Introduction to Complexity and Applied Complexity, Spring 2021

Module 21 — Applied Complexity

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Readings

- N/A

We'll use this final module to put a bow on the ideas we've talked about throughout the course.

In applied complexity, we are primarily looking for ways to generate and navigate a world we don't and can't understand.

A Review of the Course Arc

In this course, we've looked at…

- Emergent properties and the failure of reductionism.
- How iterated rules can produce complex behavior.
- Systems with nonlinear dynamics.
- The first challenge to Laplace's demon: deterministic chaos.

- Self-organization and the disconnect between laws and outcomes.
- Pattern formation, design without a designer and order without control.
- The second challenge to Laplace's demon: computational irreducibility.
- Multiscale structure and scaling behaviors, the breakdown (or not) of internal logic from disparate scaling rates, computational complexity and Big-O notation.
- Another breakdown of Laplace's demon: some systems are infeasible to compute.
- Connectivity, closure, and its nonlinear implications for space.
- Stochastic processes and ergodicity.
- Probability, tails, and extremes. The central limit theorem and fat-tailed cascades.
- Variety and entropy, order, disorder and communication.
- Open systems, autopoiesis (synthetic closure), self-constructed boundaries, anticipatory behavior, functional properties, morphogenesis and development (parts from wholes).
- The relational and contextual nature of "mind", skilled action, "gut feelings", knowhow, affordances, non-reducibility "all the way down" and the non-primacy of "internal modeling".

- Collective behaviors, transitions between coherent and independent states, decentralized control.
- The functional structure and dynamics of ecosystems, growth and collapse. Additionally, resilience and fragility, ecological vs engineering resilience and boundaries.
- Evolution, the generation and refinement of functional complexity, the essentiality of space for pattern forming and confined extinctions, coevolution and multiscale selection.
- The adjacent possible, exaptation and functional fluidity and a new face of nonergodicity.
- A further breakdown of Laplace's demon: lawless behavior.
- Fragility and antifragility, concavity and convexity and a way of approaching uncertainty heuristically.
- The rise and coevolution of society and civilization, the limits of central control and the necessity of networked bottom-up structures.
- The use of distributed knowledge via sparse signaling (price signals), self-governing of local communities to solve complex challenges and the primacy of local knowledge in attending to complexity.
- The need for methods to produce complex systems beyond the complexity bottleneck of central-control-blueprint-processes.
- The timeless way, pattern languages, and the genesis of complexity through step-by-step iteration and adaptation, as well as the essential role of human

judgement in getting it right.

- Engineering for the enterprise as an ecosystem, overcoming limits of requirements-driven processes that are based in (misapplied) reductionism.

- Localism, the primacy of scale in sociopolitical systems, and the need to come to terms with this and govern accordingly, for the sake of all.

The IYI Mistake

Again, we make reference to **Nassim Taleb's idea of the IYI** — the Intellectual Yet Idiot — from Chapter 6 of *Skin in the Game*. In general, looking at failures is more educational and informative than looking at successes. Hence, let's look at the mistakes that the IYI makes in his thinking.

- The IYI believes that order is generated exclusively from the top-down. He assumes that all things that look as if they were designed were, in fact, designed in a top-down manner. Quite ironic, considering the fact that the IYI typically scoffs at creationism, yet makes the same mistakes. Instead of a god, the IYI believes in people, and more specifically "experts".

- He doesn't know that most order is generated bottom-up (especially functional order).

- He insists that "experts" are the sole bringers and keepers of order.

- The IYI is ultimately dangerous: he destroys functional complexity and emergent order with top-down fuckery.

Ultimately, this style of thinking is what we're trying to gain sensitivity to and avoid.

To make an adjacent point: we mustn't apply tools exhaustively, in a global manner. Rather, we need to understand what tools apply to what situations, and where their limits and boundaries lie. In this course, we've been building intuitions about the limits of the tools we inherit (especially in modernity), thereby saving ourselves from a lot of pain in not trying to apply them inappropriately. It's not that hammers aren't useful, but hammers aren't for every job.

Two Aspects of Systems

This table shows the dichotomy between two different aspects of systems we've been exploring: mechano-industrial and organic. Some systems are purely mechanical, and some are purely organic. However, many systems are somewhere in between, containing aspects of both. We should aspire to build and/or cultivate organic systems.

Mechano-industrial	Organic
The whole can be understood by a single mind	No vantage point from which to ascertain the whole
Can be fully represented abstractly	No full representation
Can be constructed "all at once" (direct)	Must develop / evolve, one step at a time (indirect)
1 or very few primary "resolutions" of the system	Many resolutions, very fine-grained details matter in addition to large scale behaviors
Mechanism drives function	Function drives mechanism
Assembled from preexisting parts	Parts differentiate from the whole
Can be disassembled without harming integrity of parts	Disassembly changes, harms or destroys parts
Surprises are not good	Surprises may be good
Denial of the informal	Embrace of the informal
Instability is malfunction	Interplay of stability and instability to achieve adaptive function
Consumption -> Waste	No waste — each "side effect" feeds other processes
Fragile / maintenance required	Antifragile / Self healing
No novelty, behavior is prescribed	Enters novel state space, the adjacent possible

The Proper Role of Models

So what is the proper role of models, considering everything we've been talking about?

- Models are handy for educational (especially unlearning) purposes, and more generally, for communication ideas.

- In practice, they help surface and test assumptions you have about a system — you're forced to articulate all of your assumptions down to the detail of the model. In addition, models surface inconsistencies and gaps in your understanding.

  Imagination is overrated. As we work through things in our mind, our mind is very good at pasting over gray areas with a feeling of understanding. Yet when you start to dig in, you find that there's nothing there. Build models to externalize your understanding.

- Another use for models is to widen our awareness of possibilities — to gain a greater sensitivity to the kinds of things that might happen in the system we're interested in.

- You should NEVER use models to narrow your awareness (e.g. using models for prediction).

Principles

Let's examine some of the main principles of applied complexity.

- **Risk first.**
  One of the main ideas here is to separate out systemic risk from non-systemic risk. Systemic risks are those that can scale and propagate through the whole system. Take the approach of handling risk first — what are the things we're

messing with, and what things are unacceptable to destroy?

- **Details last.**
  If risk is first in our considerations, then details are last. As we saw with Christopher Alexander, work with something fuzzier first, and fill in the details later. Coarse-to-fine. Moreover, when you work this way, you learn things that then inform the kinds of decisions you make at a finer resolution.

- **Focus on the fuel, not the spark.**
  This gets back to the idea of predictability. What does it mean to predict, as opposed to anticipate or mitigate? If the system is structured in a way such that it can generate fires (i.e. there's fuel), it's important to address the risk at a systemic level instead of focusing on the specific incident that causes the fire (i.e. the spark).

- **Imagination is overrated.**
  As mentioned above. This is a way of saying that this 'single mind hypothesis' of order and innovation is wrong. This doesn't mean that imagination is bad and shouldn't be celebrated — it's just a way of triggering people and getting them to engage with the idea. We think of imagination as this thing that can restructure and reform the world, when really it's the unanticipated consequences, stumbling into possibility space, exaptations, etc that change the world. Most things have evolved rather than been imagined.

- **Complex integration and sameness (or, lack of boundaries) are at odds.**
  When complex systems become integrated, they actually depend on nice, clean boundaries between components. This allows interaction between components through interfaces. In other words, integration and unity necessitate the right boundaries in the right places. The process of evolution discovers where those boundaries should exist. If you try to take away all boundaries, you won't get an integrated complex system — you'll get a mess with all sorts of buggy and weird

behavior, pathological cascades, and too much interdependence at the fine-grained level to possibly manage any kind of functional behavior.

Another point to make here: if you mix everything up and eliminate all boundaries, you'll end up with a system that isn't capable of larger-scale behaviors. Boundaries are a way to keep things from mixing together, allowing for larger-scale interactions.

All complex systems are open systems by definition. Borders and boundaries are not about absolute isolation from an integrated system. They're about defining interfaces and enabling interaction at those interfaces. The idea is selective permeability.

- **Formal systems live inside informal systems.**
  Formal systems could mean technically formal (mathematical, computational, logical) or anything that's made explicit in the form of a protocol (bureaucratic systems). There is always something outside of the model, both in a technical and bureaucratic sense.

  Informalities often preserve the integrity of the system — make space for them so that they can patch up holes in the formal model. No formal model is free of exceptions.

  Even something as formal as MATH is ultimately informal — it is a human project. When a mathematician comes up with a novel idea, they're often operating outside of the deductive logic of the models they're building. Formal systems are all about deduction — what necessarily follows from some stated assertions or axioms? Take number theory: **Gödel's incompleteness theorems** show that number theory is bigger than any model of number theory! There are truths that are sitting latent within number theory that the axioms will never reach — you cannot deduce these truths. This figure from Hofstadter's *Gödel,* *Escher, Bach* illustrates the point:

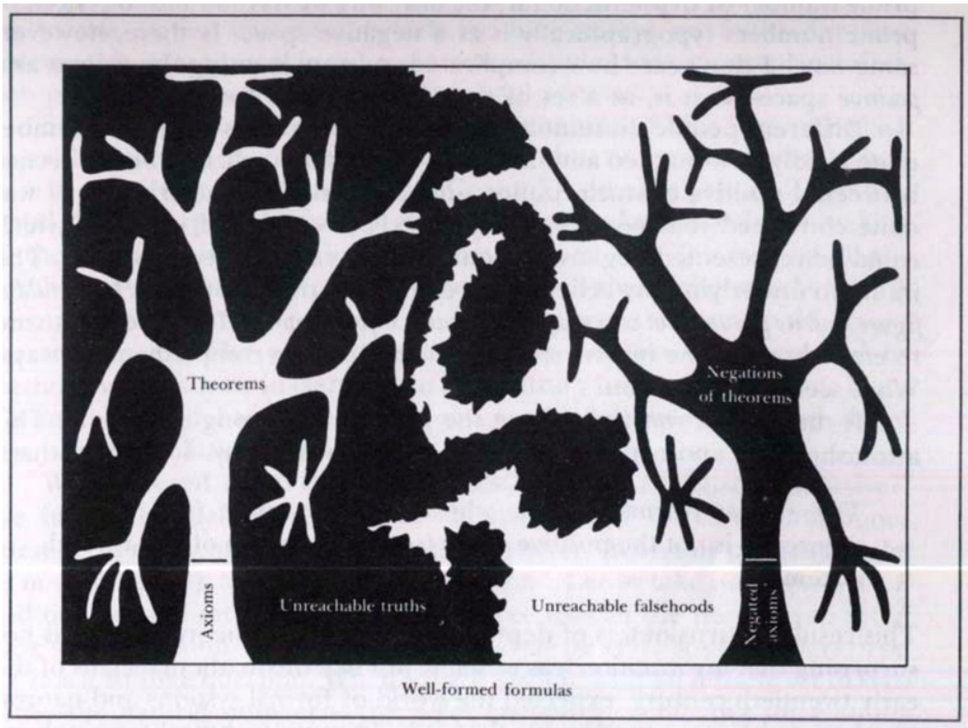


*FIGURE 18. Considerable visual symbolism is featured in this diagram of the relation between various classes of **TNT** strings. The biggest box represents the set of all **TNT** strings The next-biggest box represents the set of all well-formed TNT strings. Within it is found~ set of all sentences of **TNT**. Now things begin to get interesting. The set of theorems pictured as a tree growing out of a trunk (representing the set of axioms). The tree-symbol chosen because of the recursive growth pattern which it exhibits: new branches (theorems constantly sprouting from old ones. The fingerlike branches probe into the corners of constraining region (the set of truths), yet can never fully occupy it. The boundary beta the set of truths and the set of falsities is meant to suggest a randomly meandering coastline which, no matter how closely you examine it, always has finer levels of structure, an consequently impossible to describe exactly in any finite way. (See B. Mandelbrot's book Fractals.) The reflected tree represents the set of negations of theorems: all of them false yet unable collectively to span the space of false statements. [Drawing by the author.]*

Of course it's possible that any informal system is really part of some larger formal system, but from a practical standpoint it doesn't matter. The point here is to not focus purely on the formal, but rather leave room for informality, spontaneity and creative potential.

- **Interdependence is both a source of opportunity AND risk.**
  It's easy for people to focus on the opportunity and neglect the risk, especially when the risk is hidden. But as we said before, risk first.

- **Managing fine-grained complexity requires local agency.**
  Due to bandwidth limits, you need local agents that are situated in their environment to evaluate the needs of that environment.

- **The agent must fit the environment, and the environment must fit the agent.**
  Both of these notions are restatements of the law of requisite variety. However, the latter part often gets neglected.

  Think of something like school. Students are often forced to fit into the environment of the school. But of course, students are more complex than the school environment. In such cases, you need the school to be more flexible and have more variety so that it can fit to the students' needs.

- **An ecosystem is not an organism.**
  These are different types of entities. Organisms live and die, ecosystems evolve. Organisms have variety at scale that matches their scope, ecosystems don't. Organisms lack functional redundancies (at an organ system scale). In certain cases you want to aim for an organism, whereas in others you might want to nurture an ecosystem.

- **Expect the unexpected.**
  There are always unintended consequences. We tend to think in terms of *action → consequence*. But really, it's more like *action → a myriad of consequences*. We're really bad at predicting all consequences that stem from an action.

  For example, people talk about the side effects of a drug. But really, all "side effects" are just the effects of that drug.

- **Scale always matters.**
  There's no situation — when thinking about complex systems — where scale isn't a hugely important parameter. Something good at a small scale can be bad at a large scale, and vice versa.

- **Complex behavior is performed *unconsciously*.**
  Both at the individual scale and at the collective scale. Complex behavior depends on a decentralized coordination between the units of a system, as opposed to a centralized, conscious controller.

  The role of consciousness is to select the things that work and discard the things that don't — like pruning a tree. It's not to micromanage and direct *how* things ought to work.

- **Systems interact via interfaces.**
  There should be an attention placed on developing interfaces, when you want pieces of a system to interact in a constructive way. Technical equivalence does not imply practical equivalence. It is an IYI mistake to assume it does.

  When talking about programming languages, the notion of **expressivity** comes up. Even though all languages are Turing complete and thus technically equivalent, different ideas can be expressed more elegantly or less elegantly depending on the language you use.

- **Social interactions around concrete action promote harmony. Social interactions around abstractions promote dissonance.**
  In the land of abstractions, it's easy to find differences to argue about. However, when you get down to real things that give you concrete feedback, those differences become backgrounded.

This quote from Alexander Pope complements this notion:
"For Forms of Government let fools contest; whatever is best administered is best."

- **All things are relational.**
  We can't make a clean statement about anything in the real world that is divorced from the things around it. Nothing exists in a vacuum. This is what complex systems science is all about — properties and behaviors emerge out of interactions.

- **A function is what a thing does for other things.**
  It's not just about what a thing does, but also how that action relates to and influences the things around it.

- **Closures (circular flows/dependencies) form units/building blocks of complex systems.**
  This kind of recirculation dynamic forms things that are placable into different contexts and enables different relationships to form.

  Closures are induced by boundaries and constraints.

- **Healthy units manage their own boundaries.**
  Boundaries should not be imposed on units, but rather produced by the units themselves.

  In political and social systems, to the extent that this is true, you see much more healthy behavior. Compare this to the top-down imposition of boundaries, the track record of which is much more murky.

- **Optimization is the enemy of robustness and evolution.**
  It is the enemy of robustness because optimization removes redundancies and makes the system more fragile.

  It is the enemy of evolution because focusing narrowly on the function being optimizing for makes it hard (if not impossible) to capture useful side effects.

  This doesn't mean that you should never optimize. But when you want something robust or potentially evolving, overoptimization is harmful.

- **Evolution is the non-survival of the not-fit-enoughs.**
  An add-on to the evolution modules, and a reframing of the 'survival of the fittest' idea. In evolution, some set of patterns survives and persists. Those patterns can then take the step into the adjacent possible.

  Some of those patterns may appear to be very minor in the system, but may later be essential to the next evolutionary step. For example, when the dinosaurs went extinct, that created an opportunity for mammals to fill niches that were previously unavailable to them.

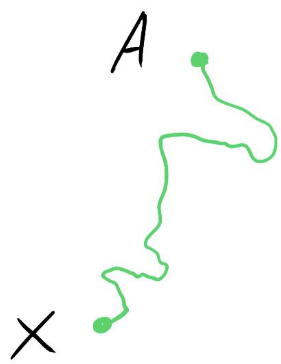
  The main goal of a species is not to dominate the space, but to stay in the game. In other words, you want to avoid ruin — the logic of evolutionary processes is that of ruin and non-ruin.

- **Intentions don't count.**
  Look at what someone does instead of what they say, for example.

- **Constraints can enable.**
  Constraints are not just a destructive force that keeps things from happening. They also create conditions that allow something else to happen that wouldn't

have happened without those constraints.

- **A "wished for" state is not a solution**
  If we imagine some state we'd like to get to — point *A* — from where we are now — point *X* —, without some pathway to get there, there's nothing to talk about. *A* is not a valid solution unless there exists some path to get from *X* to *A*.



- **Simplicity and complexity complement.**
  We've seen repeatedly that complexity doesn't arise from some super complicated blueprint of something, but rather from the repeated application of simple rules.

Pattern Archetypes

We've seen a number of pattern archetypes throughout the course — patterns that occur over and over.

One is this **whole-to-part** pattern. We see this in development of organisms, but also in things like software development (monoliths → microservices).

Related but slightly different is the **coarse-to-fine** pattern. In a given domain, you want to first apply some fuzzy, coarse structure, and then proceed to fill in the details.

Of course, we've also seen a pattern that goes in the other direction — the **part-to-whole** pattern. When you're building a car, for example, you have parts that fit that specific model of car. The car gets built up from the parts. It's important to ask yourself: am I trying to generate a part-to-whole system or a whole-to-part system? This will help clarify the approach to take when working on a project.

Another common pattern: **boundaries and interfaces**. This is something to be taken into account when building systems. It's very hard to say upfront where those boundaries and interfaces should be, but it should be something that you're constantly seeking to discover. When you get these things right, the system will hang together in a much more integrated way.

"Be the Change"

Let this serve as a sendoff. When a system is unfolding in real time, it's bound to hit points of instability. If you're already doing what you believe in, when the instability manifests, you become a little nucleus of stability and lead by example. So be the change you want to see, now in the present moment, so that when the crisis hits, you're there.