound argument that the first and second waves were *complementary to one another and didn't need to be seen as competitive and mutually exclusive*, which is one of the important insights that led to the third wave of systems thinking.

The Third Wave

The third wave is sometimes given the umbrella term 'critical systems thinking' (CST) [1,2]. It started in the mid 1980s, was influenced by critical social theory (e.g., [106]) and placed an emphasis on dealing with power relations [79], enabling civil society dialogue (e.g., [77]), being critical about boundary judgements and distinction making [18,24] in systemic inquiry [77,78], addressing conflict and marginalization processes [22,80–84], and mixing methods drawn from both the first and second waves to create a more flexible and responsive systems practice [13,105]. Methodological diversification was encouraged to give us a growing 'tool kit,' so we could pursue multiple purposes of intervention in multiple contexts.

The third wave of systems thinking therefore introduced a 'big tent' pluralism [18] that embraced a rich diversity of approaches and methods of systems thinking. The third wave promoted the idea that we can learn a lot by looking at the world through different lenses (e.g., structural-functionalist, interpretive, complexity science, emancipatory) [7], or look for a multi-faceted philosophy that explains the methodological diversity that was welcomed [11,31,107]. This shift led to what Cabrera [18] calls a 'Cambrian Explosion of systems thinking frameworks' (both technical and social).

The third wave remained the dominant paradigm throughout the 1990s and much of the 2000s. Some would say it remains so. Recently, however, the emphasis on methodological pluralism has been subject to critique for encouraging 'a thousand flowers (methodologies and methods) to bloom' without keeping a sufficiently strong core narrative about the fundamentals of systems thinking [18,23]. Without the latter,

newcomers cannot easily get to grips with the field [23], and nor can the field mature into a viable scientific endeavor [91,92,108–115]. Also, despite the methodological diversity, there remained a focus on rational analysis (albeit with a broadened understanding of rationality), with arts-based and other approaches mostly marginalized [57,108].

By the second decade of the 2000s, the field of systems thinking was undergoing major change, brought about by a number of forces, including: (1) the continuing proliferation of methodologies and methods, resulting in an even greater plurality of systems ideas; (2) a fragmentation of the systems research community into multiple, smaller communities focused on subdomains of practice, resulting in more and more diversity of systems terminologies and resultant siloficiation; (3) the lack of accessibility to newcomers to systems thinking had become acute; and (4) the DSRP theory of systems thinking made new insights into universality possible, and we believe now carries the potential to provide renewed coherence to the field.

The Fourth Wave

We certainly believe that the problems with the third wave (discussed above) are significant enough to warrant the emergence of a fourth wave, but it is unclear at this point whether the 'first swellings' we are currently seeing will culminate in a full wave, or whether they will be overtaken by some other movement that ends up becoming the thrust of a new set of ideas. Of course, such judgements of a fourth wave are properly made retrospectively, not prospectively: whether a set of ideas propels a new wave of innovations or merely represents a brief swelling of the water before subsiding depends on whether it galvanizes the collective imagination of a larger research community and addresses real problems that are recognized as important [64,116]. Thus, we have been cautious over the past twenty years about declaring that a new wave is upon us. Up to this point in the narrative, we have emphasized that, if it is indeed upon us, it is likely in its infancy. Despite this abundance of caution, there is also reason to be optimistic. For example, since Cabrera's first writings [17,18,25,34,117–119], we now have the benefit of over 20 years of hindsight on the possible start of a fourth wave (which is as long as the gap between the first and second waves, and twice as long as the gap between the second and third waves). During those years, we have seen considerable testing of Cabrera's DSRP theory, including: (1) a burgeoning amount of empirical evidence (at least as much as has been offered in the previous waves [109])[7]; (2) substantial private sector funding to develop tools for systems thinking [120–122]; (3) substantial public funding for research[8] [123]; (4) a substantial peer reviewed publication history, and sizeable citation histories, including several special issues dedicated to DSRP [26,124]; (5) considerable public exposure and critique[9]; (6) public adoption[10]; (7) high attendance annual conferences [125]; institutional recognition and

[7] Many frameworks originating in the first three waves are methodological, so when they have included empirical findings these are measures of their effect during interventions (e.g., in case studies of practice). While there is also *effectiveness* research on DSRP, the vast amount of empirical work on DSRP is basic research on its *existence* in both mind and nature. In this sense, previous frameworks have rarely been subjected to empirical research on their existence as real-world phenomena.
[8] Over $8 million in total funding of DSRP from public agencies and $16 million in public and private combined.
[9] Aside from the exposure and critique in peer reviewed journals, DSRP is also widely debated on social media systems groups totalling ~50,000 people, received the 2017 AECT Book Award, and was the subject of an award-winning documentary film titled 'Re:Thinking.'
[10] As examples; Cabrera Research Lab YouTube channel has received ~500,000 views; their books have sold more than 30,000 copies, Cabrera's TED Talk has reached over 220k and their short film 175k.

support[11]; and (9) as yet, few competitor theories (at least, none that have been explicated and communicated to the same degree).

Having introduced this caution about saying a fourth wave is evident, we are nevertheless committed to bringing something new into being, so we will take the plunge and proceed in this narrative by *assuming* that these 'first swellings' are indeed significant enough to initiate a full wave. With this in mind, we are comfortable in saying that the present moment is at least 'the end of the beginning' of the fourth wave. We will see in ten or twenty years whether or not we were correct.

The fourth wave has been brought on by a renewed search for universal structures of systems thinking, initiated by Cabrera [126–128]. We say 'renewed' because the desire to identify the universal properties of all systems was already present in some early-to-mid-20th century systems theory [129], which provided the conceptual foundations for the first wave of applied systems thinking. However, there is a significant difference between this early work and Cabrera's: the latter concerns systems *thinking* (thinking in terms of systems) *and its relationship* with systems themselves, while the early work only concerned systems in the world. Cabrera [17,18,25,130] characterizes the thrust of the fourth wave as being threefold:

First, a search for *universality* (that there are underlying 'universal' patterns of mind and nature) across the systems thinking field, as well all forms of knowledge (e.g., 'consilience') [25,108,131]. Cabrera has sought to identify the parallel patterns of how systems exist in reality *and* how humans think about that reality. This discovery reveals a parallel structure (D, S, R, and P, standing for identity-other **D**istinctions, part-whole **S**ystems, action-reaction **R**elationships, and point-view **P**erspectives) in both real-world systems and the mental models we build of them. Thus, an understanding of the universality in nature and mind means that this theory is a *bridge between the physical[12] and cognitive sciences [19,109,133,144]*.

Second, the fourth wave focuses on the onto-epistemic or physico-cognitive complexity that Cabrera proposes [18,19,21,144–146] is inherent not only in systems thinking as a field, but also in its name: *systems* (ontological-physical-nature) + *thinking* (epistemological-cognitive-mind). This second thrust involves an explicit recognition that systems thinking must fundamentally rest on both a *physical* ***and*** a *cognitive* science. That is, systems thinking is informed by studies of cognitive systems, especially metacognition, neuroscience, psychology, development, etc., *and also* studies of physical systems, such as physical, chemical, biological, social, and economic systems in the real world. Systems thinking is especially influenced by the complexity of systems in both mind and nature, and the explicit recognition

[11] DSRP and VMCL are both the focus of two graduate level courses at Cornell University. In addition, two certificates in systems thinking are offered. LinkedIn, after an extensive review of systems thinking, chose DSRP and VMCL for their course on the topic. Including venerable institutions such as Cornell and West Point, approximately 30 universities have adopted DSRP textbooks and thousands of K-12 teachers and schools have adopted DSRP as well as over 250 organizations.

[12] The research for the existence of DSRP in both mind and nature is extensive [109] (see [132] for a summary) and for most readers it is clear how D, S, R, and P are universal and existential to mind. Indeed, most readers have little difficulty thinking of real-world, material examples of D, S, and R in nature. Where they struggle is with P in nature, for which there are countless examples from group (statistical perspectives) to individual perspectives of various types of neural organisms. But there are also countless and burgeoning examples of empirical research showing perspectives in non-neural life forms and nonliving compounds too [133–143].

that systems thinking itself is a complex adaptive system (CAS).[13] It assumes a world of systems, within which the human mind evolved towards metacognitive systems thinking capabilities. Thus, systems are *both* real and conceptual, with systems thinking being a set of skills to help us engage with a systemic world more effectively and prosocially [21].

The first and second thrusts of the fourth wave outline an elegant theoretical framework that may be elucidated by an example. In the 6 January 2021 assault on the US Capitol by insurgents, congressional staffers used *barricades* to buttress themselves in their offices to avoid danger. Minutes before the uprising, those same staffers sat at *desks* in their offices. But notice that the barricades and the desks are the same existential identity (the same thing). Let's call that existential thing 'A'. So, in one scenario *A is a desk*, and in the other scenario (when the context has changed) *A is a barricade*. That *A actually exists* in both scenarios refers to the ontological, physical, real-world system. But, *A being a desk* OR *A being a barricade* refers to our mental model of A (our epistemological or cognitive reality). What DSRP shows is that the DSRP structures are the common denominator or 'bridge' between mental models of A (EITHER *A is a desk* OR *A is a barricade*) AND the existential reality of *A*[14]. This example elucidates that all three entities (i.e., the mental models *desk* and *barricade* and existential reality *A*) utilize identity-other distinctions, part-whole organization, interrelationships, and perspectives, albeit in different configurations and with different information-content. Thus, the *universality* of structure and the *diversity* of configuration and information. Ergo, Cabrera points out, the function of universality (i.e., DSRP) is to provide a common denominator between analogous systems, such that one might increase the probability of alignment through parallel structure. If that sounds esoteric, think of it this way: when two people (or systems) speak the same language, a channel of communication between them is made possible, even if

[13] Cabrera refers to DSRP theory as a 'physico-cognitive bridge theory,' in that it applies to the physical world every bit as much as it applies to the cognitive or conceptual world, and considers this quality to be a necessary function of any theory that makes a claim to universality.

[14] The constructivist and/or anti-realist reply to such an argument (e.g., [103]) would be that we can only ever know these mental models: we experience a desk becoming a barricade as the context changes, but we only have a concept of A in reflection on the situation, and as soon as we try to instantiate what A is (i.e., we say that the wood is held in common between the desk and the barricade), this involves the introduction of a new mental model of a wooden structure. At best, A is therefore an abstraction from our observation that there is something in common between the desk and barricade, and to say that it is the essence of the thing-in-itself is itself a mental model! There is therefore nothing we can say about reality that is not constructed by us. Our reply to this is that we experience things as both real and as products of our perspectives [147,148], so why would it make sense to say that we are allowed to assume one of these things is the case (our perspectives) but not the other (reality)? Granted, the relationship between the two is complex, such that what, at one moment, we take to be reality might be revealed, at another moment, as a limited perspective after all. This is why scientists tend to adopt a basic attitude of skepticism, and why Popper [149] argues that what constitutes 'truth' at any moment of time is dependent on a consensus in the scientific community, and not any given piece of evidence that, tomorrow, may be reinterpreted. Despite the complexity in the relationship of mental models to reality, our concern with saying that our experience of the former is a generalizable truth while our experience of the latter is not, comes about because of the extraordinarily counter-intuitive stance this logic leads to: ultimately, if there is only mental models, and we cannot talk of reality, then I logically cannot accept you as a real sentient being, or the reality of the language we are using to construct our mental models, and all I am left with in terms of anything other than my mental models is my own consciousness. This runs so counter to our experience, that it has to be dismissed as unreasonable. Better to allow discussion of both mental models and reality, but always stay alert to the possibility that what we take as reality at any given moment might actually be a product of a non-universal perspective. In addition, Cabrera [150] explains that the mind (e.g., psychology and sociology) did not evolve separately from, distinct to, or outside of reality. Indeed, chemical processes evolved within the laws (bounds) of physics, and subsequently biology evolved within the bounds of both chemistry and physics. Likewise, psychology and sociology evolved within the bounds of physics, chemistry, and biology. Thus, our brains did not evolve with absolutely *no correspondence* to nature. Do they always get everything right? Of course not: human beings construct their mental models based on fragmentary sense data, and the resulting models are our predictions or anticipations of what will be most relevant to us in the immediate future, so they are informed by our inevitably partial and biased histories of experience [151–153]. But do they have a statistical correspondence with reality? Yes, otherwise we could not survive in ongoing relationships with our social and ecological environments or predictively solve the complex problems and situations in which we find ourselves.

they speak with different dialects and about different ideas. Thus, DSRP provides a way for our mental models to speak the same language as the universe.

The third thrust of the fourth wave is what Cabrera has called 'approachability + maturity,' by which he means that, for the field of systems thinking to survive and thrive, it must balance *approachability* and *maturity*, and *universality* significantly helps in the development of both. *Approachability* refers to the degree to which the field is welcoming, accessible, etc., to newcomers. Any field requires fresh minds and next generation adoption, and this is very relevant for systems thinking at the present time, given the highly complex global-to-local problems that we are experiencing, where systems approaches are sorely needed. The Cambrian explosion of frameworks made the field fragmented and unapproachable. As the field evolves, it needs to be welcoming and embrace newcomers (unlike the 'weed out' often seen in the cultures of physics, chemistry, biology, and medicine). In order to do so, systems thinking must be explained succinctly, and people must see its value readily, which is something that we argue DSRP theory makes possible.

At the same time, the field must *mature*. Historically, across disciplines, the discovery of universals has significantly contributed to the maturation and legitimacy of disciplines. In physics, chemistry, biology, and numerous others, when the field discovers universals, it unifies effort, dramatically maturing the field, and sends discovery and utility into hyperdrive. Two notable frameworks in this wave are DSRP [18,20,21,25] and VMCL [34].

The DSRP theory identifies four universal patterns that underlie systems thinking: making identity-other Distinctions (D); organizing part-whole Systems (S); recognizing action-reaction Relationships (R); and taking multiple point-view Perspectives (P). Notably, frameworks from the three waves of systems thinking are structured by these four patterns and involve the practice of these four essential skills, yet the foundational nature of these patterns remained unarticulated until 2000 [25,34].

Figure 3 illustrates the four waves, but with only a few of the methods and influences identified.

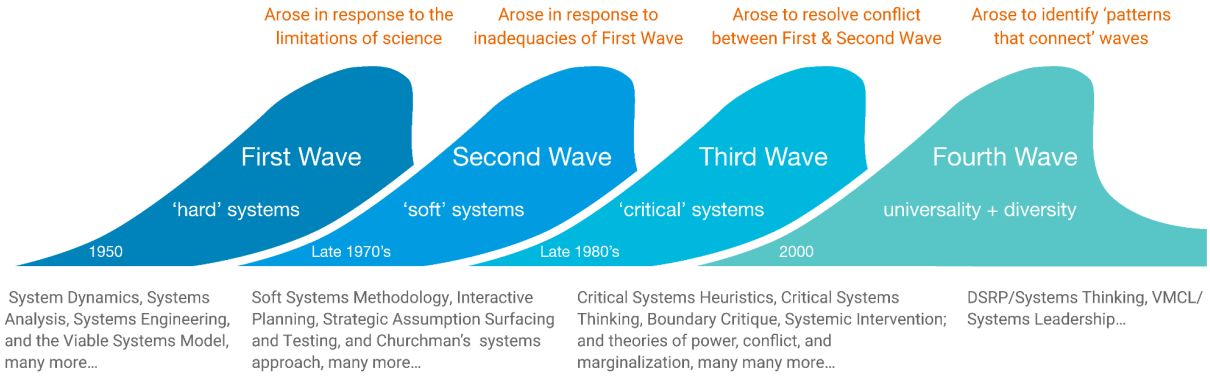

Figure 3: The Systems Thinking Waves [21].

This edited volume therefore brings together many of these frameworks and illustrates *where they started and where they are today* ('then and now'), in the hope of providing the reader with an understanding of

the breadth and depth of the field of systems thinking. We are grateful to the esteemed authors who painstakingly contributed chapters that provide newcomers and experts alike a capable introduction to the topical area as well as examples of its use, and their thoughts on what the future holds.

Diversity and Universality: The Fourth Wave

Because the fourth wave of System Thinking is predicated on *universality*, it actually requires a deep analysis of what constitutes the *diversity* of things that make up this universe (if something is universal, then it implies a universe or a 'particular sphere of activity or influence'). The first three waves produced a remarkable diversity of systems frameworks (e.g., system dynamics, systems engineering, viable systems model, soft systems methodology, critical systems thinking, etc.) that have been used successfully in various specialized contexts. Yet as a field and practice, in our view, systems thinking has yet to reach its full potential and effect. The issues are: (1) the current diversity of frameworks and their specialist languages, (2) fragmentation of the research community, which gives rise to what we might call 'silofication' of the field, and tribalism around the silos, (3) lack of a consistent message to newcomers to the field, leading to a feeling of unapproachability, (4) the lack of a common research agenda or set of unsolved research questions to attract fresh talent to continually move the field forward (we provide some examples of such an agenda later in this chapter), and (5) the lack of universality to integrate the field. These major issues result in handicapping the field from collectively moving toward more useful *discovery* and *adoption* by a wider audience of decision makers and citizens. We see this unmet potential in the frustration many feel and the 'fits and starts' many undergo when applying systems thinking to their own domain or problem. This is a time and context in which systems thinking could be applied more often to all types of everyday and wicked problems [21,154–157] because it is applicable in all fields and disciplines of knowledge. In fact, there is a veritable 'gold rush' of activity in various disciplines to 'systematize' their fields. The Cabreras use the collective noun 'Systems X' [112] to describe these fields (i.e., systemic evaluation, systems engineering, systems education, systemic leadership, systemic innovation, systems neuroscience, and many more). As the world becomes increasingly complex and VUCA (**V**olatile, **U**ncertain, **C**omplex, and **A**mbiguous) [85] due to more interconnections brought on by globalization, there has never been a more systemic set of issues that beg for the power of systems thinking [158], not only in academic disciplines, but in the public and private sectors, and in personal development.

As such, the fourth wave of systems thinking identifies the central tenets that lie beneath a plethora of valuable frameworks. We seek to uncover the universal patterns that connect them all. These patterns can not only lead to a better understanding of the current frameworks in our field, but also offer a point of accessibility for *every*one to the enormous potential of the field itself, and they make it possible to significantly expand the universe of people, problems, and systems to which systems thinking is applicable. In order to accomplish this, however, we must explore what is meant by the universe of diverse things that make up the domain of systems thinking, such that any legitimate universality can be claimed [18].

The Diversity: Where is the Boundary of Systems Thinking?

Numerous methodologies, methods, theories, concepts, and approaches (that we have collectively referred to as 'frameworks') were part of both the first and second waves (e.g., systems engineering, system dynamics, network theory, soft systems methodology, etc.). By the turn of the 21st Century, a 'Cambrian Explosion' [159] of frameworks of systems thinking had taken place. The three waves represent the rich diversity of frameworks that were, and still are, available to systems thinkers. In the third wave, critical systems thinkers [1,2,35] were largely successful in convincing academics and practitioners to welcome the diversity (a.k.a., plurality) of frameworks as contributions to a highly flexible and responsive methodological resource (or 'toolkit') for systems practice. However, with all the benefits and diversity of a 'big tent' methodological pluralism, there were also downsides. Most notable among these downsides were: (1) *silofication* of the field into separate (sometimes needlessly feuding) camps, and (2) a *lack of approachability* for newcomers to the field. These were serious problems, as managers, policy makers, and practitioners of all kinds sought new approaches for addressing complex problems.

The Universality: What is the Pattern that Connects in Systems Thinking?

The fourth wave, at its core, is about universality and diversity. The third wave embraced, and even drove, diversity through its advocacy of methodological pluralism, so few readers will bristle over the value of *diversity*. Yet justifiably, some readers will have a negative reaction to *universality* [30,41]. We hope that we are able to show, through DSRP theory, that justified fears, trepidations, and criticisms of a historical use of the term universality (i.e., that promoted by neo-positivists in the mid-20th Century) do not apply to the flavor of universality being advocated herein. We intend to argue, not only that both universality and diversity are needed, but that they are mutually dependent forces. We also hope that the reader will see that *because* universality and diversity reinforce one another, they are key to the future of our field. When the great geneticist and evolutionary biologist, Dobzhansky, once remarked, "Nothing in biology makes sense except in the light of evolution [160]," he didn't mean that the *universality* of evolutionary theory *canceled* all of the *diversity* that existed in biology. He meant that all of that diversity began to make sense together, *as a system*.

Indeed, the structure of Darwin's [161] argument of *consistency* (not entailment) about his *universal* claim of evolution is perhaps one of the most elegant arguments in the history of science.[15] Remember that the

[15]Darwin's later work, *The Descent of Man*, published in 1871[162], has been subject to extensive analysis and debate over the years. Darwin's main goal was to explore the evidence for human evolution and to discuss the role of sexual selection in the evolutionary process. In this work, he extended the theory of natural selection into the realm of human evolution. The question of whether "The Descent of Man" is racist touches on a complex intersection of historical context, the evolution of scientific understanding, and the interpretation of Darwin's views on race and ethnicity. In the text, Darwin does discuss differences between human races, and some of his language and concepts reflect the Eurocentric and ethnocentric biases of his time. It is important to note that the 19th-century scientific community often held views that today are considered racist. For example, Darwin and many of his contemporaries believed in a kind of gradation between the races, with white Europeans often unjustly regarded as the pinnacle of human evolution. This viewpoint can be construed as supporting a racist worldview, especially from a modern perspective. Darwin also speculated about the eventual extinction of what he saw as "savage races" by "civilized races" over time. This aspect of his theory has been used by some to justify colonialism and imperialism, although Darwin himself was quite clear in his abhorrence of slavery and believed in the common descent of all humans. In contrast to many of his contemporaries, Darwin argued against the idea that the races were separate species and believed in the unity of the human

term ‘species’ in Darwin’s *Origin of Species* refers to biological *diversity*. He was proposing a *universal* theory that explained the *diversity* of life we see around us. First, Darwin reviews a list of challenges to his theory and explains why none of the challenges[16] ‘kill’ his theory of “descent with modification through natural selection.” They are *consistent* with his theory. Indeed, Darwin’s argument is a long walk through the challenges—all instantiations of diversity—at each point stopping to reflect that they were “not fatal to my theory” (p. 171), and that the "facts don't strengthen but don't annihilate [my theory]” (p. 241). At the same time he admitted that, if some new fact pattern were to arise, then "my theory would absolutely break down" (p. 189) or that it "would annihilate my theory" (p. 201). In other words, Darwin understood (and threw down the gauntlet to this effect) that the discovery of certain new fact patterns in the *diversity* could *annihilate* his claims of *universality,* and *vice versa*. Thus, although there is great concern that, historically, some misconceived flavors of ‘universality’ have made diversity *subservient* to it, this is not the case with the flavor we are offering. Diversity is no more *subservient* to universality than the other way around. Both diversity and universality are two peas in a pod with the same DNA (pun intended). A fundamental change in the fact pattern in one will reverberate in the other. Darwin showed us that the *diversity* was borne of *universality*, and that even a *single contrarian-instantiation of the diversity* would call the whole edifice of universality into question!

We have seen this reciprocal effect between diversity and universality, not only in biology, but in many other fields as well. There is therefore reason to believe that it is going to hold true for the field of systems thinking. As fields find greater, more valid forms of universality, the diversity becomes richer, more useful, and also more validated. You might say that *universality*, without *diversity*, is really just *unrealized capacity*. Alternatively, you might even say that *diversity*, without *universality*, is just *stochasticity*. Universality and diversity go together like bread and butter. They make each other better, not worse.

Universality has a maturing effect on fields of study and disciplines of science, and systems thinking is arguably no different. The history of science itself offers precedence for the idea that universals help fields to mature. If physics had not sought a grand theory, it would still be largely metaphysics, characterized by mystical ether or the metaphorical elements of polyhedra. Fields of knowledge, like children, go through a natural maturation process. The mature program of physics was born as an awkward metaphysics until it found its way through modern theories, from Newton to Einstein. The handsome devil that we see in chemistry today was born as gangly alchemy. If chemistry had not sought universal patterns, it would still be alchemy. If biology had not sought universal patterns, it would still be a field largely dominated by a form of ‘stamp-collecting’ (stuffing poor specimens in jars), which it was prior to Darwin, Mendel, Watson and Crick.

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species. However, his work was appropriated by others—most notably by proponents of Social Darwinism and eugenics—who used his ideas to justify social inequality and racial discrimination. The scientific consensus today rejects racial concepts prevalent in the 19th century and recognizes that biological races within Homo sapiens do not exist. Modern genetics has confirmed that the genetic variation within what were once termed "races" is greater than the variation between them. The concept of race is understood as a social construct with no basis in the biological diversity of the human species. While "The Descent of Man" contains language and ideas that can be interpreted as racist by today's standards, it's also important to consider the historical context in which Darwin wrote and consider whether or not Darwin’s writings were pushing the boundaries (especially in regard to race) of what was the social norm at the time. The scientific evidence of the time was interpreted through the lens of the prevailing attitudes and biases of the era. Current scientific understanding–semenally built upon Darwin’s theories–refutes the notion of biological races and emphasizes the commonality of all humans.

[16] E.g., problems associated with the fact that evolutionary time is incomprehensibly long; the geological record is imperfect; not all fossils have yet been found; it is difficult to make a fossil; classification in nature is often futile; incalculable extinction is guaranteed; migration is pervasive; and, the glacial period caused significant upheaval and movement.

The truth is, most of the once-justified criticism of universality was borne of a time (especially in the first three quarters of the 20th Century) when positivists and neo-positivists exhibited *reductio ad absurdum* and pursuit of objectivity to the exclusion of all other ideals of inquiry. They also dominated academic institutions, marginalizing others with different approaches. Another problematic interpretation of universality is categorizing methodologies to organize our field, and we agree with Gregory [33,34] that this is a stifling action. Indeed, due to the very same concern, Cabrera has consistently fought the temptation of some scholars [20,163,164] to use DSRP as a set of 'buckets' to 'store' various frameworks in. This categorizing flavor of universality (which Cabrera has been extremely critical of in general [165–167]) is not the flavor of universality that we illustrate herein. Such past attempts at these kinds of misguided 'universality' are currently *conflated* with universality as we mean it, and are giving it a bad reputation. But our notion of universality need not be confused with these problematic uses of the term. Indeed, the only requirement for universality is the ontological position that there is some *order* in the universe, ergo there is some *pattern*. If one rejects the existence of order and pattern altogether, then one rejects the notion of 'system', and indeed any scientific endeavor or discipline—without pattern there would be no reason to study anything in an attempt to understand it, as nothing would repeat itself. If there is not a repeating sequence of any kind, there is no order, no anticipation, no prediction, no understanding, no isomorphisms across system types, etc. In other words, one can be against *reductio ad absurdum*, *the pure objectivism of positivism*, and the *use of stifling categorization frameworks*, while remaining fully committed to the search for *universality* and fully aware of its deep and abiding relationship with *diversity*.

Like it already does with diversity, the systems thinking field should seek, continuously debate, and develop *universality*, because it will make the field stronger. As Cabrera laments [18],

> "The question 'what is systems thinking?' cannot be answered by a litany of examples of systems thoughts, methods, methodologies, approaches, theories, ideas, etc. Such a response is analogous to answering the biologist's question 'what is life?' with a long list of kingdoms, phyla, classes, orders, families, genus and species. A pluralistic taxonomy of the living does not provide an adequate theory of life. Likewise, a pluralistic taxonomy of systems ideas [frameworks] does not provide an adequate theory of systems thinking."

In the future, as it is today, the scholar or practitioner who spends their time entirely within the realm of system dynamics, soft systems methodology, or critical systems heuristics is a systems thinker, much like the individual who spends their life studying Pará's Lungless Salamander (Bolitoglossa *paraensis*) is a biologist. But, just as biology has transitioned from being predominantly the study of speciated strains of life into a fully mature science that studies how all life is connected (DNA), how it evolves (evolution), how it can be altered (genetics), and how it interconnects (ecology), the field of systems thinking must expand its horizons. Consider that, as a biologist, you may end up studying Bolitoglossa *paraensis*, but you most certainly will not start there. In order to understand their habitat, DNA, anatomy, phylogeny, ontogeny, evolution, ecological niche, etc.—that is, in order to become an expert in Bolitoglossa *paraensis*—you will need to study the fundamentals of biology. Today, thankfully, we can discover extremely useful, specific treatments and vaccines to a global pandemic *because biologists pursued the*

connection between universality and diversity. It is one thing to be told that a virus exists, but it is quite another to understand the underlying structure that allows for the creation of effective therapies or vaccines against it. The flavor of universality that we propose is akin to DNA, in that it is instrumental and dynamically *involved* in the creation of diversity, not merely retrospectively categorical. As Darwin once beamed concerning the universality of evolution:

> "There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, *from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved [Page 490]*." [161] (emphasis added)

From "*several powers*" (the universality) Darwin says that "*endless forms"* (the diversity) emerged. He did not see the universality of evolution as *limiting* or *constraining* the diversity of life forms, but instrumental to it. Universality does not *detract* from the diversity, it *enables* it.

What we are suggesting for systems thinking is no different than what has played out in the much longer histories of the mature sciences and disciplines. Systems thinking needs the universality underpinning the diversity in order to take the next steps to help societies tackle the widest possible range of complex problems. We hope to impress upon the reader the deep symbiosis between diversity and universality. In many ways, diversity cannot, and does not, exist without universality, even if the latter is not explicitly recognized in systems theory. Consider, for example, the simple question about diversity: 'diversity of what?' In order to define the extent of diversity (in humans, animals, cultures, systems thinking frameworks, etc.), one needs to know what the unity of that diversity is. And, in doing so, one naturally asks, what is it about all this diversified set of things that cause them to 'hang together?' What is the pattern that connects? In systems thinking, if we turn our backs on making this pattern explicit, then potentially anything can be called a systems approach, and our field not only risks the incoherence that disables its accessibility to newcomers, but it is also threatened by a loss of credibility if approaches that many of us would not regard as sufficiently systemic are 'sold' as systems thinking.

This is the path we must take. First, we must establish the boundary that encloses the diversity of systems thinking (and as you will see, there are some important considerations to make about this boundary); and next we must ask ourselves, what is the pattern that connects all of these diverse things that exist inside the boundary?

Establishing the Boundary of the Systems Thinking Universe

Demarcating a boundary for this diversity or plurality of frameworks has been no small task. In 2006, Cabrera [18] suggested such a boundary, which he called the **M**idgley, **F**rancois, and **S**chwarz (or MFS) Universe, because these three authors/editors provided a large sample (if not a complete one) of all the ideas that need to fit under the 'big plurality tent.' [159] Specifically, the MFS Universe includes the 76 seminal papers offered by Midgley [168], Francois's 3800 entries in the *International Encyclopedia of Systems and Cybernetics* [60], and the thousands of nodes depicted in Schwarz's map [169], as seen in Figure 4. There are as many systems as there are objects in the universe. Thus, to truly establish a general

theory of systems or systems thinking, one must first define one's universe and then ask the question that Bateson [170] wisely proposed as a general idea in cybernetics and systems science: What is "the pattern which connects [them all]?" How does one find the patterns that connect such a vast MFS Universe of systems frameworks? The attempt to find general patterns that connect this diversity (depicted in Figure 4) is the search for *universality*.

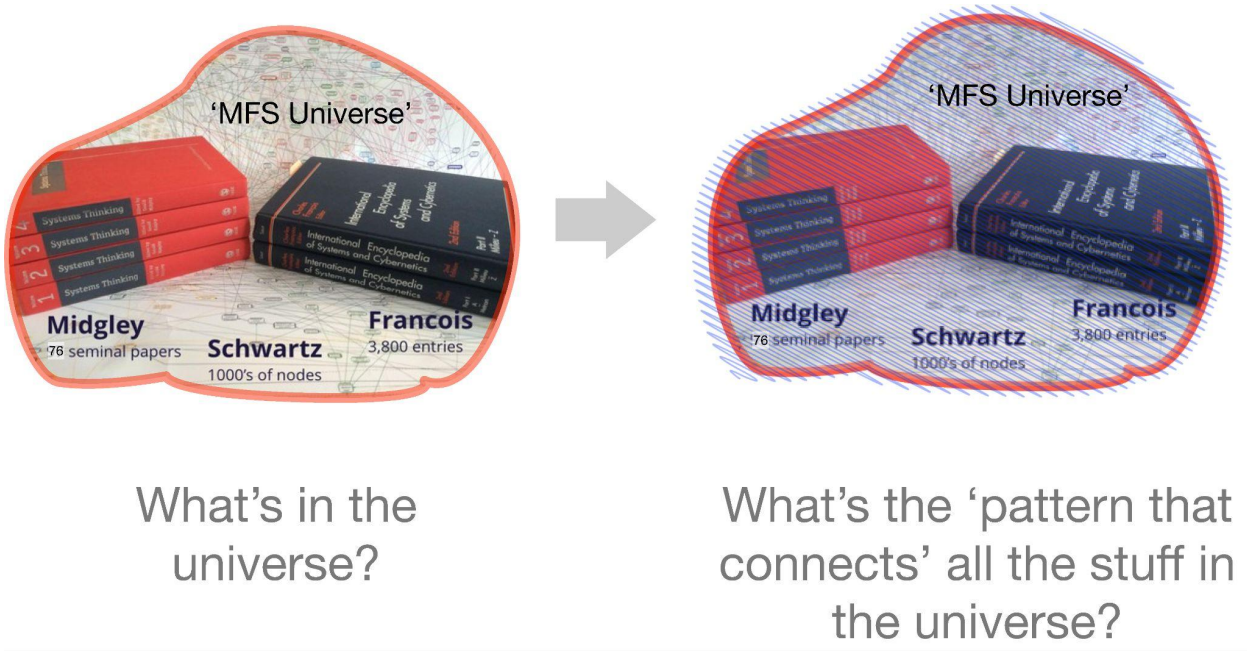

Figure 4: A two step process for universality.

This 'two step process for establishing universality' is an important point because, as mentioned previously, there are many within the systems thinking field who will react negatively to the mere mention of universality. They could decry it as *positivist* and *reductio-ad-absurdum* (two of the most vitriolic epithets a systems thinker can use!). But let us be clear about what is being said about universality, so that we may *pre*-dispel the rhetoric, hyperbole and ad hominems: *First*, the drawing of inclusive/exclusive boundary distinctions is one of the most *basic* systems thinking acts [35]. We need to be explicit about what's in, what's out, and who decides, and we can debate viewpoints on this if there are different boundary judgments that could be valid or legitimate. *Second*, perhaps one of the most important systemic questions ever asked is, *What is "the pattern which connects?"* This comes from Gregory Bateson ([170], p.8). *Third*, not only is it absolutely essential to look beneath superficial events for the underlying 'patterns that connect,' but one of the most recognizable systems thinking tropes—the systems thinking iceberg [171]—extolls us to do so. We must look for the underlying structure (see Figure 5).

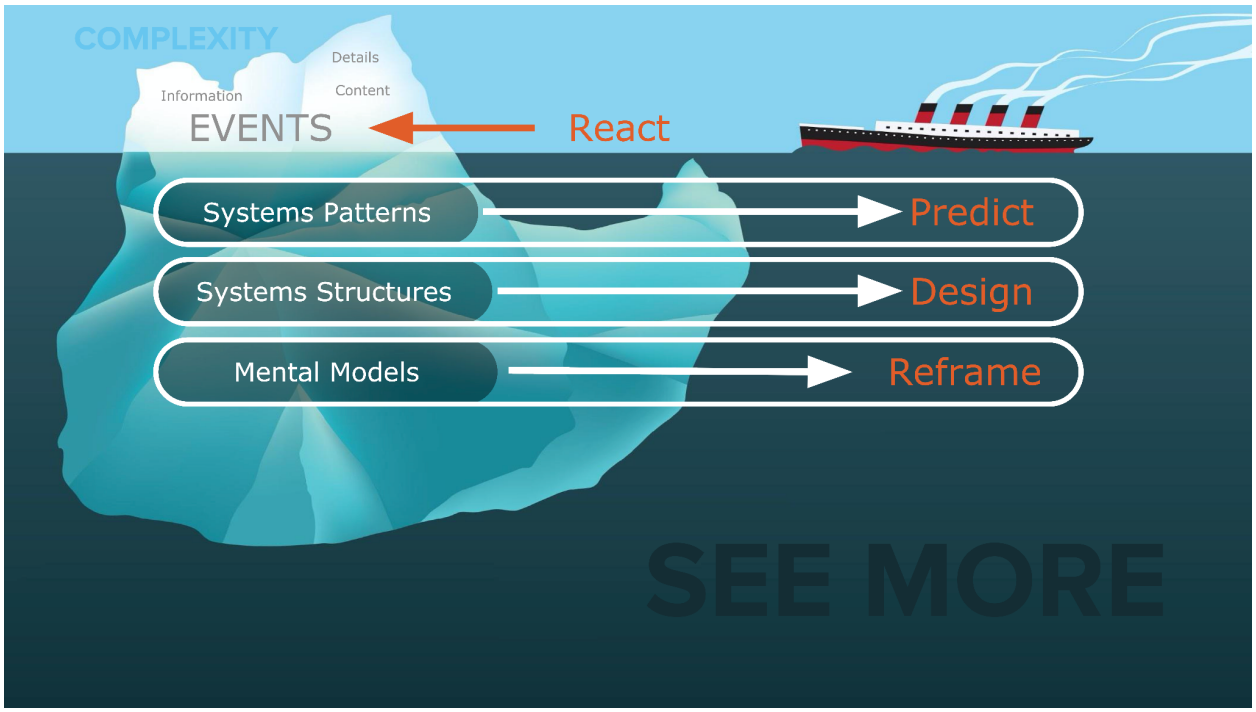

Figure 5: The Systems Thinking Iceberg (adapted from Senge [171]).

Thus, a person who reacts negatively to the mere mention of *universality* needs to ask him or herself: How does doing *to* systems thinking the same thing that we tell everyone they *should* be doing *to* systems (i.e., thinking systemically about them), become anti-systems thinking (i.e., absurdly reductionistic and positivist)? The answer is, it doesn't. There's nothing inherently positivistic or absurdly reductionistic about universality. In effect, what Cabrera did to discover DSRP theory was as simple as asking the most basic systems thinking questions, recursively, about systems thinking itself:

1. First, what is in the systems thinking universe?
2. Then, what are the underlying patterns/structures that connect stuff in the systems thinking universe?
3. Then, what are the patterns/structures that connect systems (i.e., ontological systems)?
4. Then, what are the patterns/structures that connect thinking (i.e., mental models or epistemological systems)?
5. Finally, [recursively] what are the **patterns/structures that connect** the **patterns/structures that connect systems** *and* the **patterns/structures that connect mental models**?

Answer: DSRP. As the origin point for the fourth wave, DSRP theory proposed four universal patterns that underlie systems thinking: as discussed previously, these are identity-other distinctions (D), part-whole systems (S), action-reaction relationships (R), and point-view perspectives (P). In other words, these 4 patterns connect all of the frameworks of the MFS Universe.

Actually, it turns out that the universe that 'belongs' to systems thinking is much broader than the frameworks of the first three waves alone. We can expand this universe by asking, not merely which systems thinking scholars and forms of scholarship (frameworks) comprise the MFS Universe, but rather,

what types of people are thinking about what types of systems in what types of ways (generally speaking)? [114] To better understand this expansion of the universe that we are dealing with, we can begin with asking a simple question: *What is a system?*

Expanding the Boundary of the Systems Thinking Universe

To understand systems thinking, one must answer in very specific terms, *what is a system?* That seemingly simple question yields a significant variation of responses that are consequential to the field and to how related inquiry is shaped. If the theorist chooses too narrow a boundary, then the type of system they define will be quite narrow as well (i.e., very specific). Some scholars include *purpose* as a necessary part of the definition of a system; others say the system's behavior *is* its purpose; others say system structure determines behavior (and therefore purpose); and still others do not include purpose at all. Defining what a minimal system is does not mean that we cannot *add* to the definition. It only means we cannot *subtract* from it. For example, if you want to define a *human developmental* system, we may want to include micro and macro factors, genotype and phenotype, environment, motivation, etc. The theorist can clearly see that the choices he or she makes will in turn affect what they look for and find.

Nearly a decade after creating the concept of the MFS Universe, Cabrera retrospectively urged us to reconsider it [17,18,25,130]. Rather than looking at which *systems thinking scholars and frameworks* should be included in the universe (the plurality), Cabrera suggested that we should be looking at which *people and systems* should be included. In order to do this, Cabrera suggested, we must first ask ourselves what constitutes the minimum viable concept of a system, so that we can look at which systems must be included in the 'universe.' Cabrera [159] suggests that the minimum viable concept of a system is two or more related parts from a perspective, involving several boundary distinctions[17] (Figure 6).

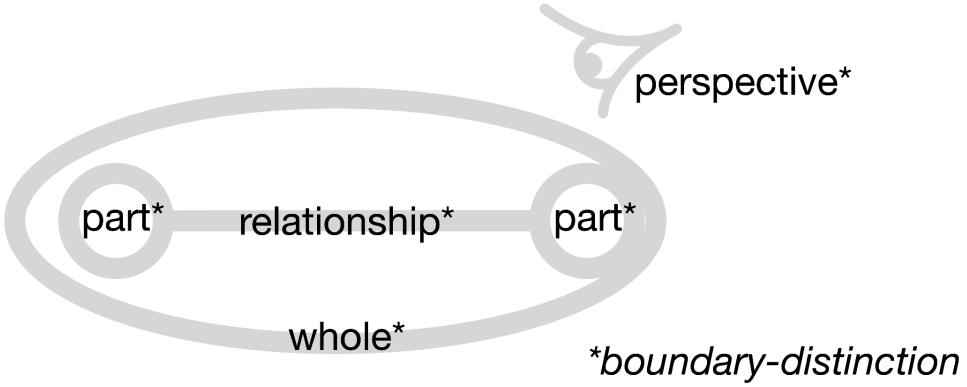

Figure 6: The Minimum Viable Concept of a System.

This is the most inclusive definition of a system, which casts a wide net and creates a big tent. Thus, most of the things in the universe *are systems*. Additionally, we know that ‘nothing exists in a vacuum,’ such that, for something to exist, *nothing* must also exist [172]. In other words, there is identity-other structure, which means that, for any one thing to exist, it co-implies that a *not*-thing exists. Therefore, any single

[17] Note that implied in this definition is the existence of bounded distinctions, not merely for the system itself, but also for the perspective, the parts, and the relationship.

thing has a co-implying relationship with the things (or not things) that it is not. Even the most rudimentary thing, entirely isolated as it may appear to be, is still (at least in its history or its potential) a system. *Everything*, in some respect, is a system. In this case, we are not just including in the universe every systems concept from the field of systems thinking—but *everything* in the universe.

So now we can ask ourselves, *what is the thinking that applies to everything in the universe*? This considerably expands the scope of systems thinking as a field, as it includes people who are *thinking* about *systems* of all kinds. A physicist would answer this question with the fundamental laws of physics. But a physicist is just one type of scientist—providing one perspective among many—interested in certain types of phenomena based on certain types of knowing. What about others? What about a biologist, sociologist, entrepreneur? Or what about a skateboarder or quilter? Surely, by the law of computational equivalence,[18] the systems that skateboarders and quilters are interested in are equally complex and sophisticated. So what would they say? And, since behavior is a far more consequential indicator of beliefs or mental models than one's words, the more important question is, *what would these people do*? Or more specifically, *what do all people of all types do when thinking about all of the systems that are important to them*? In other words, even though they think about different systems, and their thoughts about those systems yield dramatically different specific content, what are they all doing that is the same? What are the patterns that connect?

By way of a simple example, a physicist distinguishes a *force*, a sociologist distinguishes a *norm*, a quilter distinguishes a *stitch*, a skateboarder distinguishes a *trick*. Forces, norms, stitches, and tricks have little in common, so what do we do? A physicist says, well, they are all the result of fundamental forces, so physics is the answer. But a quilter says that, while the physicist may be saying something true with reference to a scale of 10^{-5} meters (0.000000000001 meters or 1 picometer) it does little to inform my practice at the human scale of 10^{0} meters. Or alternatively, the quilter might say, even if gravity (which is part of the physicist's domain of inquiry) affects my stitching, which it does, it isn't affecting it in a way that knowing the equations for gravity will aid that stitching. They could of course disagree, with the physicist arguing that the equations would indeed be useful to the quilter; but *in practice*, sociologists, quilters, and entrepreneurs aren't factoring gravitational force or the fundamental laws of physics into their daily, minute-to-minute decisions. Thus, when physicists talk of a theory of everything (TOE), they really mean a TOE that applies to everything in the universe *from the unique perspective* that physicists have decided is important.

A theory of everything, technically speaking, should be more generalizable. One would imagine that if you had a theory of everything—a true TOE—then it would be applicable to *everything* and therefore

[18] Cabrera (2006, p. 61) explains, "Even if one studies an open system and achieves balance in focusing on both parts and whole, it is not clear how thinking about a system becomes systems thinking. In other words, the systems thinking one is doing to study X is going to be considered reductionist or atomistic thinking by another researcher who studies Y, which includes, among other things, part X. If every part is itself a whole, how can we ever truly claim systems thinking? The situation becomes even more complex when one considers the theory of computational equivalence, in which 'all systems of sufficient complexity are equally complex.' If Wolfram is right, then any system of sufficient complexity—by which he means any system that appears complex, like a slime mold or a human or a society, but not like a rock—is equal in complexity to any other system. Wolfram's theory makes an important point: a scientist studying the eye of a fruit fly and a scientist studying the Amazonian rain forest may be studying two different systems that are equally complex. One is prone to incorrectly argue that the fruit fly's eye is part of the fruit fly system that, in turn, is part of the Amazonian ecosystem and, therefore, that the ecologist is more of a systems thinker than the entomologist."

useful to *everyone* [108,173]. Returning to our simple example, we see that we are likely looking at the wrong unit of analysis:

> A physicist *distinguishes* a force, a sociologist *distinguishes* a norm, a quilter *distinguishes* a stitch, a skateboarder *distinguishes* a trick.

In this example, we see that the different thinkers are all distinguishing something of importance to them from other things of importance to them. In other words:

- A *force* gets its specificity, meaning, identity, and definition from a differentiation from other concepts in physics (e.g., energy and motion);
- A *norm* gets its specificity, meaning, identity, and definition from a differentiation from other sociological concepts (e.g., deviance and class);
- A *stitch* gets its specificity, meaning, identity, and definition from a differentiation from other aspects of quilting (e.g., a cut or a design); and
- A *trick* gets its specificity, meaning, identity, and definition from a differentiation from other aspects of skateboarding (e.g., kicking off, riding and stopping).

Likewise, particular kinds of force, norm, stitch, or trick get their specificity, identity, and definition from differentiations from other forces, norms, stitches, or tricks (i.e., for force, gravitational, electromagnetic, strong, and weak; for stitches, simple stitches, running stitches, back stitches and chain stitches; for tricks, ollie, frontside 180, backside 180, pop shove-it, frontside pop shove it, kickflip and heelflip, etc.)

Thus, we can say that people universally *distinguish* in order to better understand the systems they think about. When they distinguish, they distinguish between *identity* and *other*. Running stitch is not chain stitch, and vice versa; an electromagnetic force is not gravitational, and vice versa. Ironically, this simple example also shows how universal the DSRP patterns are, because for physicists, the four forces they distinguish make up a set—a *system* of parts making up a whole called 'the fundamental forces.' These forces, both as conceptual parts of the conceptual whole and in actuality, are *interrelated*. And all of that thinking occurs from a particular *perspective*, as the fundamental forces of a volcano[19] are not the same as the fundamental forces of the known universe. In a similar way, we can see that, in order to define a quilting stitch, we distinguish it from its near-neighbors (other stitches), which together forms a part-whole system of 'quilting stitches,' each of the parts of which can be interrelated—and all of this occurs from a unique perspective (in this case, the quilter's perspective). All of which is distinguished from the stitches defined by surgeons (i.e., purse-string stitch, figure-8 stitch, subcuticular stitch, etc.).

Summary of Evidence for the Universality of DSRP theory

The evidence-base for DSRP theory is extensive [18,46–50,108,109,174] (also see [132]) in the systems sciences, systems thinking, cognitive science, and neuroscience literatures, as well as across the disciplines, from physics to sociology. A summary of a vast literature is often difficult, if not inadvisable. This holds true for systems thinking, which is of interest to scientists and academics, as well as practitioners and the general public. For this reason, we have tried to summarize the literature in a way

[19] Thermal convectives leading to fluid molten material in the mantle along with gravitational effects on the Earth (e.g., erosion, deposition, etc.) drive plate tectonics and subsequently volcanism.

that is accessible *and* maintains fidelity to what the literature says. A summary of the transdisciplinary literature relating to systems thinking points to the following conclusions:

1. There is a *universality* of certain structures (DSRP), namely:
    a. Identity-Other Distinctions — D($i \rightleftarrows o$)
    b. Part-Whole Systems — S($p \rightleftarrows w$)
    c. Action-Reaction Relationships — R($a \rightleftarrows r$)
    d. Point-View Perspectives — P($\beta \rightleftarrows v$)
2. These DSRP structures exist in both mind (cognition) and nature (a.k.a., reality);
3. Awareness of these structures (a.k.a., metacognition) makes a significant difference in all walks of life, and success in all domains; and
4. Systems thinking is an emergent property of the DSRP simple rules.

It is increasingly clear that these D, S, R, and P structures cannot be separated from each other. In other words, they are in a constant and dynamic interplay. It is clear that all of the D, S, R, and P structures are *necessary* and *sufficient* for each of the individual structures (DSRP) to exist. This means that, in order for an S (part-whole system) to be formed, Ds (distinctions) need to be made, Rs (relationships) need to exist, and Ps (perspectives) need to be taken; and it is the same for the others—each one requires the other three. In addition, any given D, S, R, and P structure cannot be divorced from its two elements, and nor can the elements be divorced from each other. For example, we are near-constantly making identity distinctions (D*i*), and more often than not unaware of the *other* distinctions (D*o*) we are implying. Nevertheless, they exist. Said another way, it is impossible *not* to make distinctions, connections, groupings, and framings.

That DSRP structures exist in both mind (cognition) and nature (a.k.a., reality) is perhaps read as a philosophical statement, but it is based on *empirical* findings [18,108,109,174]. It does not mean that every DSRP structure that we build in our minds exists in nature, or vice versa. It means that the D, S, R, and P structures are found in both realms. This is important because it tells us something about one of the goals of systems thinking: to increase the *probability* that our mental models are in *alignment* with reality and that our predictions (what will unfold ahead of us in reality) have a higher probability of 'getting it right.' Working with a set of structures that is common to both mind and nature—akin to finding the same denominator to add fractions—is an essential first step in increasing the probability of alignment[20] between our *thoughts* (mental models) about the real world and the *actual* reality in which they exist (including the predictive or anticipatory nature of our thinking and reality).

Two further well-known goals of systems thinking are also enhanced by DSRP: (i) exploring possibilities for addressing uncertainties, and/or (ii) taking future action: we can think about what will, can, could, would or might be, either now or if we undertake an intervention. The capability that enables this is *anticipatory* thinking: what Cabrera calls 'structural predictions' [21,111,175–177] (also see [111]): we can rethink boundary Distinctions, explore different part-whole System configurations, take different Perspectives, and look for possible new Relationships. This kind of critical thinking generally has to be anchored in an alignment with unfolding reality, as the conditions surrounding a given uncertainty might

[20] We have deliberately chosen the word "alignment" here because it indicates increasing the probability of sufficient congruence to enable survival/thriving. This is not about knowing the "truth" about reality in any absolute sense. [68,131].

be relevant to addressing it, and action for change has to take us from the current situation to a new one, so knowing about that current situation and its likely evolution matters.

Finally, *deliberate departures* from alignment with unfolding reality can produce creative fantasies, ranging from scenarios that are just a small plot twist away from our current status quo, to totally surreal worlds that are hilarious in their absurdity. The creation of 'what if' scenarios or creative thinking can be aided by DSRP. What if we Distinguished a universe existing within each living cell? What if our known universe was just a part of a larger System with different physical laws? What if it was possible for an altered mind to establish Relationships with the minds of others and exert control over them? What if we took an unusual Perspective, such as that of an insect living in our house? It is clear that DSRP can underpin the creation of fiction as well as fact. Given strong claims in the fields of systems thinking and systems science that what we do is transdisciplinary (i.e., using ideas that work across disciplinary boundaries), it makes sense to us that this should not only work for the sciences (e.g., [178]), but can extend into the arts too.

***Awareness* and capable use of these DSRP structures constitute 'systems thinking skills'**. *Cognition* often occurs, whether we like it or not, in ways that we are unaware of. *Metacognition,* or the awareness of *how* we think (in D, S, R, P structures and dynamics), shows us the structural underpinnings of the mental models we build about the unfolding world. This structural understanding further allows for the identification of gaps in our knowledge, and provides insights into how to fill them. DSRP can be thought of as a set of metacognitive *skills* that can be taught, learned, and practiced [28,51,126,179–184]. The Systems Thinking and Metacognition Inventory [114,115,185], or STMI, is a validated edumetric test of these four skills. The STMI measures individual mental capabilities and processes to think systemically; i.e., to think about one's thinking (metacognition). The STMI serves as a tool and resource to help educators, institutions, and individuals track their progress in developing systems thinking skills.

The idea (mentioned earlier in this section) that systems thinking is an emergent property (i.e., it is a Complex Adaptive System or CAS) [18,21,23,111,186,187] is a significant shift in pragmatic terms. It means that if one wants to 'do systems thinking' or 'get better at (developing the skill of) systems thinking,' one must recognize that systems thinking itself is an emergent property of a process. It is not something you can 'do' per se, but is rather something you 'get' when you do DSRP. Although 'doing DSRP' does not require metacognition (it is hypothetically possible for a person to be good at doing DSRP without knowing it), being aware of the DSRP structures (metacognition) significantly increases the probability of one 'doing DSRP' and therefore 'getting systems thinking.' It also means that (technically speaking) neither DSRP, nor the various frameworks launched in the first three waves, are 'what systems thinking *is*.' Systems thinking is a complex and adaptive system, an outcome—an emergent property—of the DSRP simple rules and information agents. While those multiple frameworks/methodologies from the first three waves might not *be* systems thinking, they can usefully support the operationalization of the DSRP elements in complex combinations that are useful for different purposes (and the many visualization and modeling techniques that come with the frameworks likewise aid operationalization) [33]. At the same time, such frameworks and methodologies may lead to 'hammer-nail' bias—where to a hammer every problem appears like a nail—if they are regarded as the "one best way" to do systems thinking [9] or simply preconceived biases posing as frameworks, and practitioners may be better served by creating bespoke models for novel situations and problems based on

the atomic elements of DSRP [46–50,109], borrowing from the frameworks and methodologies as required by the circumstances. It is in the sense that the frameworks represent limited manifestations of DSRP that they are *systemic*, although simply knowing how to implement one of them is not enough for successful practice, as there needs to be an alignment with the purposes and context of an intervention too [6,7,35].

Universality Reveals New Structures and New Futures

As we consider the potential for a fourth wave of systems thinking and contemplate both its *diversity* and *universality*, it becomes clear that our new understanding of the universal, atomic structures of DSRP provide opportunities to see the field in a new light that was heretofore hidden from our view. It becomes increasingly clear, for example, that we must look beyond the boundary of systems thinking as a field (originally established within DSRP theory as the MFS Universe) made up of *scholars and scholarship*, and look instead to *the varied ways that varied people are thinking about various systems*. It becomes easier to see that the Systems Thinking Loop (Figure 7, step 1) provides something akin to the evolutionary process of systemic thought, but without the specificity of DSRP, it is akin to Darwin's theory of evolution prior to Mendel, Watson and Crick and their discoveries of hereditary traits and DNA. With DSRP, we see not only the *importance* of mental models, but how they are fundamentally structured. We see (Figure 7, steps 2 and 3) that the fundamental structure of mental models includes DSRP Structures *and* Information content. Thus, we begin to see how different 'pieces' of knowledge can look altogether different at the level of *information-content*, but may be very similar *structurally*.

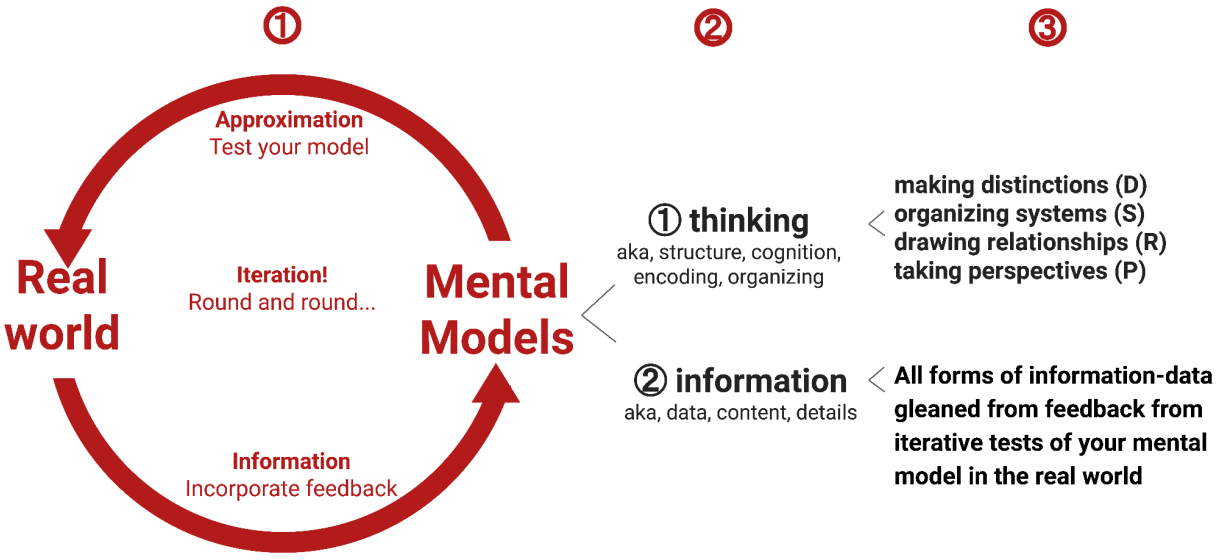

Figure 7: The Systems Thinking Loop and Its Information-DSRP Structure [21].

It is important to note that this dual-structure of mental models (information and DSRP universals) is what allows universality and diversity. The infinite combinations and permutations of structural variables combined with infinite informational values means that an infinite diversity is possible, despite its universal structural basis. In addition, there are structural and dynamical aspects of DSRP itself (namely the identity-other Distinctions (D*io*) variables and the point-view Perspectives (P*ṗv*) variables, that make DSRP intersubjective (i.e., the opposite of universal objectivism) and therefore capable of underpinning tremendous diversity. Intersubjectivity (made possible by DSRP) , along with subjectivity and objectivity, is essential to applied systems thinking [86].

Where should future development focus?

Importantly, the advent of DSRP structures provide us with a quantifiable basis upon which to differentiate types of mental models based on the *ratio* between structure and information content (i.e., how much is purely structural versus informational). In other words, the DSRP structures provide new insight—much in the same way that the discovery of DNA did—into other types of structures that are differentiable based on the ratio of information to structure. DSRP structures provide insight because they are 'atomic'—they are a set of universal building blocks. In turn, we begin to see the underlying pattern of structure and information which reveals new structures: 'molecular,' and 'compound' structures [114,188–190]. Let us clarify what we mean:

Atomic Structures[21]: These are structural only, and thus information-agnostic. The four structures of DSRP, each with a pair of elements, are not reducible to simpler structures. In other words, they exist at the base of things. Atomic structures are universal. In the case of systems thinking, we are referring to identity-other Distinctions, part-whole Systems, action-reaction Relationships, and point-view Perspectives. As is shown in Figure 7, a mental model ($\mathbb{M}$) is the complex product ($\otimes$) of information ($\mathbb{I}$) and DSRP simple structural rules of thinking ($\mathbb{T}$) shown in Table 2. Thus the definition of a mental model: $\mathbb{M} = \mathbb{I} \otimes \mathbb{T}$.

The Identity-Other Distinctions Rule	
D := (*i*↔*o*)	A Distinction (D) is defined as *identity* (i) co-implying an *other* (*o*)
The Part-Whole Systems Rule	
S := (*p*↔*w*)	A System (S) is defined as *part* (*p)* co-implying a *whole* (*w*)
The Action-Reaction Relationships Rule	
R := (*a*↔*r*)	A Relationship (R) is defined as *action* (*a*) co-implying a *reaction* (*r*)
The Point-View Perspectives Rule	
P := (*ṗ*↔*v*)	A Perspective (P) is defined as *point* (*ṗ*) co-implying a *view* (*v*)

Table 2: The universal structural simple rules of thought [21].

[21] Also called 'universals,' 'universal patterns,' 'simple rules,' 'universal structures,' 'structures,' and 'patterns,' or 'patterns of thinking'.

These atomic structures can be combined to form even larger *molecular structures of thought*.

Molecular Structures: These are combinations of atomic structures that are almost entirely structural and mostly information-agnostic, or so information-general as to be effectively agnostic.[22] They are a group or set of atomic structures that come together to form a more complex structure. These structures are not universal, but they are found generally across domains. A 'jig' or 'move' [114,189,191] is the prime example of a molecular structure (see [114]). A 'move' is simply the act of applying a jig (a structure). There is a process for discovering molecular structures (a.k.a., jigs or moves), and a relatively strict definition for what constitutes one, but they are not easy to discover, which is especially true as more and more are found. By today's count, we have discovered 43 cognitive jigs/moves [192]. Examples of molecular structures include: analogies, metaphors, similes, feedback loops, hierarchical trees, and a circle of perspectives around an object or phenomenon. Take, for example, the very well-known framework called SWOT (Strengths, Weakness, Opportunities, Threats) Analysis, which is typically provided in a four quadrant framework. The quadrants can take additional information. Note, however, the difference between SWOT (which is a compound structure) and its molecular predecessor in Figure 8.

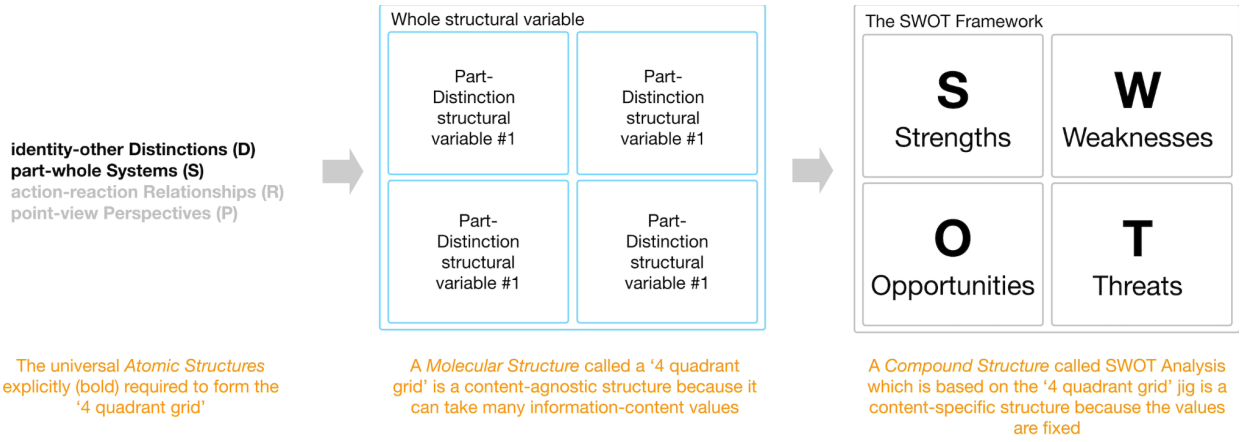

Figure 8: Using SWOT to Differentiate Atomic, Molecular, and Compound Structures.

Note that the information content (the values attributed to the structures) are specific and required in the SWOT Analysis framework (much like most systems thinking frameworks). These content-specific quadrants can in turn take additional information values. However, if we were to remove the specific informational-content (i.e., Strengths, Weakness, Opportunities, Threats), then it is no longer the SWOT Analysis framework. It is just a generic four-quadrant empty structure that *any* type of information-content can be added to. In other words, if we remove the content specificity, then it becomes a molecular structure or 'jig' that we might call the 'four quadrant jig'. We can see, too, that this Molecular Structure is made up of two Atomic Structures, D and S. Thus, Molecular Structures are relatively

[22] Content-agnosticism means that the information content (value) associated with a structural variable is irrelevant (it could be anything). Content-generality means that while the information content (value) associated with a structural variable is prescribed, it is so general in nature as to effectively be (almost) universally generalizable across domains and applications. An analogy is a good example of such a structure, as it requires specific information content (is, is like) that is very general in nature.

information-independent structures, and they in turn make up even larger, more complex information-dependent phenomena called *Compound Structures*.

Compound Structures: These are more complex derivations of atomic structures (often including molecular structures) that are information-specific, information-dependent, and usually more specialized in their application as a result. They are a larger, much less general group or set of structures with increasing content-specificity, and therefore increasing specialization (in terms of application). Compound structures include *all specific mental models* (therefore all human knowledge) such as frameworks, methods, conceptual models, approaches, etc. That is, any mental model in which the specificity of the information is necessary. If we can remove the information and the model remains the same, then it is *not* a compound structure. Examples include all of the frameworks in the MFS Universe, all DIY, self-help, developmental 'sliders,' [189,191,193] as well as all frameworks of knowledge of various kinds (scientific, folk, experiential, etc.; a.k.a. all of science and all of human knowledge).

Figure 9 illustrates how four *atomic structures* or distinctions, systems, relationships, and perspectives lead to even more *molecular structures* or 'jigs' that subsequently roll up into numerous *compound structures* or mental models, frameworks, etc., found in every discipline, that are relevant to the near-infinite number of people, systems, or problems that exist. This figure also illustrates, on the right, the driving differentiator of these distinctions: *increasing content-specificity and specialization* or *increasing content-agnosticism and universality*. In other words, moving from the atomic structures to compound structures *increases* content-specificity and specialization.

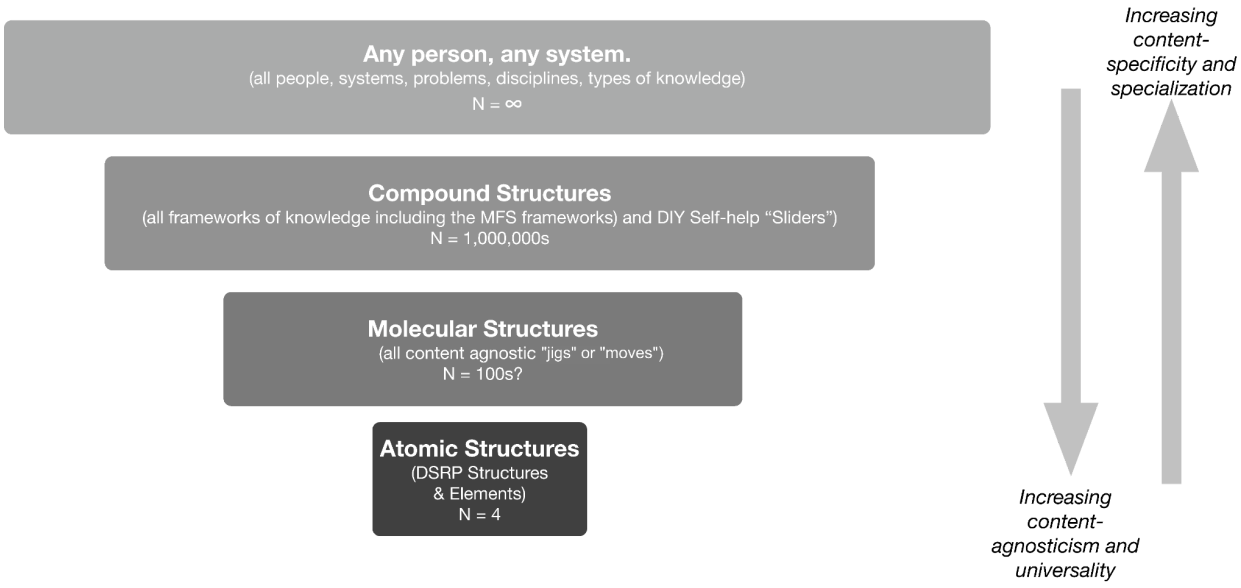

Figure 9: Atomic, Molecular, and Compound Structures.

As indicated in Figure 9, we see that, as we go 'up' in the world, we *increase the information-content specificity* and *the specialization* of mental models; and as we go 'down' in the world, we *increase the content-agnosticism* and *universality*. This understanding in turn reveals differences in the *ratio of information-content to structure*, which becomes important in determining the broad utility of mental

models. The recognition of these structures (again, made possible and quantifiably distinguishable by the advent of DSRP) has significant implications for the future path and trajectory of systems thinking. The question we must re-ask ourselves is, how do we establish the *boundary* for what defines the *diversity* of systems thinking? Should we—as we have mostly done in the past and up until now—*only* include *frameworks* (compound structures) developed by *systems thinking scholars* in the *field of systems thinking scholarship (e.g., the MFS Universe)*?

Or should we consider a far larger boundary of compound structures based on *the varied ways that varied people are thinking about various systems*? This may at first seem like a silly question, but if system dynamics and soft systems methodology (two well-known approaches to systemic modeling for intervention) are considered systems thinking frameworks, is SWOT Analysis[23]? What about CRISPR[24]? Is Evolutionary Theory? Newton's Second Law? Network Theory? Chaos Theory? Total Quality Management (TQM)? What about Covey's Seven Habits of Successful People? Design Thinking? Or, your grandma's time-tested recipe for fried chicken? What, or who, determines that system dynamics, or critical systems thinking, or soft systems methodology, are card-carrying members of the systems thinking Universe? What or who determines whether *any* framework designed to help people understand a particular system or solve a particular problem is part of the systems thinking Universe? What, or whose, rationale or logic is used to determine what is in and what is out? This is an important question about power and legitimacy that is core to the methodology of critical systems heuristics [77], so in asking it, we are effectively applying a systemic question to systems thinking itself. We suggest that "*the varied ways that varied people are thinking about various systems"* provides a good litmus for inclusion in the systems thinking Universe.

This expansion of the boundary creates an interesting tension between the *ideal* of inclusion (just explained) and the *current realities* of inclusion, which have evolved in various parts of the (somewhat fragmented) systems research community. A defined set of human beings (like a research community) will always be operating with boundaries that enable the exploration of particular foci, and therefore they put other knowledge that has the potential to be viewed as part of systems thinking outside their remit. This is inevitable [35,77], and will continue, but awareness that the ideal of inclusion is broader than our current boundaries of inquiry (in part established by convention) gives permission for 'explorers' to journey into other knowledge domains in search of systemic ideas that might make a difference to our thinking and practice.

Expanding the boundary causes us to ask different andragogical/pedagogical and developmental questions as well. As we consider the most effective way to train for personal mastery and skill development in systems thinking, are we better off teaching people the frameworks (e.g., the *field's* compound structures, such as system dynamics, systems engineering, soft systems methodology, critical systems thinking, viable system model, etc.), or should we focus on *atomic and molecular structures* rolling up into a broader set of compound structures that transcend the currently defined systems thinking field? We suggest that the realization of atomic universals leads us to see a whole new layer of structures (molecular structures) that precedes the frameworks that are currently considered 'systems thinking,' and this causes

[23] Strengths, Weaknesses, Opportunities, and Threats— a popular policy analysis model [194].
[24] Clustered Regularly Interspaced Short Palindromic Repeats— a family of DNA sequences.

us to expand upon the compound structures that are included in this latter group—thereby massively expanding the domain and applicability of systems thinking to what we believe is its rightful status. Although our experience, basic logic, and some research [26] point to our conclusions, this is not yet a settled empirical question. Time will tell.

In other ways, it becomes a question of leadership. The question is twofold: (1) whether to focus the field's efforts more on the development of atomic and molecular structures? Or (2) whether to significantly expand the compound structures well beyond the domain of current systems thinking scholarship to "any person, any system?" [108] We think the answer is yes in both regards, if for no other reasons than (1) the atomic and molecular structures are more generally applicable, useful, and adaptive, and (2) the domain of systems thinking's applicability will grow, opening more opportunities for us to make a difference in practice. Atomic and molecular structures are more adaptive because they can be mixed and matched, combined and recombined, adapted and altered, to build entirely new compound structures, oftentimes on-the-fly. Rather than just use off-the shelf frameworks (like system dynamics or soft systems methodology), systems thinkers in this new context will need to build ready-made, bespoke, custom frameworks that are ideally suited to the job at hand [37,114,115,188–190,195–198]. As an example, where system dynamics is a compound structure (framework), one of the concepts that was popularized through the methodology is 'feedback loops,' which is a molecular 'jig' or 'move' structure. Which of these structures is more universal? More useful? More used? More adaptive in its use with other structures? More combinable? The answer is clear: the molecular 'jig' structure of feedback loops. If we face both *novel and wicked problems that are framework or model resistant*—which we suggest is common—success depends on the systems thinker's ability to *adapt* in situ to real-world, on-the-ground information, and the atomic structures (DSRP) and molecular structures (jigs or moves) provide adaptive capabilities.

This sets the stage for a different future for systems thinking as a field. The universality of DSRP theory causes us to ask fundamentally different questions, much like the advent of evolution, hereditary traits, and DNA has done in biology. Not that the old questions aren't still important, but we may start to ask them in slightly different ways, and there may be even more important, as yet unanswered, questions to be framed. Examples of the kinds of different questions we can now ask that will guide the systems thinking field in the future include:

- How can the universal structures (DSRP) of systems thinking be used to characterize the strengths and weaknesses of existing systems thinking frameworks (across the waves) [33]?
- How can these structures be used to improve various methods and methodologies, such as those represented in this *Handbook*?[25] For example, how do the universal DSRP structures extend the first wave frameworks of systems engineering (see [91]), network theory (see [111]), and agent based modeling (see [199]).
- What are the best ways to visually map the structures of systems thinking? How can we make visual mapping, and the systemic visual and logical grammar that underlies it, more accessible to all people so that they can use it to understand and improve any system (see [200,201])?

[25] This is a very big question, and one that drives the contributions contained in this *Handbook*. This single question represents a tremendous amount of research and practitioner work to be done.

- What can we learn, through effectiveness studies, of how the structures of systems thinking improve learning, school and university education, executive education, problem solving, creativity, etc.? What are best practices in the teaching and learning of systems thinking skills, from novice to expert (see [112,114,115,202,203])?
- How can the universal structures of systems thinking be used as a vehicle for making *structural predictions* and aid innovation, invention, creativity, future scenario planning, and new knowledge discovery (see [108,111,204])?
- How can the universal structures of systems thinking be used to decrease one's cognitive biases (see [109,111,203,205,206])?
- How can the universal structures of systems thinking be used to increase one's personal mastery, professionally and personally (see [114])?
- What is the relationship between systems thinking and other forms of thinking, like cognition, metacognition, critical, scientific, analytical, creative, interdisciplinary, interpersonal, prosocial, structural, and visual thinking (see [114,115,201,203,207])?
- Are there existing molecular structures that have not yet been explicated? Are there molecular structures (jigs or moves) that are globally generalizable (to all disciplines and types of knowledge)? Are there molecular structures (jigs or moves) that are locally generalizable (within a single discipline) (see [114])?
- How should we continue to pursue theory, basic, and applied research into universals? For example, how precisely do boundary distinctions form, both in mind and nature? And, how do they correlate? How precisely does hierarchy, permutation, and combination, belonging, and containment result from the configuration of part-whole structures, both in mind and nature? And how do they correlate? How precisely do causality and connectivity patterns result from the configuration of action-reaction structures, both in mind and nature? And how do they correlate? How precisely do emergent patterns of empathy, compassion, insight, physical, spatial, and anthropocentric forces, and bias, etc., result from the configuration of point-view structure, both in mind and nature? And how do they correlate? (see [132,206])
- How does an understanding of the structure-information make-up of mental models drive new insights in the cognitive sciences (see [207])?
- How can the universal structures of systems thinking be used to enhance interdisciplinary, multidisciplinary, and transdisciplinary practice? In what ways do they provide a common language to attack Tower of Babel problems? What should continued research into the universal structures of systems thinking across all domains and within specific domains look like to support the transcendence of disciplinary boundaries and transformation/evolution of specialist jargon (see [132,206])?
- How can we develop better practices for helping disciplinary experts to transform their fields by using the universal structures of systems thinking to determine what 'Systems X' (e.g., systemic evaluation, systems engineering, systems neuroscience, systems education, systemic leadership, systemic innovation, etc.) should mean to them (see [91,92,110,113,199])?
- What does systems thinking look like in the organizational domain, and for leadership and management practice? How do systems thinking structures occur at local and global agent levels in individuals, dyads, groups, etc? How does culture form as an emergent property of mental models, and how does culture then feedback to enable and constrain those models (see [92,115,203,208])?

These are just a few of the more general questions, and there are many, many more specific ones, some of which are addressed in this *Handbook*. These new questions illustrate the different approach to *diversity* that our newfound *universality* makes possible.

Indeed, it is possible that the future of the systems thinking frameworks from the first three waves may depend on the universal structures of the fourth wave. There is an old educational/parenting expression which states that our job is to give our children roots and wings. To a large extent, the universality of the fourth wave provides roots and wings for the diversity. Roots to keep them grounded and connected: the acknowledgement that these frameworks share a similar 'DNA,' or that they are 'birds of a feather.' Each framework is connected by the ‘patterns’ of DSRP. But the universality of the fourth wave also provides wings. Its value as a tool for making structural predictions allows scholars and practitioners to extend, not only any given framework or method, but any given thinking about any given system.

For example, take system dynamics. This approach is powerful. It does a lot of things really well. But where can it improve? An answer is by better accounting for Perspectives (Ps), and transforming relational entities into 'RDSs' (relationship-distinction-systems) [21,176]. Also, nesting system dynamic networks inside of each other (S-nestedness). Some of these things are already being explored by prominent system dynamics researchers, especially dealing with different stakeholder perspectives (e.g., [87,209]). Nevertheless, the emphasis is still mostly on seeking a *convergence* of perspectives, while other possibilities exist: e.g., modeling the contrasting views on causality held by different stakeholders, to enhance mutual understanding. It is DSRP theory that tells us where areas for improvement could lie. The patterns that connect all of these frameworks can also be used to make each of them better, and to help them all 'play well together.'

Conclusion

In this chapter, we have reviewed the waves of systems thinking, culminating in the present day and the possible development of a fourth wave. We believe the approaches and frameworks with origins in all three previous waves provide an exceptionally rich and useful resource for systems practice. We are proud to present them to you in this *Handbook* in a form that demonstrates—not just what the founder(s) of each framework advocated—but also how the ideas have evolved over the years. And we expect them to continue to evolve: this edited volume is no more than a snapshot in time.

We have talked about the possible first swellings of a fourth wave, and have taken some space to explain how DSRP theory (which we see as representative of the concerns that are likely to be core to the fourth wave) is about both universality *and* diversity. The diversity of approaches and frameworks is already with us, as a product of previous waves of systems thinking. If we are right that a new wave now needs to turn to a focus on universality to underpin the diversity of systems frameworks, then we expect more candidate theories (in addition to DSRP) to start appearing in the literature. We are aware of individuals and small groups around the world working on such ideas, and time will tell which of these matures into a form that research communities will cohere around.

We have presented DSRP theory as an approach that we believe addresses some significant challenges faced by contemporary systems thinkers. The challenges are:

1. The continuing proliferation of frameworks, approaches and methodologies, with each having its own specialized lexicon, so the complexity of the field (beyond any single methodology) is hard for anyone to fully understand;
2. The concomitant partial fragmentation of the systems thinking research community, with divisions that reflect preferences of both methodologies (system dynamics, viable system modeling, soft systems methodology, critical systems heuristics, etc.) and application domains (engineering, public policy, environmental management, etc.);
3. The near impossibility of offering a two-minute introductory narrative to a newcomer to our field that respects the variety of systems approaches; and
4. The need for clarity and common purpose around unresolved questions and prospective research.

DSRP explains the universals that underpin the diverse frameworks. This can provide some structure for understanding the field, without requiring specialists to reframe their own approaches using a purely DSRP language. DSRP offers an understanding of the fundamental systems thinking structures and capabilities that are instantiated in different ways within the frameworks. Nevertheless, the concepts and lexicons that have evolved within those frameworks are *also* necessary, as they are responsive to the various purposes and contexts of systemic intervention faced by different specialists. This is a 'both/and' solution to the problem of massive diversification: understanding the universals lying behind the diverse frameworks will bring a new level of understanding, and will help people appreciate more clearly what a systems approach actually is, and how the boundaries of our field can be demarcated. What is more, DSRP (drawing in and reinterpreting some ideas about methodological pluralism originally developed in the third wave) offers new insights, such as the idea that 'jigs'or 'moves' are far more adaptable in practice than whole methodologies with a standard set of methods. This opens the door to new approaches to practice, where bespoke intervention designs can be created in response to the unique contexts of our projects.

All of this addresses the second problem (fragmentation of our research community), as DSRP provides an element of common language to allow communication across sub-community boundaries. Importantly, if DSRP can help to reveal the capabilities, strengths, and weaknesses of each framework or methodology, using a common language, then the utility for each sub-community will be two-fold: improving specialist practice (addressing the limitations of our own approaches) and contributing to new practices that come into being when we combine approaches where the strengths of one correct the weaknesses of the other. We suggest that it is primarily this utility that will drive adoption of the common language, enabling communication across boundaries without the loss (indeed, with the enhancement) of specialist expertise.

Finally, we argue that DSRP is simple in its basic structure, even though the concepts can be combined and recombined to offer almost infinite flexibility and complexity, so its essence can be communicated (albeit superficially) in a two-minute 'elevator pitch.' This can pay respect to the diversity of frameworks, as the elevator pitch can end with an explanation that there are a variety of specialist approaches for particular purposes and contexts, and each of them supports the practice of the systems thinking capabilities explained by DSRP. DSRP can therefore be a gateway to further learning about the panoply of

methodologies and approaches available to those with particular practical needs and desires. It overcomes the problem of having to choose between a massive over-simplification, when talking with newcomers (which might mislead them into believing that only one methodology is the whole of systems thinking), or baffling them with the complexity of the full variety of ideas.

This relatively new framing of the *diversity* of systems thinking—now made possible by the *universality* of DSRP—helps us to see several things more clearly:

1. **Where we have been:** It helps us recast the various frameworks originating in past waves as having deep similarity in their underlying structures, and to see the strengths and weaknesses of these frameworks.
2. **Where we are today:** It helps us to better understand where the field sits in the present day, its challenges and opportunities.
3. **Where we could/should go:** It helps us to better think about and chart the future of the field.

One wonders, what will a *Handbook of Systems Thinking* written in ten years time describe? Will it continue to be a chapter by chapter explanation of the most popular frameworks [62], or will it be something altogether different?

Articulating the possible fourth wave of systems thinking not only describes a recent event that has occurred (the first swellings of the water, mentioned earlier), but also reveals/uncovers an opportunity for the future direction of the field. That opportunity stems from the ability to recognize the underlying universals among the remarkable diversity the field offers; in other words, it (1) shifts the focus away from solely being on frameworks and methodologies, and also (2) significantly expands the current boundaries of the field. Importantly, it shows that systems thinking applies to, and is of great value for, all disciplines, all types of knowledge, all problems and needs, all people, and all systems. The fourth wave of systems thinking builds the *biggest* tent: illustrating how systems thinking applies as much to quantum mechanics as it does to the auto mechanic. It is relevant to all professions, from poets to politicians, sociologists to physicists, and farmers to pharmacists. It has an ability to be coarse or fine grained in its use—that is, it can be a chainsaw or a scalpel—and it has both extremely general applications as well as highly refined ones. It needs to be both welcoming and accessible to any newcomer; any person, interested in anything—which means the field of systems thinking can begin to meet its potential to truly transform our thinking and the world we think within.

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