Center for Engineered Natural Intelligence

University of California, San Diego

Reverse engineering the brain:
From neuroscience to engineering and commercial products

January 2017

Center for Engineered Natural Intelligence

Imagine if ...

- your phone tells you that there's no ice cream in the freezer so you should stop... because it knows it's Friday, where you are, and that you're headed home to host a birthday party.
- the firewall at work calls you to say that you have a data ex-filtration underway, because it knows you don't do business with Russia...yet data is going there...and nobody requests >100 repetitive copies of a 404'ing website.
- your database and transaction server give real-time fraud detection and user authentication, because it can tell where people are, and understands that most people don't buy exactly $100.00 of gas on a credit card.
- the information leads server at the Bloomberg News Intelligence Desk sends you a tip on an emerging story otherwise unreported because it can mechanize fact-pattern identification and discovery of emerging/hidden events 10,000x faster than existing methods.
- your sunglasses, which you wear due to your blindness, describe the world around you in context-aware phrases, because it knows where you are, what you're doing, and what you would care to know about.

Center for Engineered Natural Intelligence

What is the Center for Engineered Natural Intelligence?

We discover and use biological and physiological principles of the brain to develop mathematical models, algorithms, and hardware that replicate the useful elements of neural processing.

We leverage these algorithms and hardware to design next-generation engineering of hybrid neurobiological-artificial neural networks capable of achieving real-time, robust, adaptive analytics and pattern recognition to situational and context dependent inputs achieved with ultra low power and minimal training.

Real-time, Off-line, Context aware, & Ultra low power

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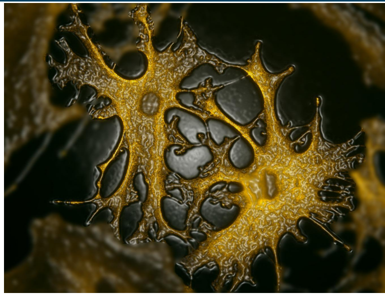
Founding faculty



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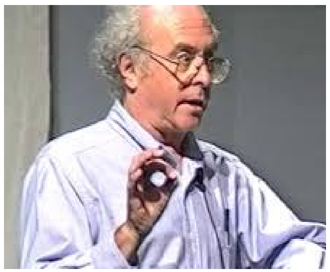

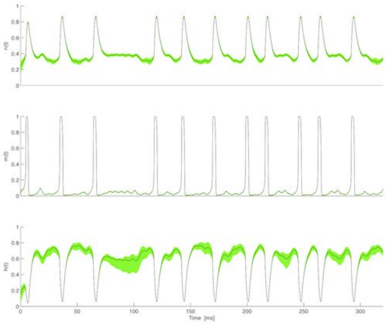

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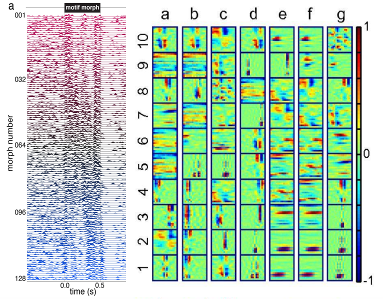

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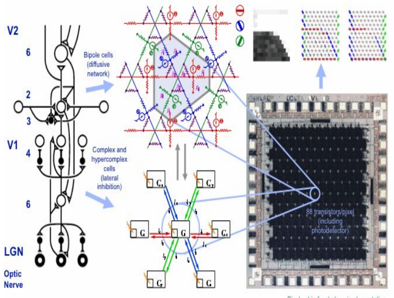

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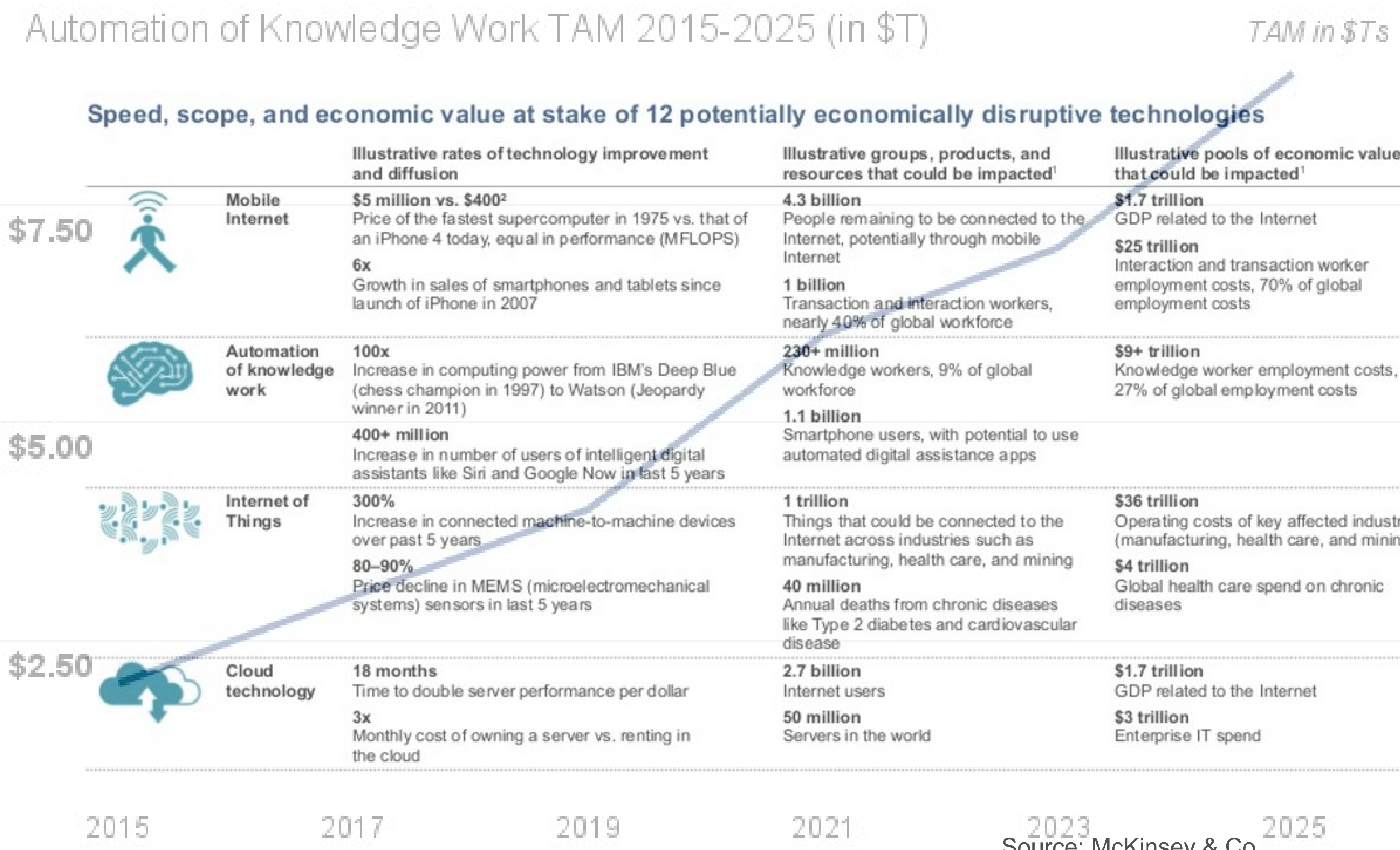
Engineered Natural Intelligence:
an exciting high-growth market



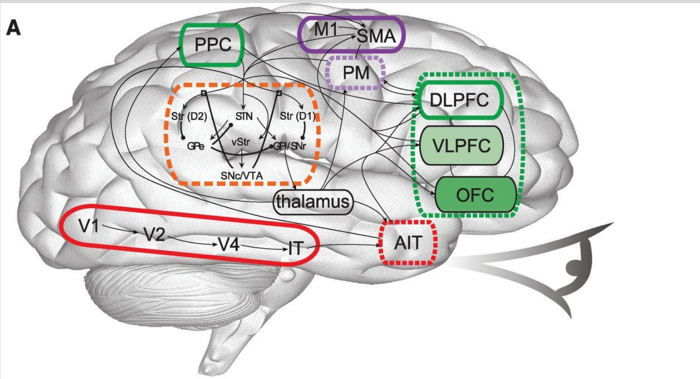
Speed, scope, and economic value at stake of 12 potentially economically disruptive technologies

	Illustrative rates of technology improvement and diffusion	Illustrative groups, products, and resources that could be impacted[1]	Illustrative pools of economic value that could be impacted[1]
Mobile Internet	**$5 million vs. $400[2]** Price of the fastest supercomputer in 1975 vs. that of an iPhone 4 today, equal in performance (MFLOPS) **6x** Growth in sales of smartphones and tablets since launch of iPhone in 2007	**4.3 billion** People remaining to be connected to the Internet, potentially through mobile Internet **1 billion** Transaction and interaction workers, nearly 40% of global workforce	**$1.7 trillion** GDP related to the Internet **$25 trillion** Interaction and transaction worker employment costs, 70% of global employment costs
Automation of knowledge work	**100x** Increase in computing power from IBM's Deep Blue (chess champion in 1997) to Watson (Jeopardy winner in 2011) **400+ million** Increase in number of users of intelligent digital assistants like Siri and Google Now in last 5 years	**230+ million** Knowledge workers, 9% of global workforce **1.1 billion** Smartphone users, with potential to use automated digital assistance apps	**$9+ trillion** Knowledge worker employment costs, 27% of global employment costs
Internet of Things	**300%** Increase in connected machine-to-machine devices over past 5 years **80–90%** Price decline in MEMS (microelectromechanical systems) sensors in last 5 years	**1 trillion** Things that could be connected to the Internet across industries such as manufacturing, health care, and mining **40 million** Annual deaths from chronic diseases like Type 2 diabetes and cardiovascular disease	**$36 trillion** Operating costs of key affected industries (manufacturing, health care, and mining) **$4 trillion** Global health care spend on chronic diseases
Cloud technology	**18 months** Time to double server performance per dollar **3x** Monthly cost of owning a server vs. renting in the cloud	**2.7 billion** Internet users **50 million** Servers in the world	**$1.7 trillion** GDP related to the Internet **$3 trillion** Enterprise IT spend

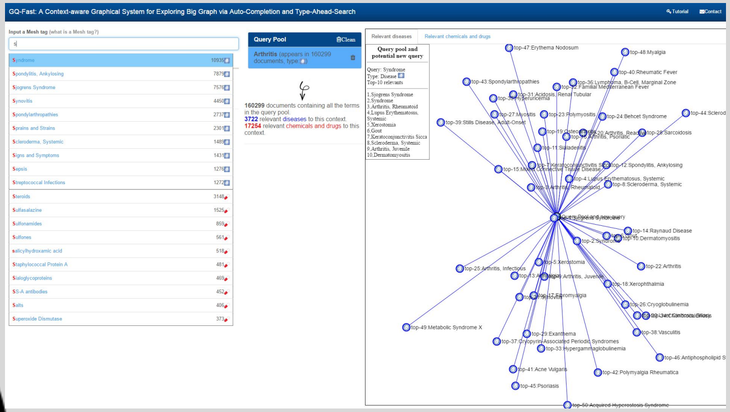
Source: McKinsey & Co.

CENI: Grand Challenges

Novel neural network architectures and approaches



Advanced context-aware search and decision aids, and near-realtime advisors



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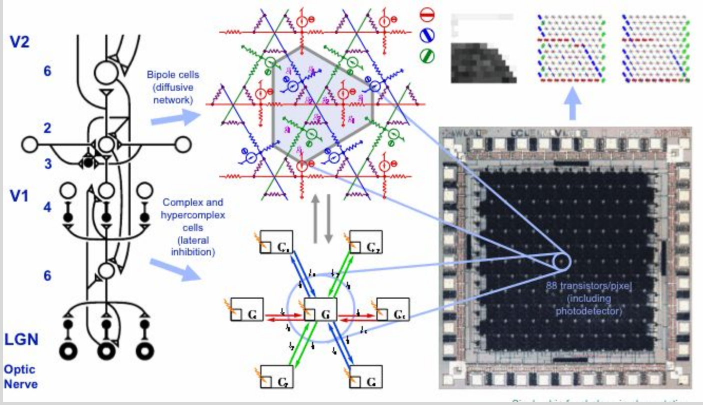
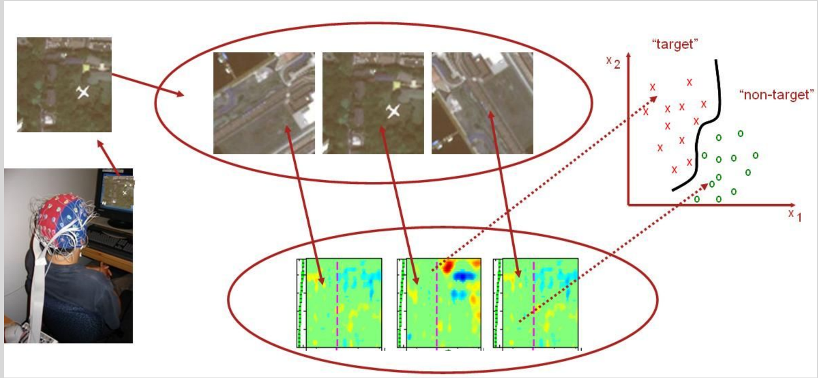
Novel chip architectures



Real-time threat ID and avoidance



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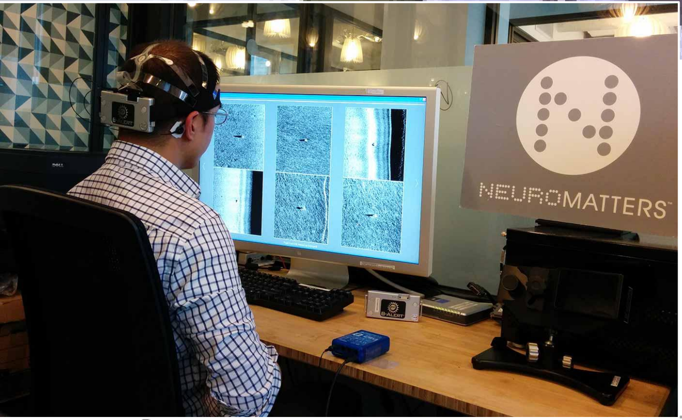
Why aren't we there now?



Size & Usability:

Artificial Neural Networks are simply not portable, and remote interface and significant data inputs are required

Battery Life:

Need ultra-low-power systems to maximize operational service cycles

Utility:

Need to develop algorithms & sensors that are <u>useful</u>

Our Mission:

Address these issues through innovative cross-disciplinary research

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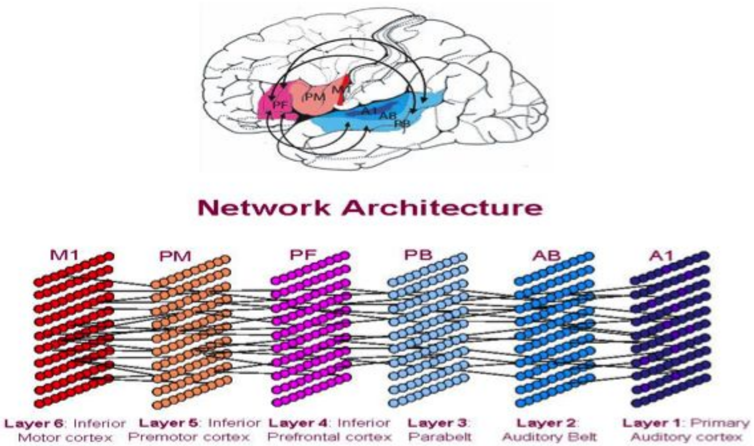
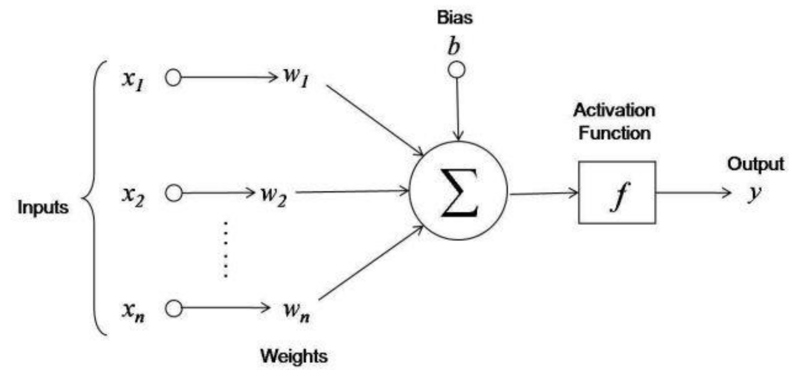
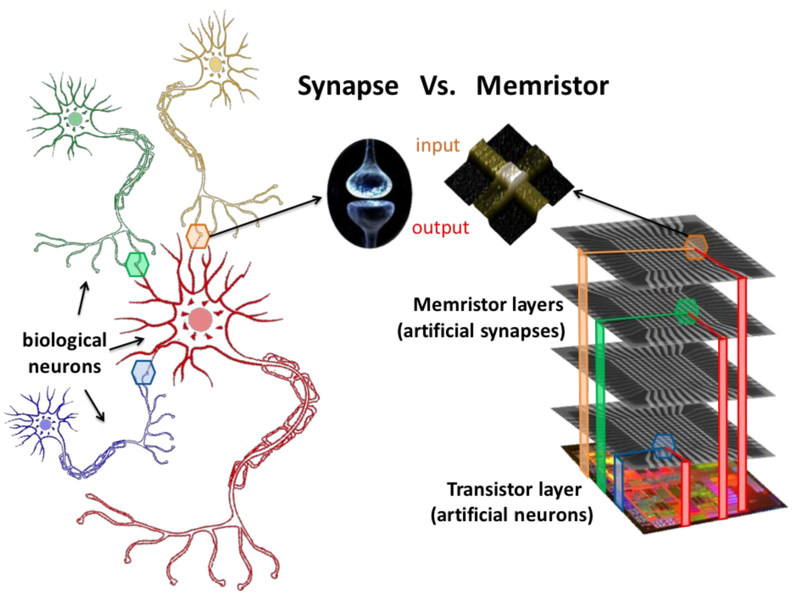
What is the problem?

1) There is very little *neural* in artificial *neural* networks



2) Existing algorithms and structures are essentially 1950's neuroscience with 2016 computing power!





3) The 'algorithms' of the brain and how the brain computes are VERY different than the algorithms and structures of existing ANN's, and this is reflected in the *properties* and *functions* that distinguish the two. The brain is constrained by its physical structure and dynamics, and its unique computational properties *emerge* from this structure.

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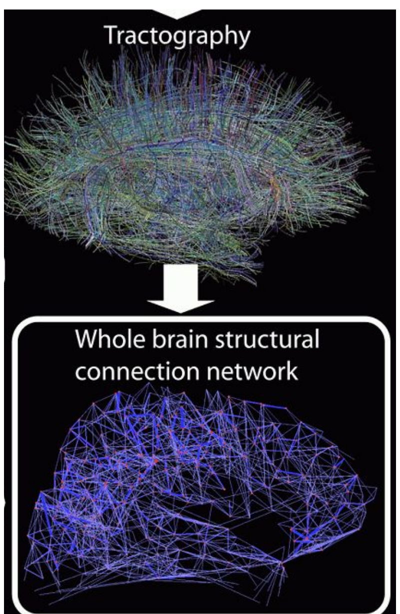
The Brain differs from ANN

- Learns by analogy and abstraction of concepts using minimal training sets (e.g. approaching n = 1)
- Robustly adapts to different situations and contexts it may not have previously encountered. AI systems cannot extrapolate beyond their training sets.
- Has tremendous computational power and is self contained (3 lbs of ‘stuff’)
- Accomplishes all this using insanely little power, about 20 W, barely enough to power a dim light bulb. (In contrast, a robot with the same computational power as the brain would require 10 MW.)



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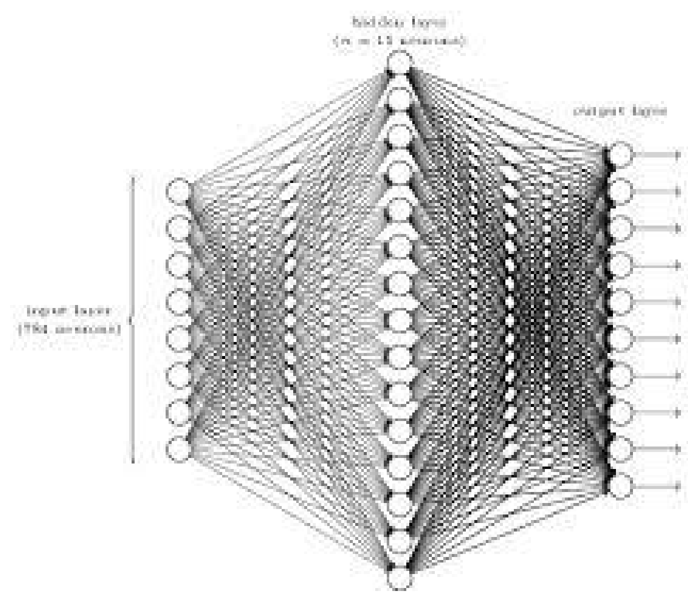
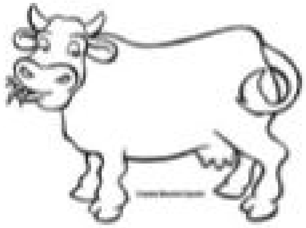


How is the brain different?

The brain learns by analogy and abstraction of concepts using minimal training sets



For example: These two images are completely physically different, but a three year old very quickly learns they represent the same *concept* and thing. An ANN system cannot accomplish this.

The brain robustly adapts to different situations and contexts it may not have previously encountered. ANN systems cannot extrapolate beyond their training sets.

The brain has tremendous computational power and is self contained (3 lbs of 'wet-ware')

The brain accomplishes all this using very little power, about 20 W, barely enough to power a dim light bulb. A robot with the computational power of the brain would require 10 MW.

Artificial neural networks vs. biological neural networks in the brain

Existing artificial neural networks that underlie artificial intelligence are still VERY limited in what they can do, and how they can do it!

There is very little neural in artificial neural networks.

Existing algorithms and structures are essentially 1950's neuroscience with 2016 computing power!

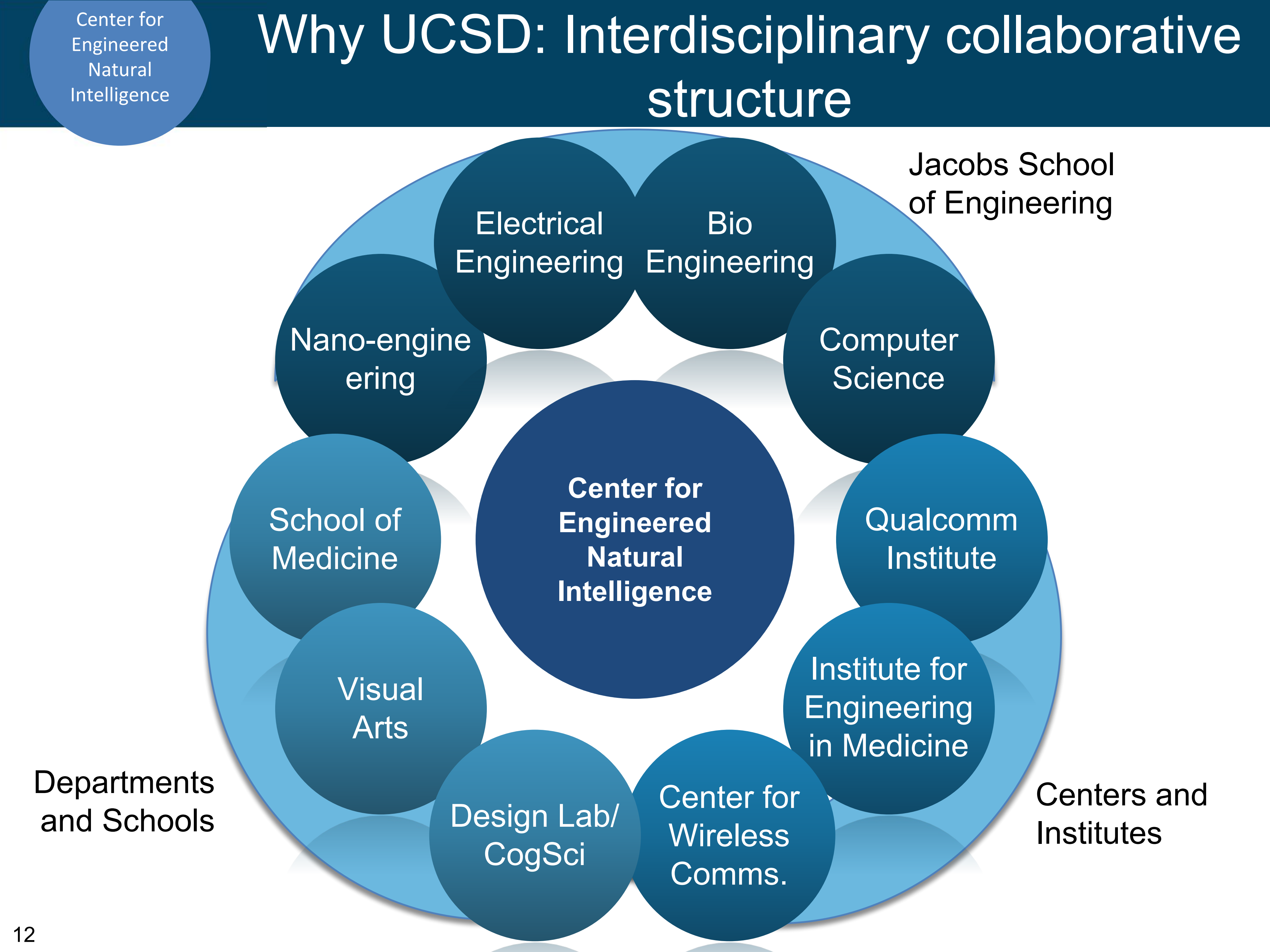
Are not designed to benefit from or be improved by growing understanding of neuroscience and the brain.

They are computationally expensive.

Consume huge amounts of power.

They require being on-line (to produce powerful results).

Why UCSD: Interdisciplinary collaborative structure



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CENI: An Agile Research Center

- CENI is an *Agile* Research Center
  - We are responsive to your needs and vision
  - We want to build a tight feedback loop between industry and academic research towards solving far-reaching problems in engineered Intelligence
- Overall goal: develop the next-generation of context-aware advisors and biologically-inspired intelligent algorithms