Artificial Intelligence and Quantum Physics

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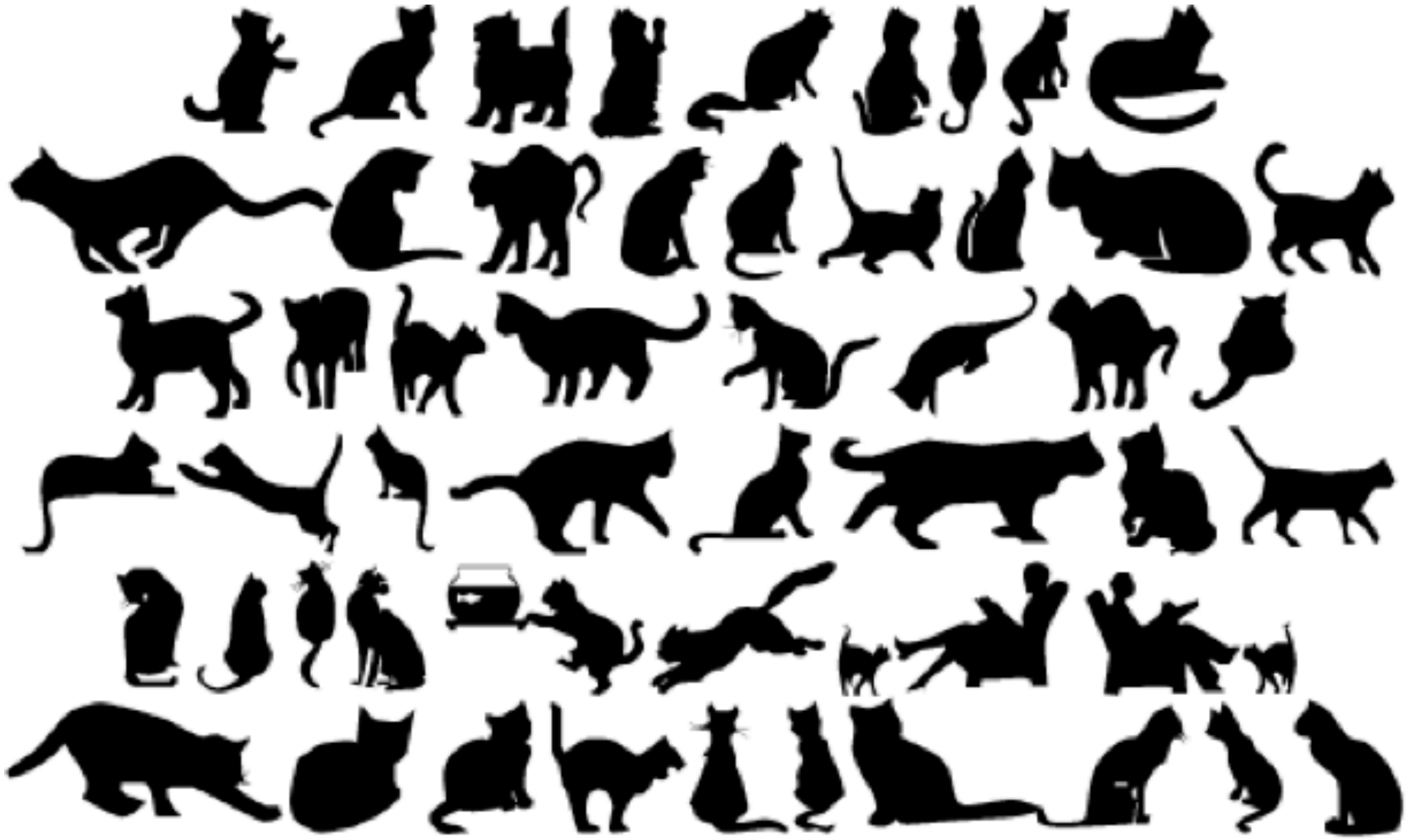
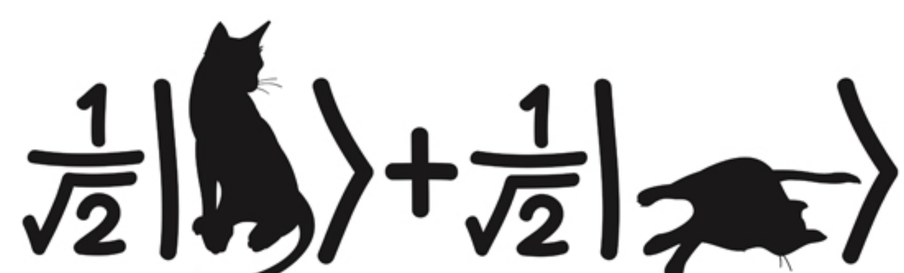
https://wangleiphy.github.io

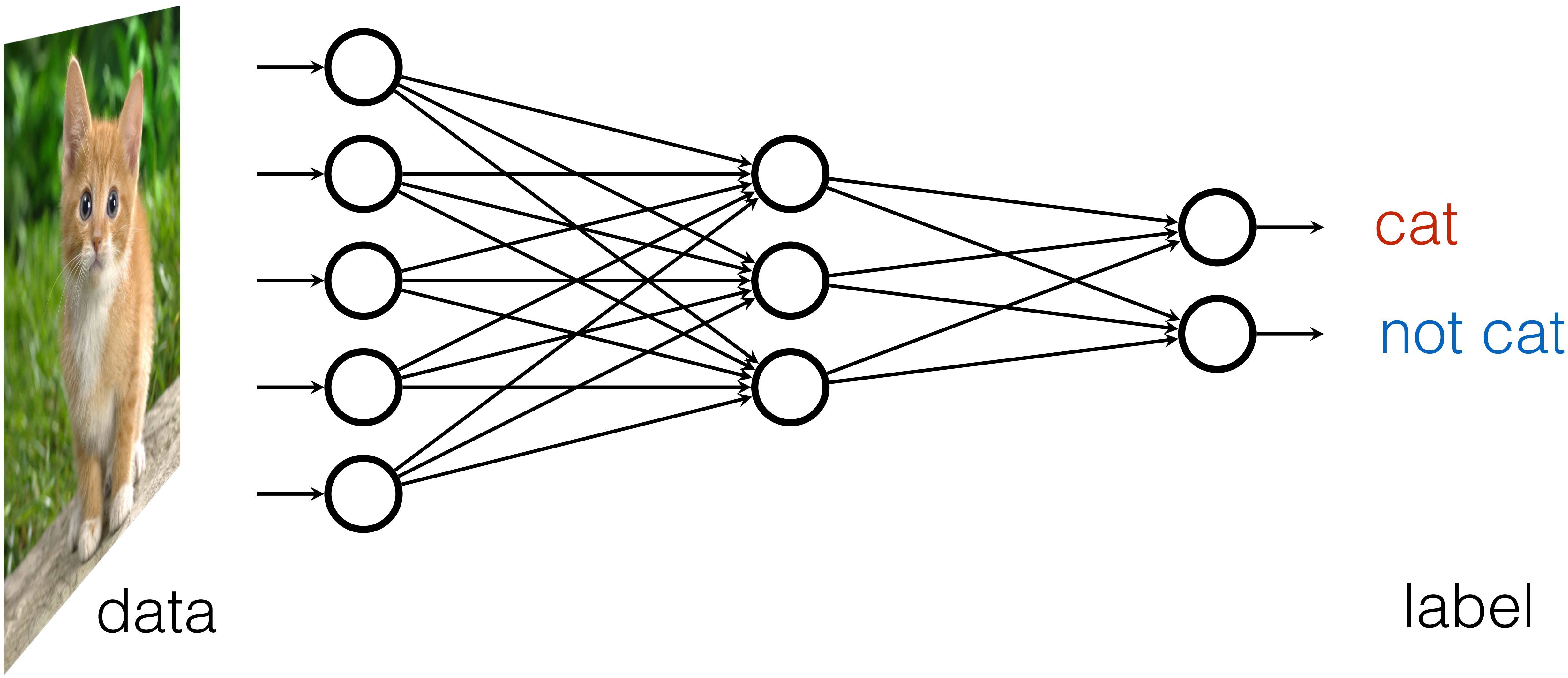
What is common of AI and quantum physics researches ?



We both love cats!



How to recognize a cat ?



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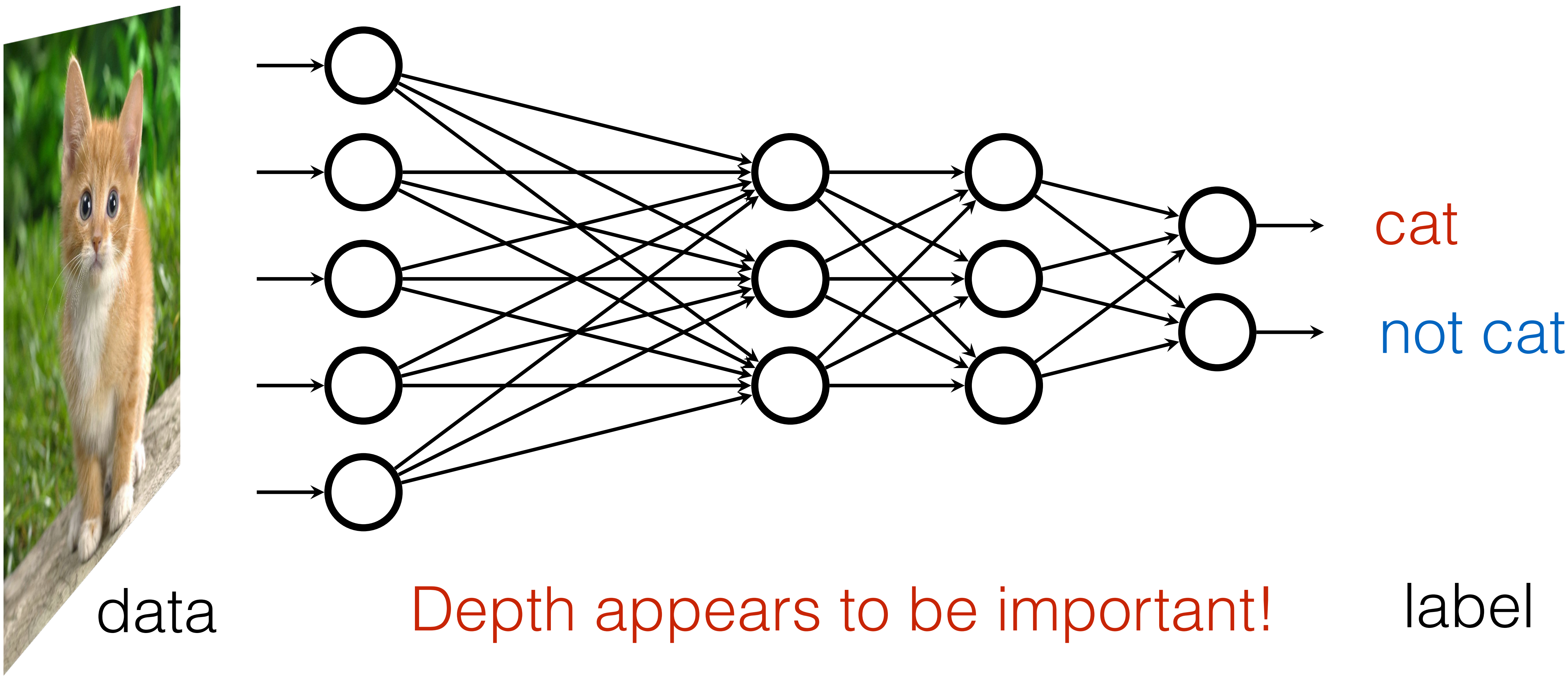
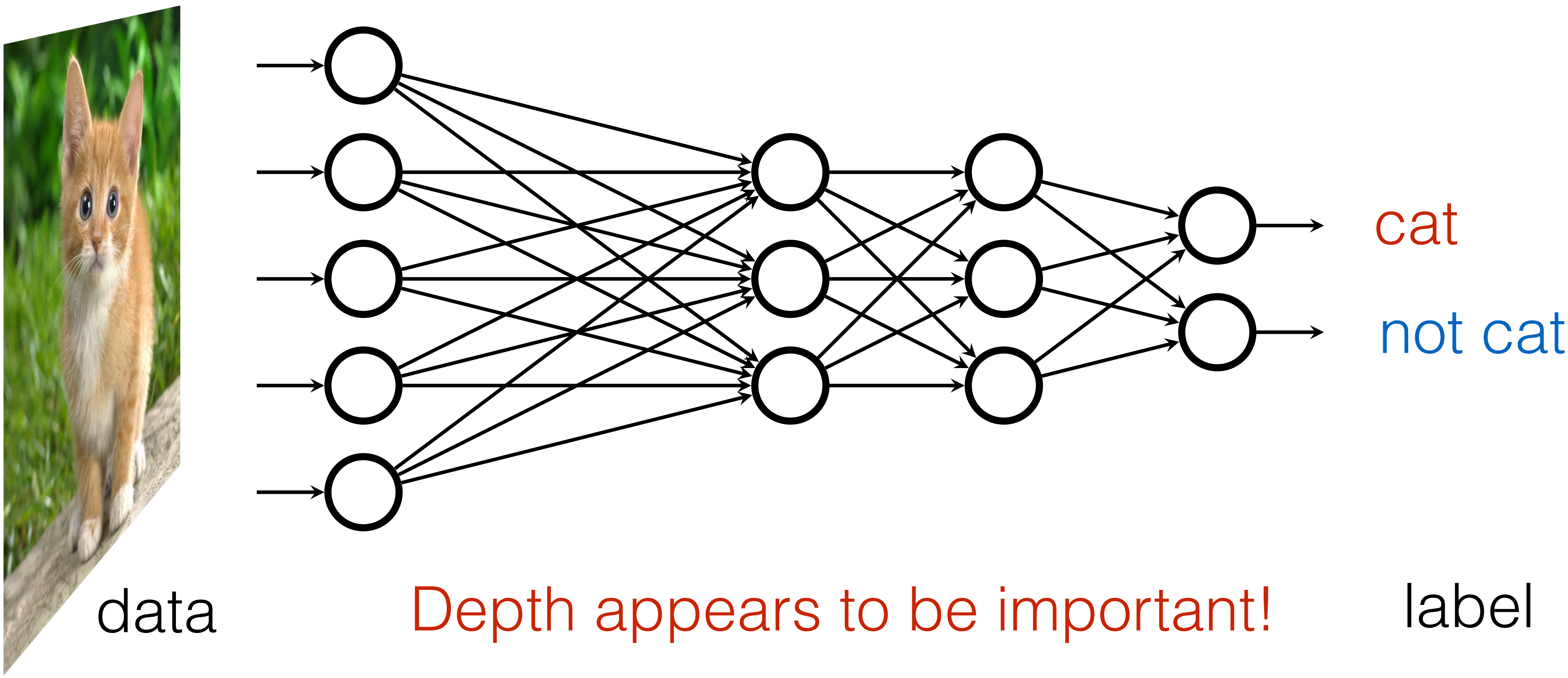


Depth appears to be important!

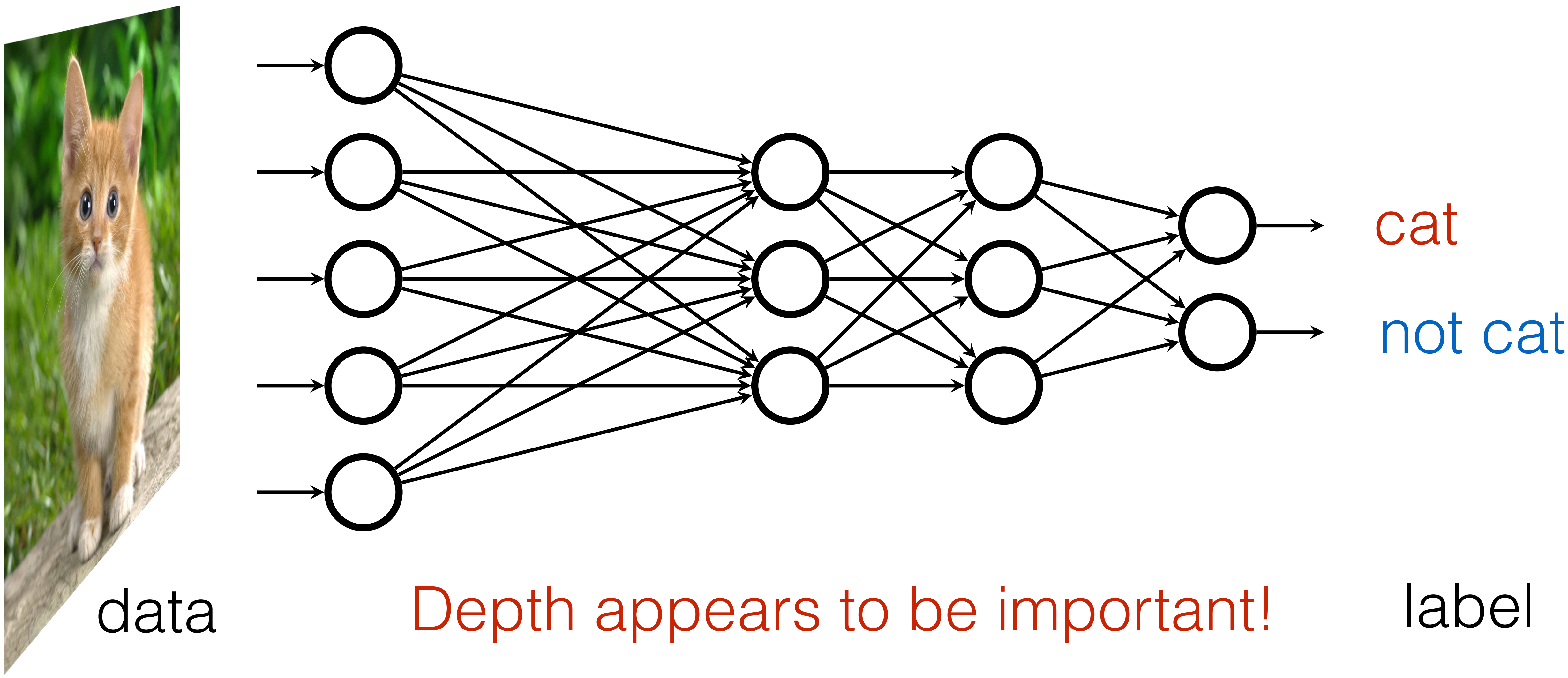
How to recognize a cat ?



Depth appears to be important!

Q: Why does deep learning work?

How to recognize a cat ?



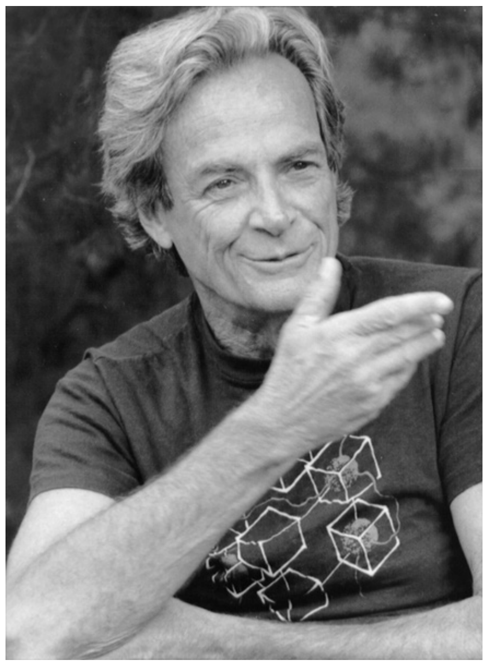
Q: Why does deep learning work?

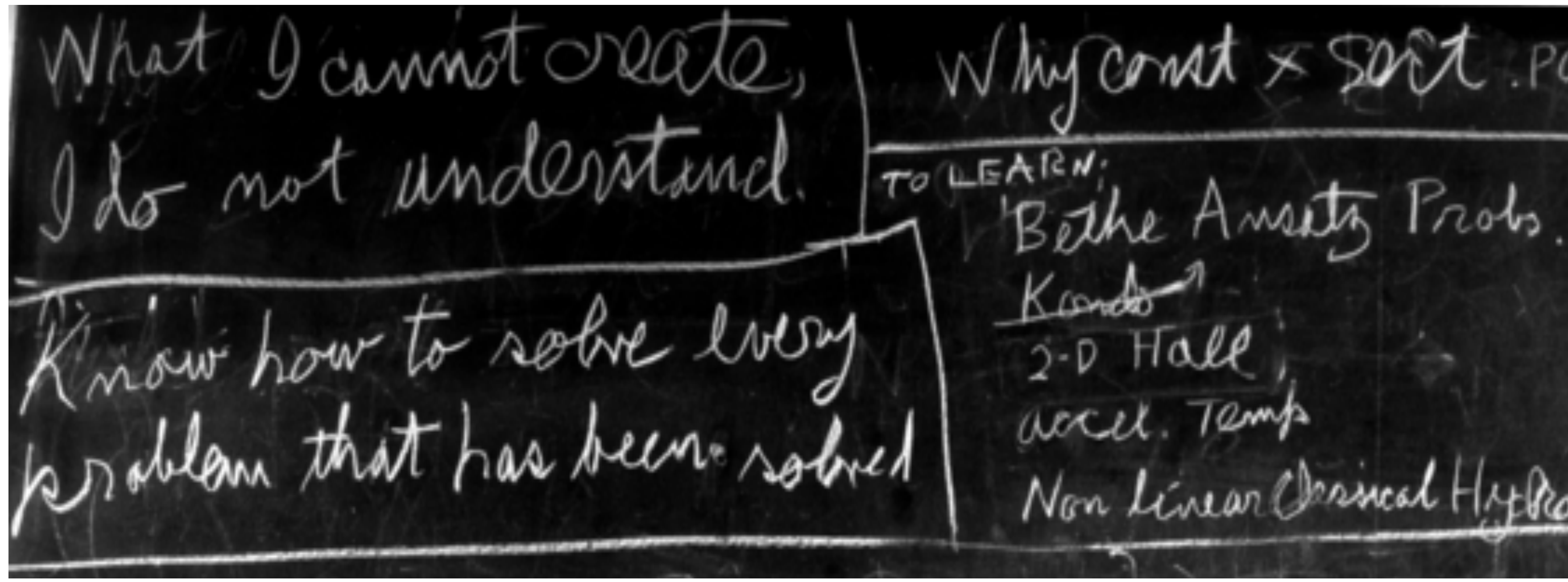
A: Law of physics: symmetry, locality, compositionality, renormalization group, and quantum entanglement.

Lin, Tegmark, Rolnick ,1608.08225 Mehta, Schwab, 1410.3831 Levine et al, 1704.01552 …

Deep learning is more than function fitting

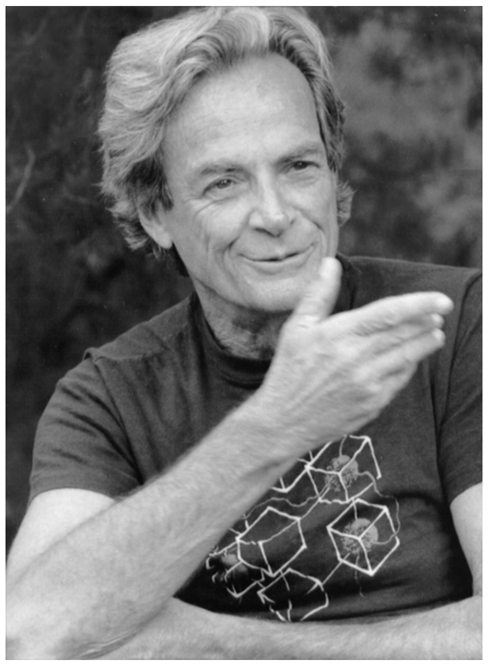
Deep learning is more than function fitting

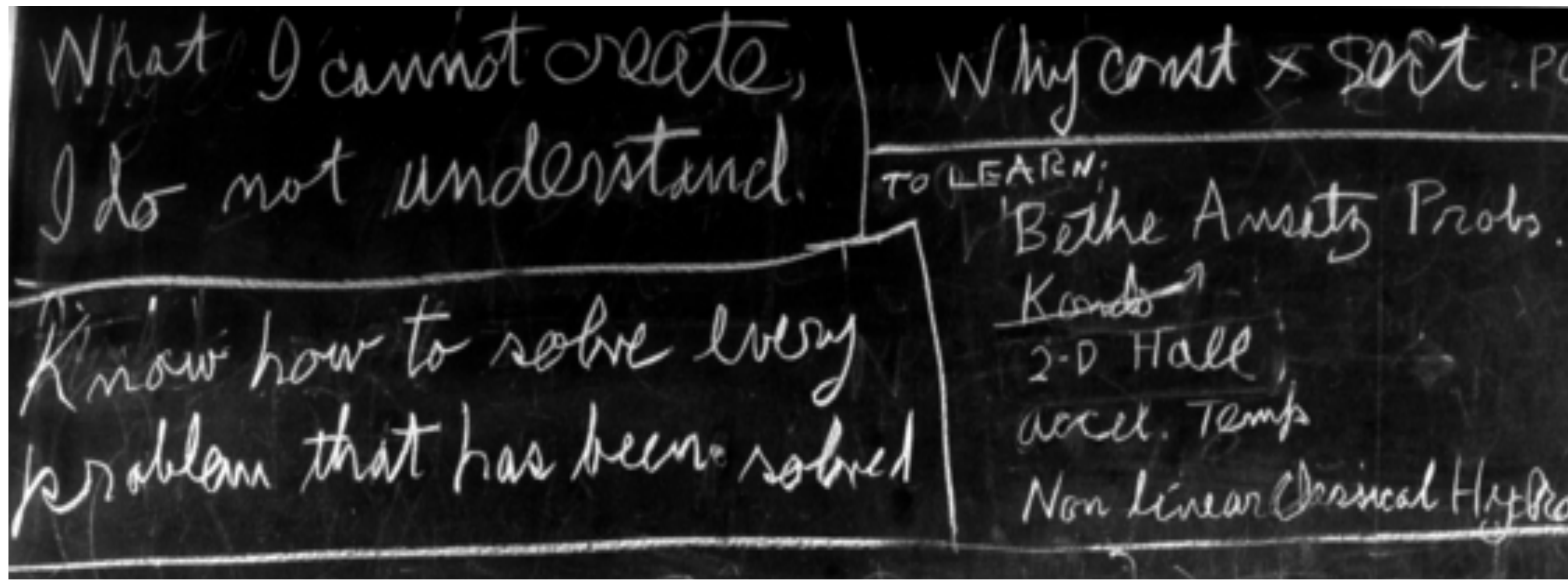




"What I can not create, I do not understand"

Deep learning is more than function fitting



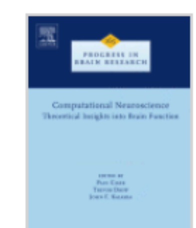


ELSEVIER

Progress in Brain Research

Volume 165, 2007, Pages 535–547

Computational Neuroscience: Theoretical Insights into Brain Function

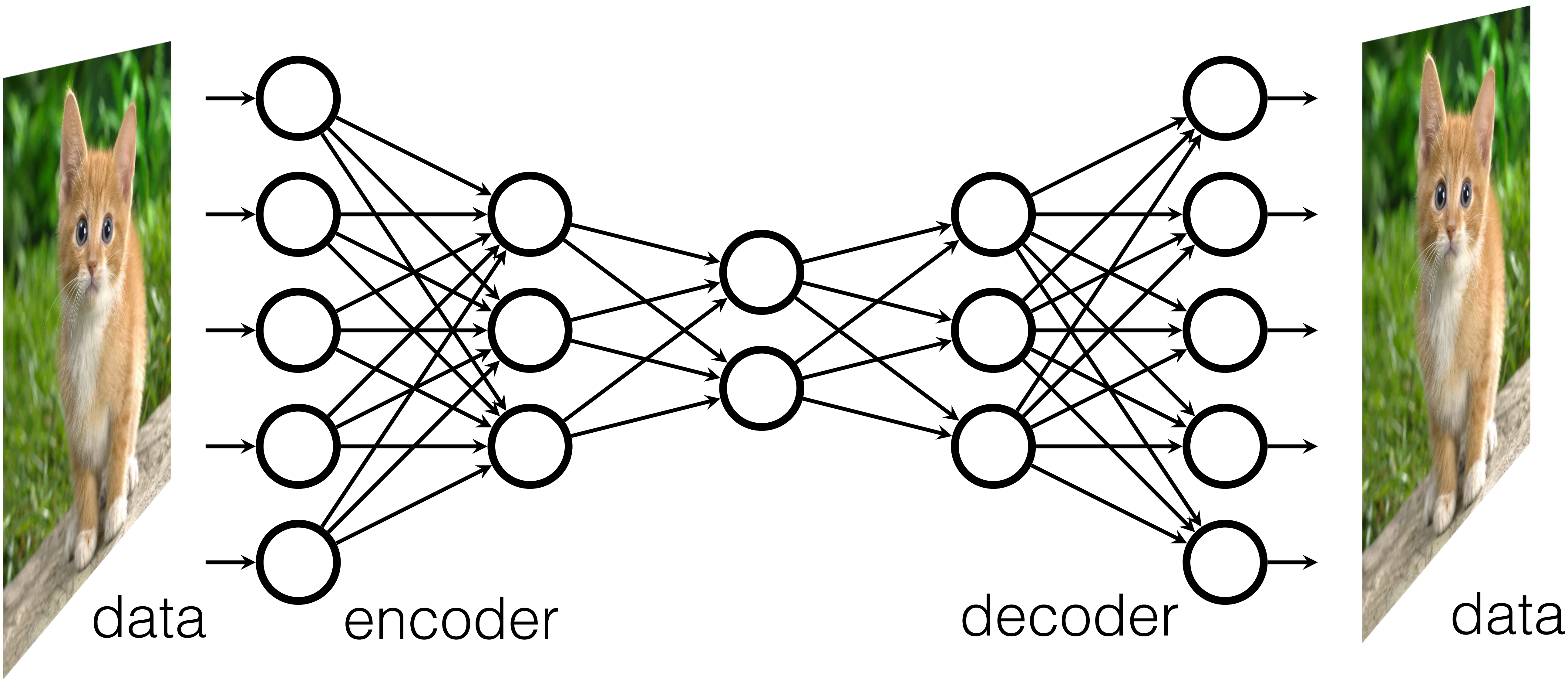


To recognize shapes, first learn to generate images

Geoffrey E. Hinton

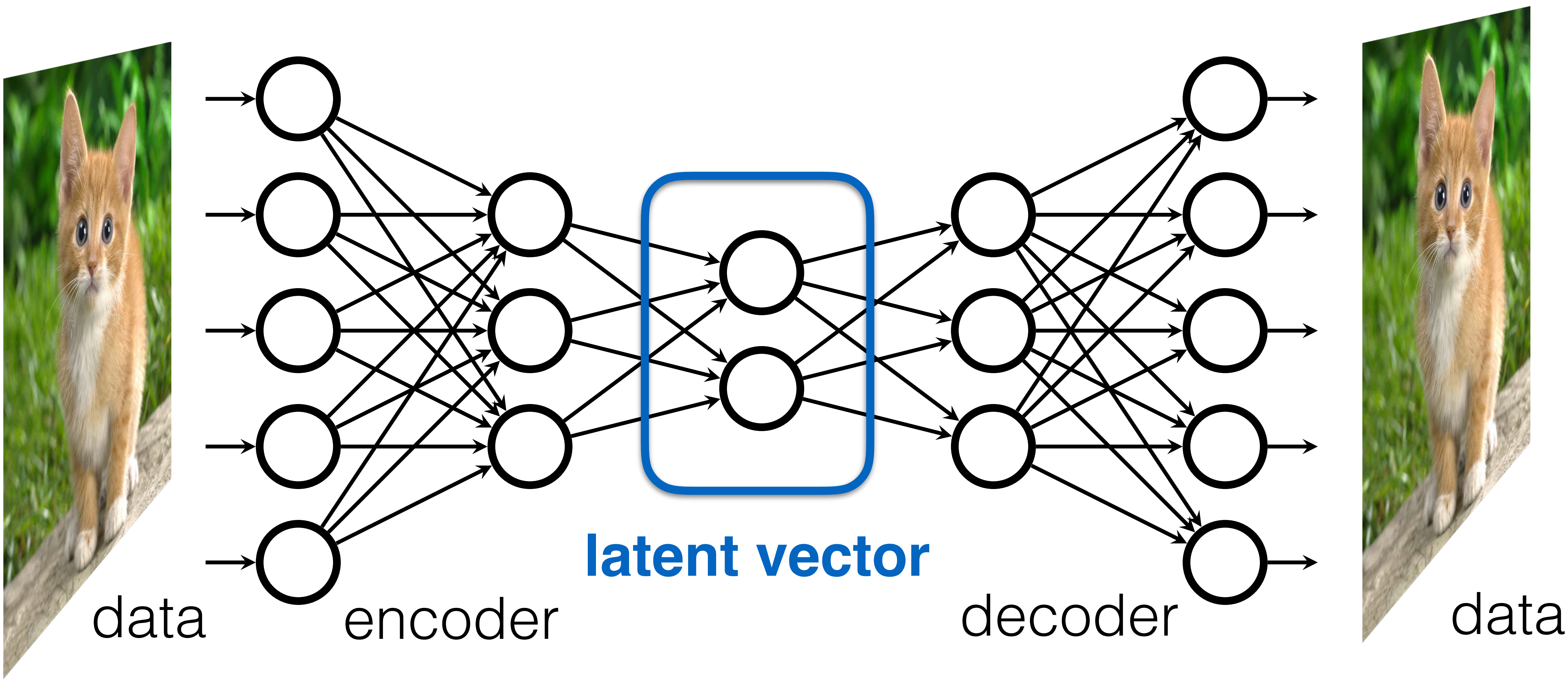
Department of Computer Science, University of Toronto, 10 Kings College Road, Toronto, M5S 3G4 Canada

Generative Learning



“Auto-Encoding Variational Bayes", Kingma and Welling,1312.6114

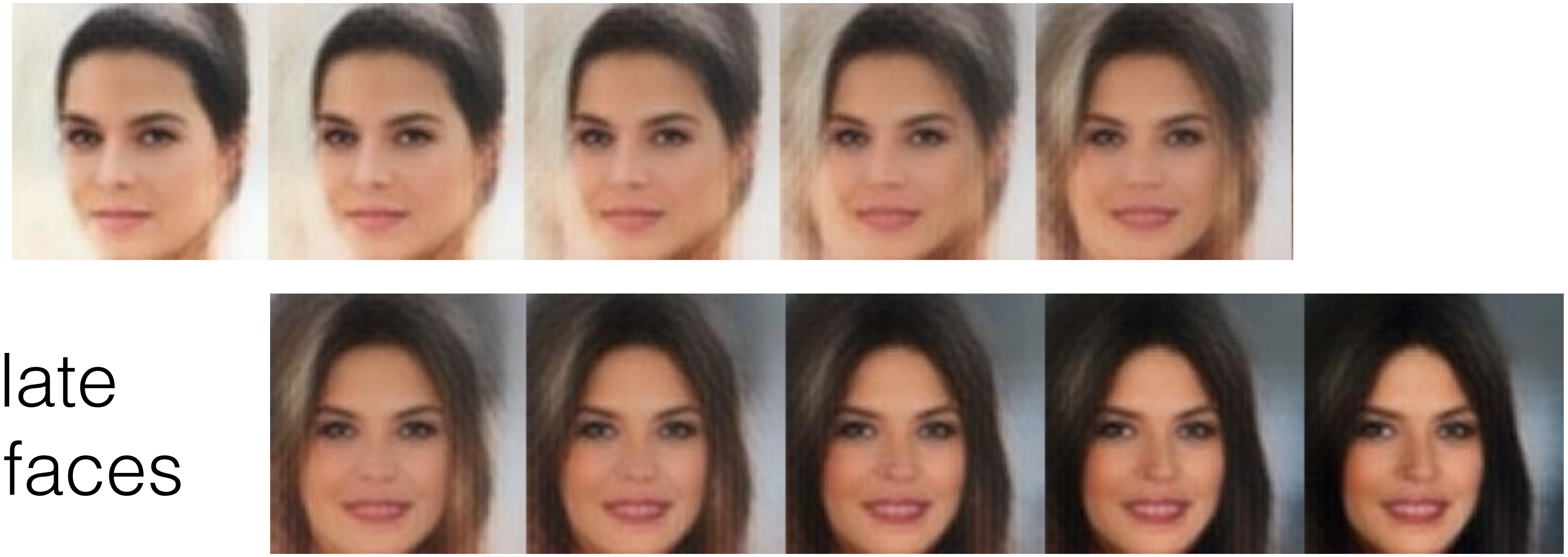
Generative Learning



“Auto-Encoding Variational Bayes", Kingma and Welling,1312.6114

Interpolate between faces

Hou, Shen, Sun, Qiu, 1610.00291



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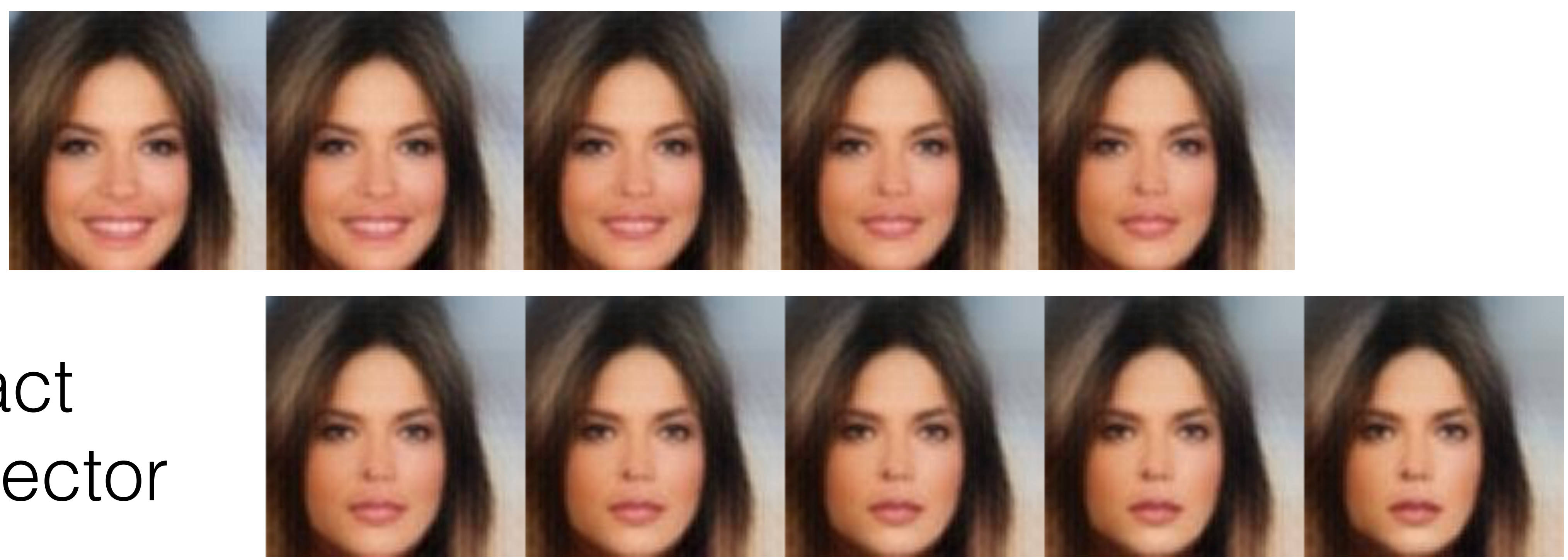


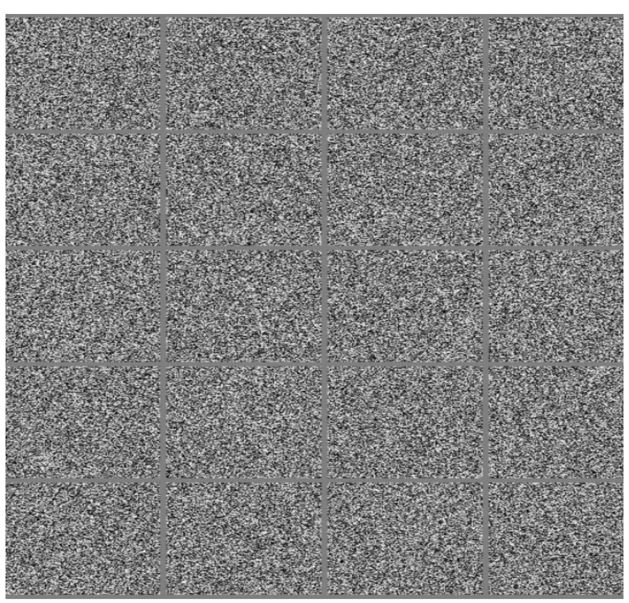
Subtract Smiling vector

Hou, Shen, Sun, Qiu, 1610.00291

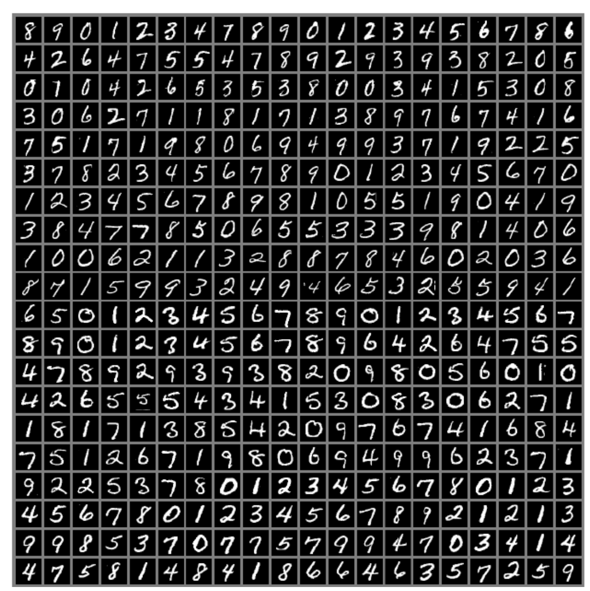
Probabilistic Generative Modeling

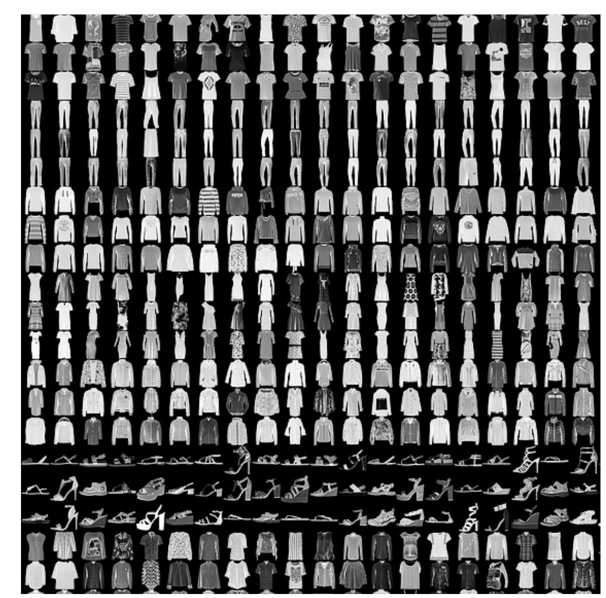
$$p(\mathbf{x})$$

How to express, learn, and sample from a probability distribution of enormous size ?



"random" images

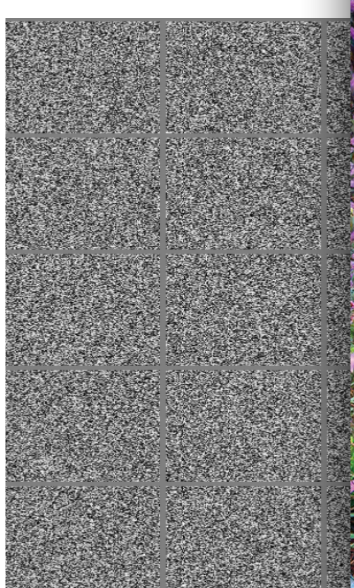


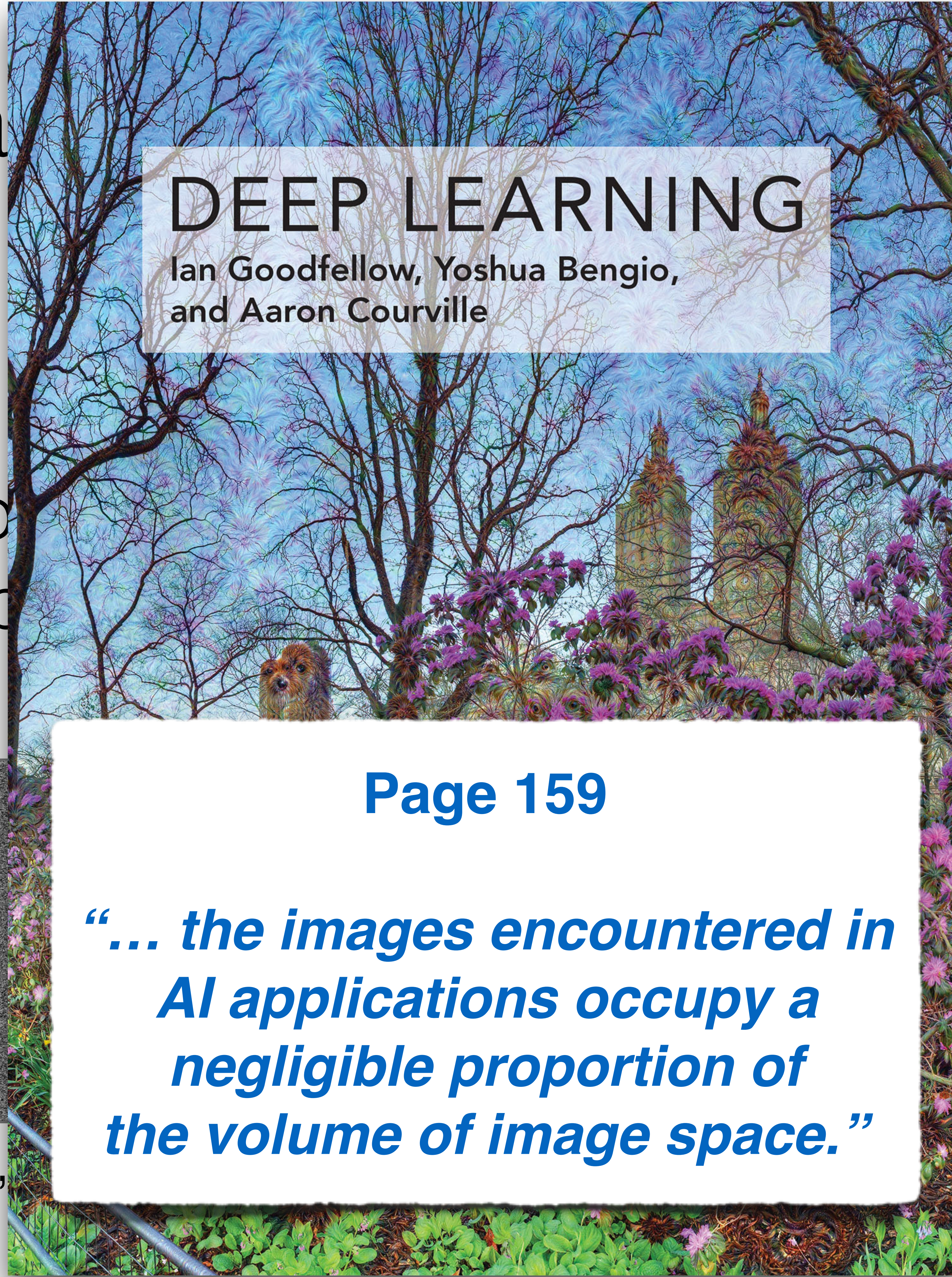


"natural" images

Proba… …deling

How to … from a
probab… … size ?





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"… the images encountered in AI applications occupy a negligible proportion of the volume of image space."

"random"

Probabilistic Generative Modeling

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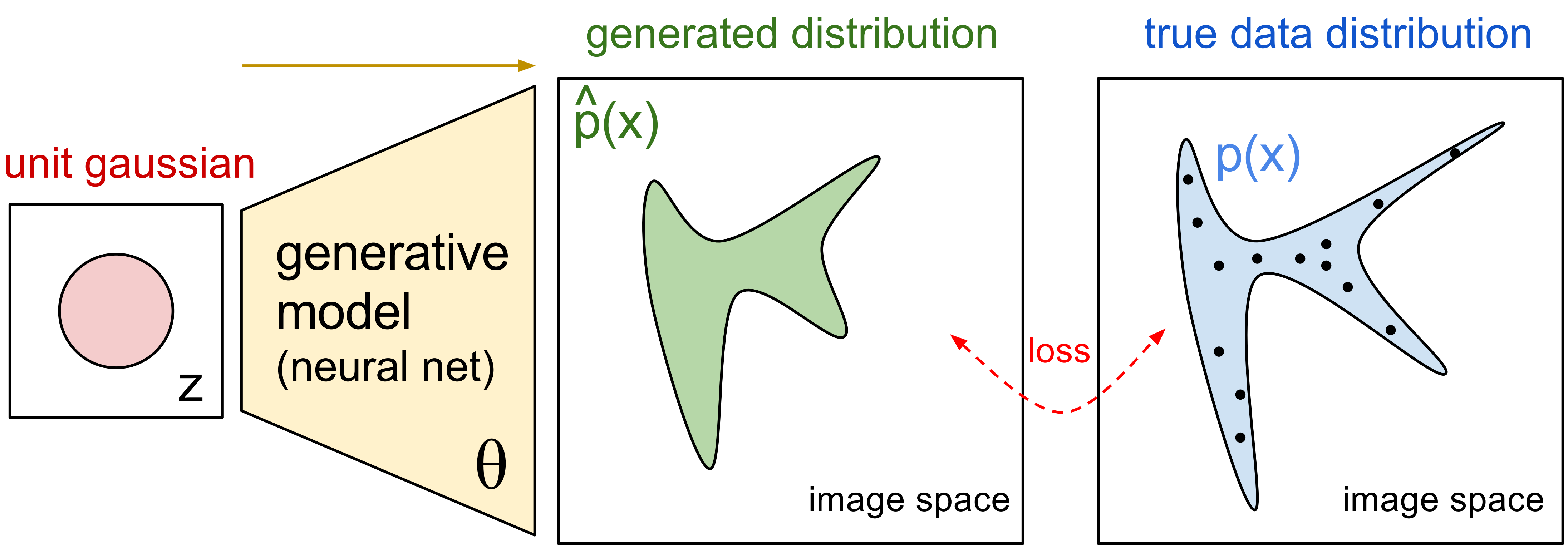
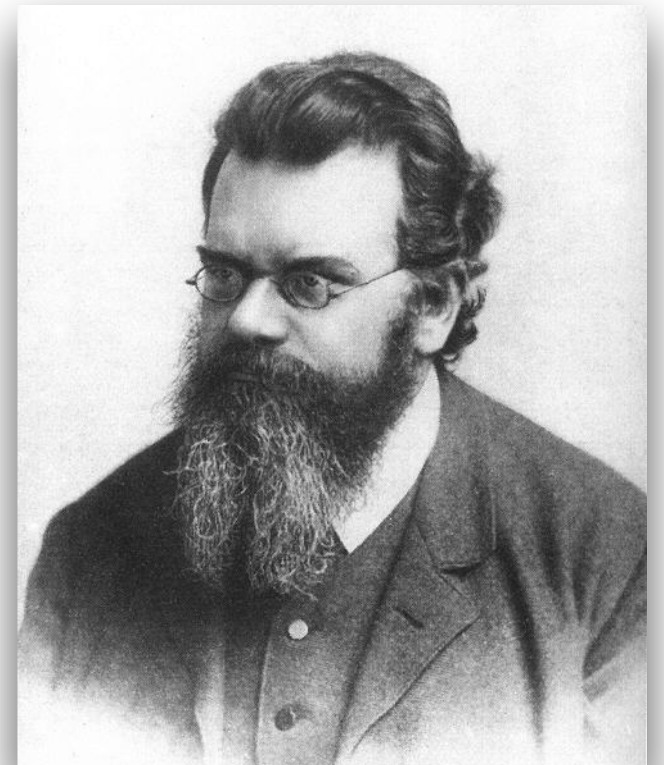


https://blog.openai.com/generative-models/

Generative Modeling and Physics



Boltzmann Machines

$$p(\mathbf{x}) = \frac{e^{-E(\mathbf{x})}}{\mathcal{Z}}$$

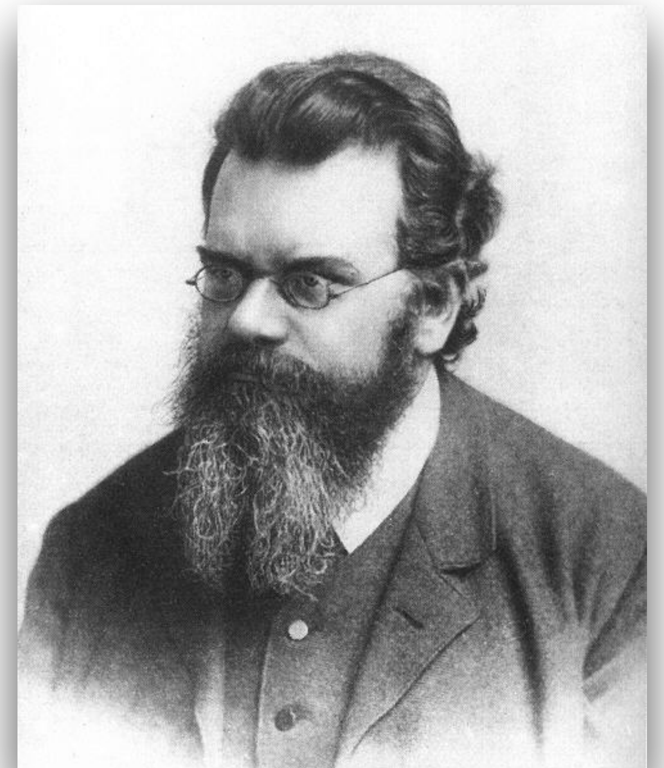
statistical physics

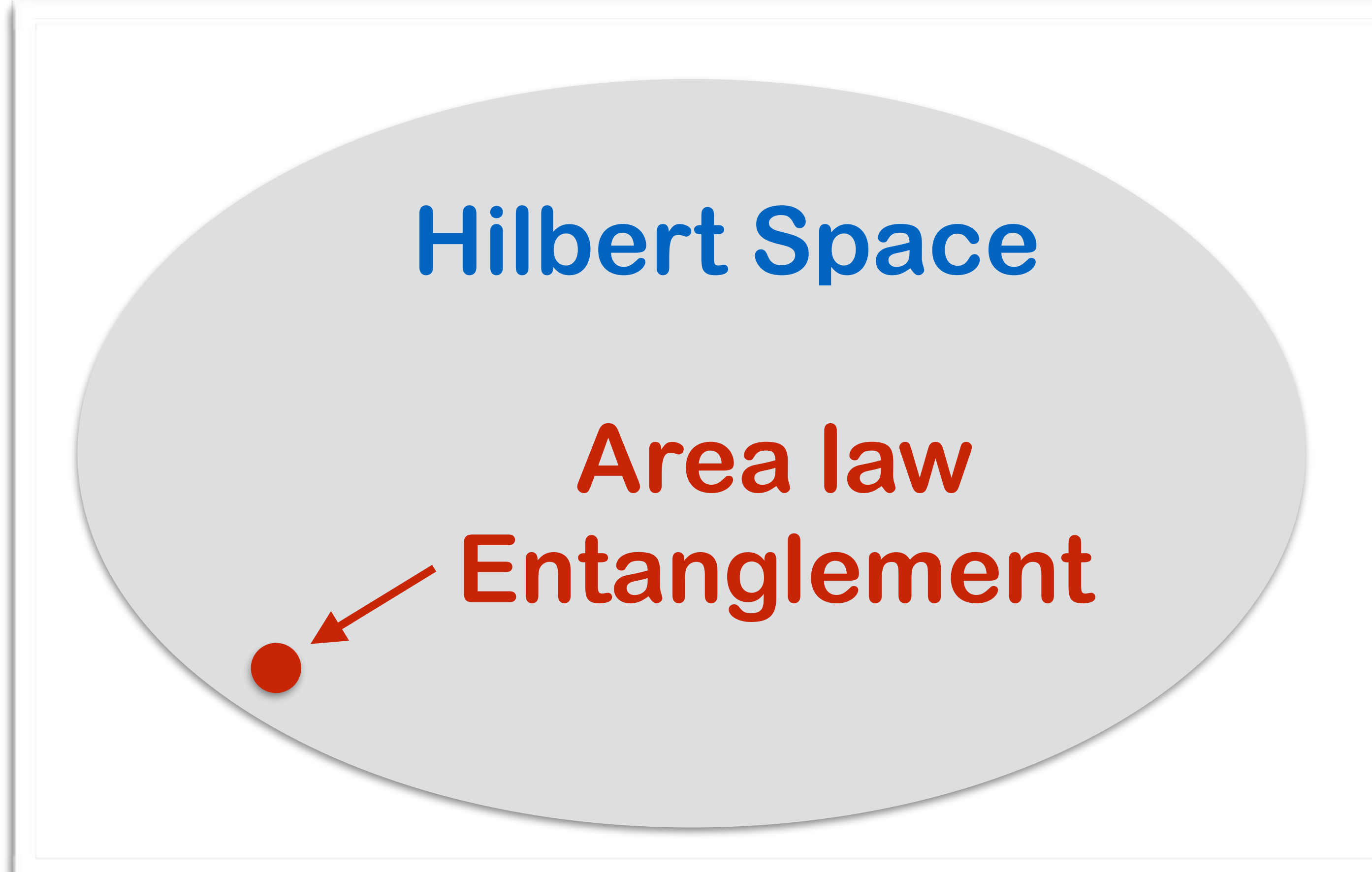
“Born” Machines

$$p(\mathbf{x}) = \frac{|\Psi(\mathbf{x})|^2}{\mathcal{N}}$$

quantum physics

Generative Modeling and Physics





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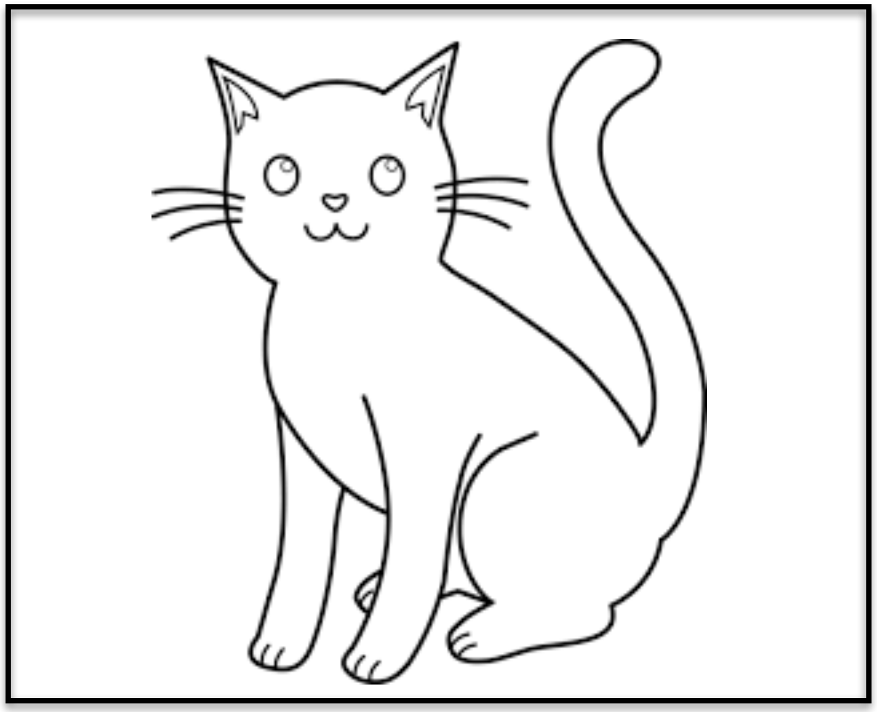
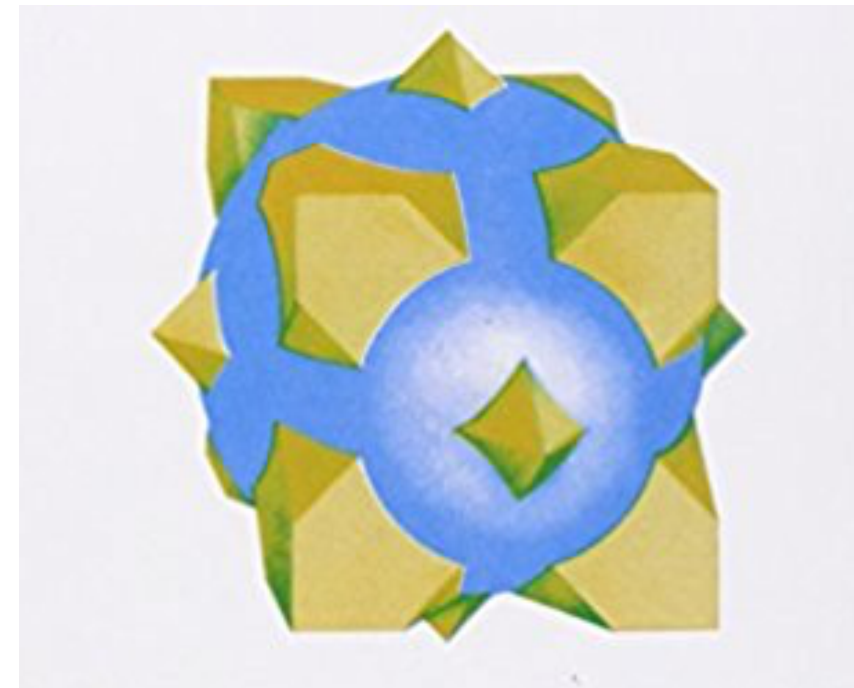
quantum physics

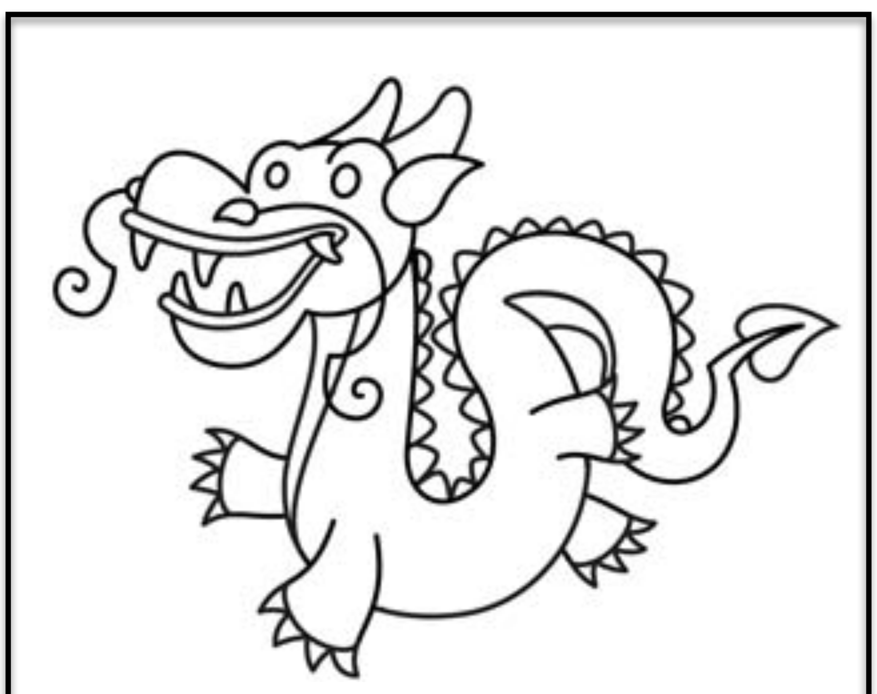
Image space versus Hilbert space



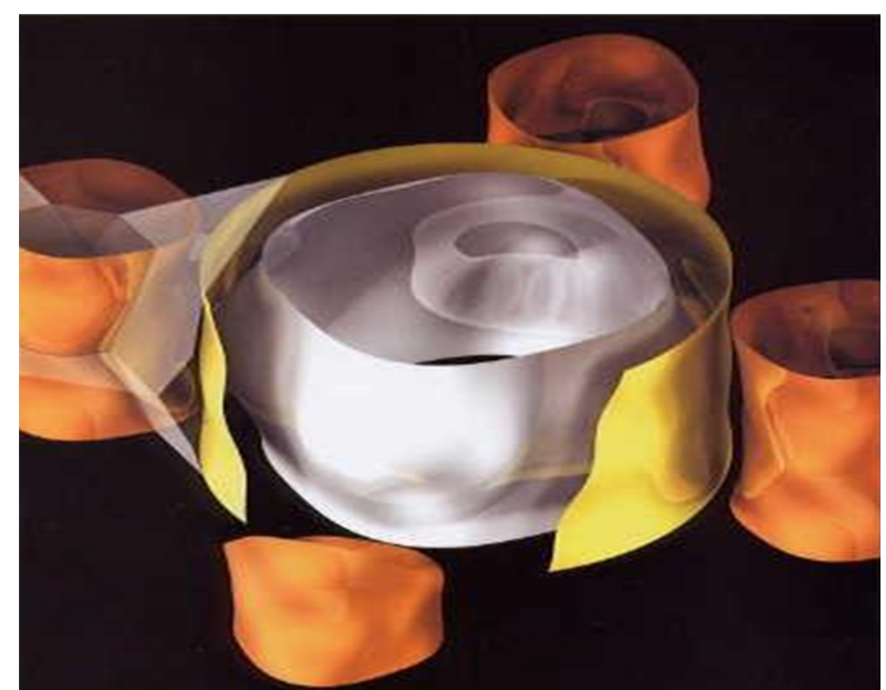
$\sim$



"ordinary" metal



$\sim$

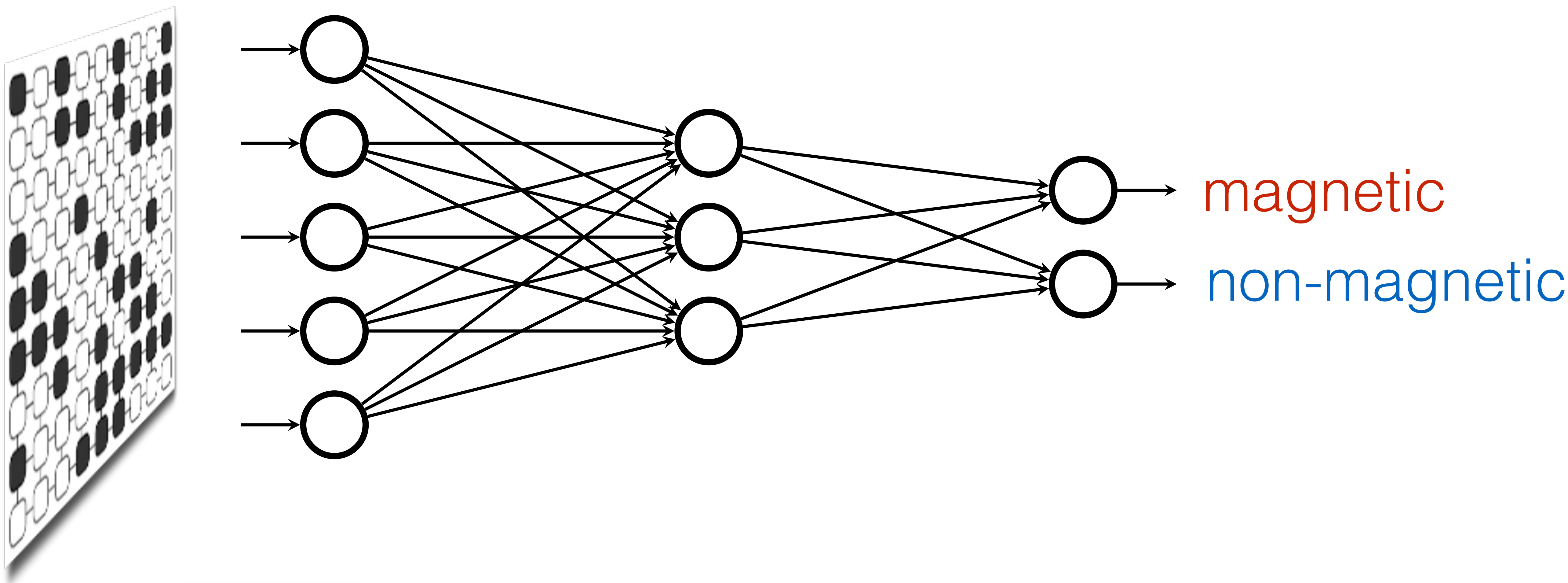


"exotic" superconductors

Quantum “Phase” Recognition

Microscopic

Configurations

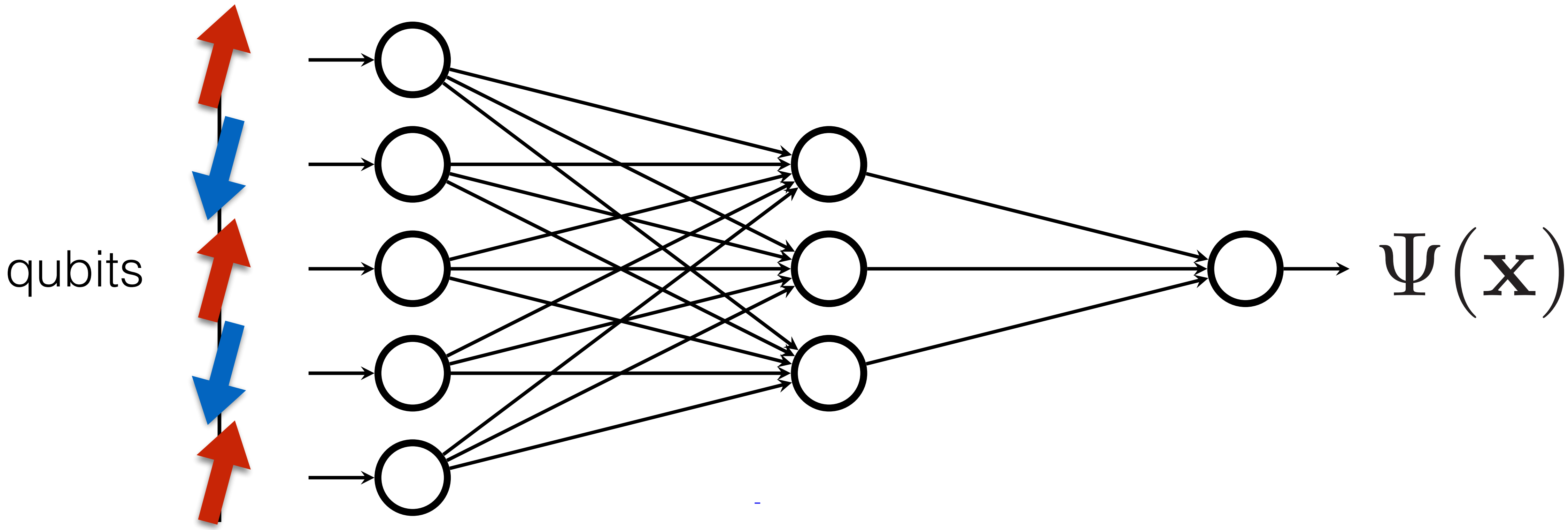


Classify quantum states of matter

Carrasquilla, Melko, Nat. Phys. 2017
Nieuwenburg, Liu, Huber, Nat. Phys. 2017

LW, PRB 2016,
and many others

Boltzmann machines as a wavefunction

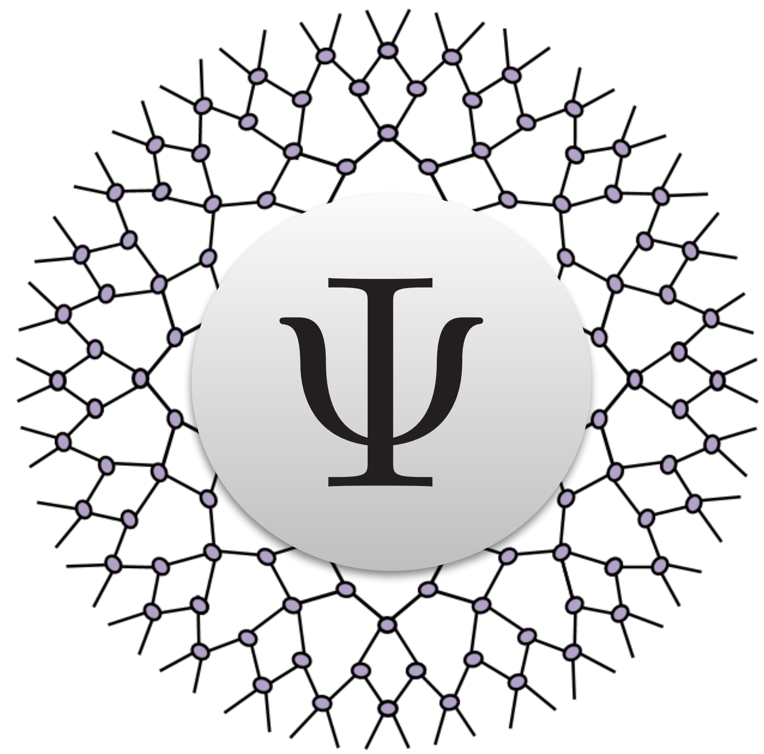


- Train the network with variational principle
- Feature discovery and abstraction power of deep hierarchical structure

“Teach a neural network quantum physics”

Carleo, Troyer, Science 2017   Deng, Li, Gao, Chen, Cheng, Xiang, Cai, LW… 2017

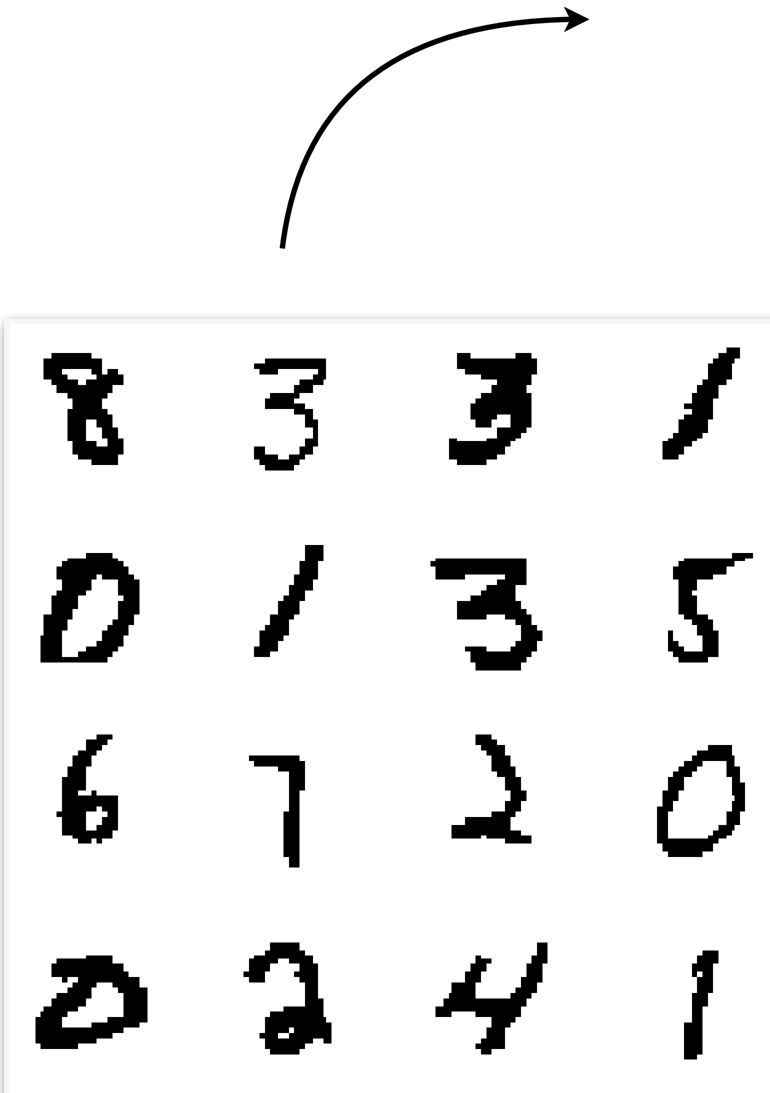
Quantum inspired generative modeling

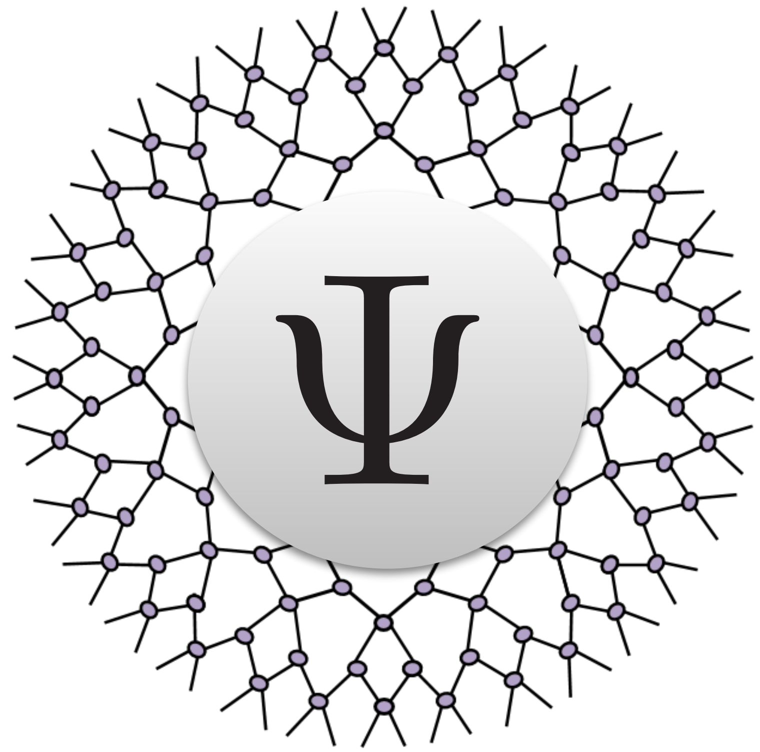


Han, Wang, LW, Zhang, arXiv 2017 cf. Stoudenmire and Schwab, NIPS 2016

Quantum inspired generative modeling

Learn



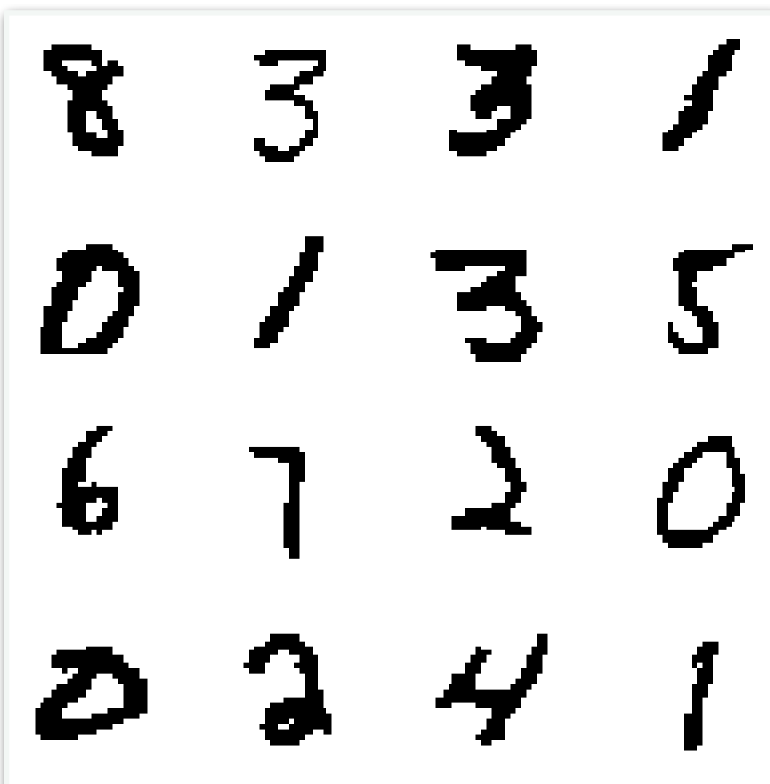


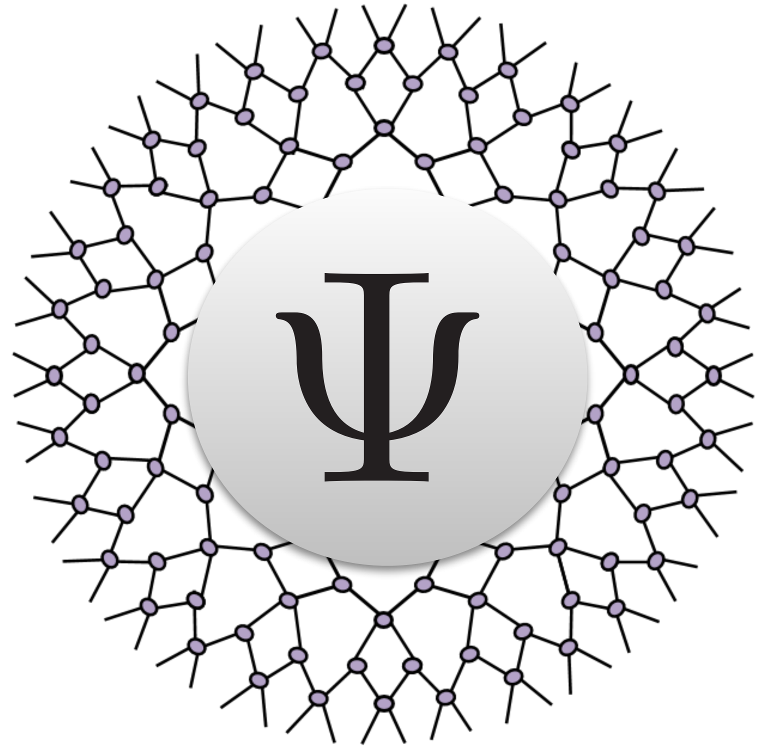
Han, Wang, LW, Zhang, arXiv 2017   cf. Stoudenmire and Schwab, NIPS 2016

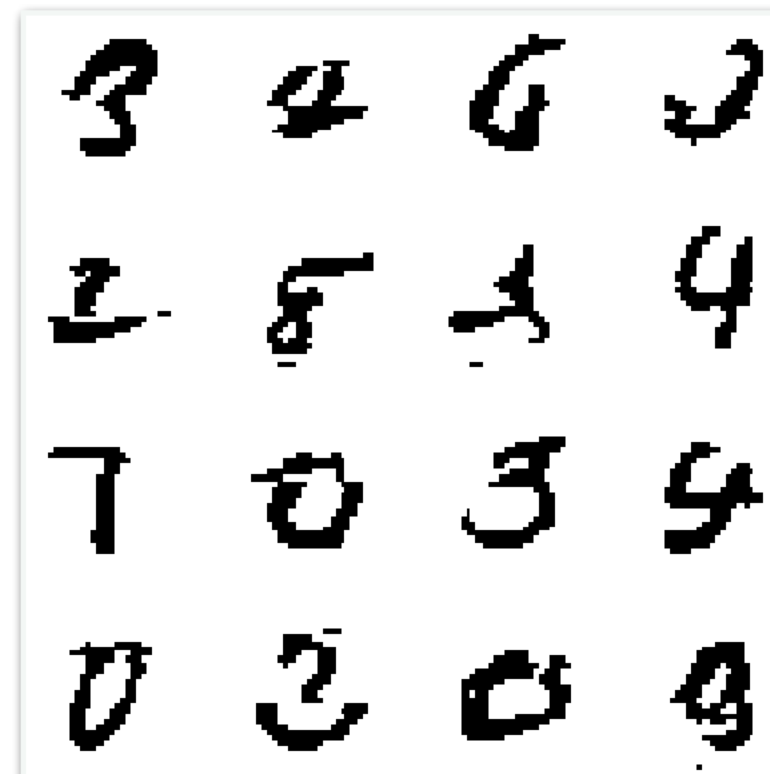
Quantum inspired generative modeling

Learn

Generate







Han, Wang, LW, Zhang, arXiv 2017 cf. Stoudenmire and Schwab, NIPS 2016

Quantum inspired generative modeling

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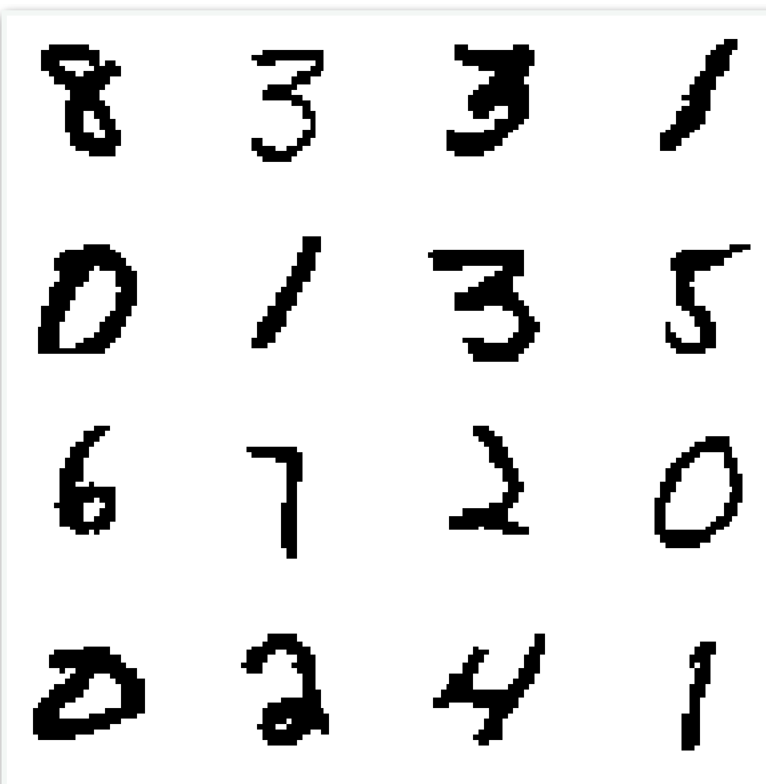
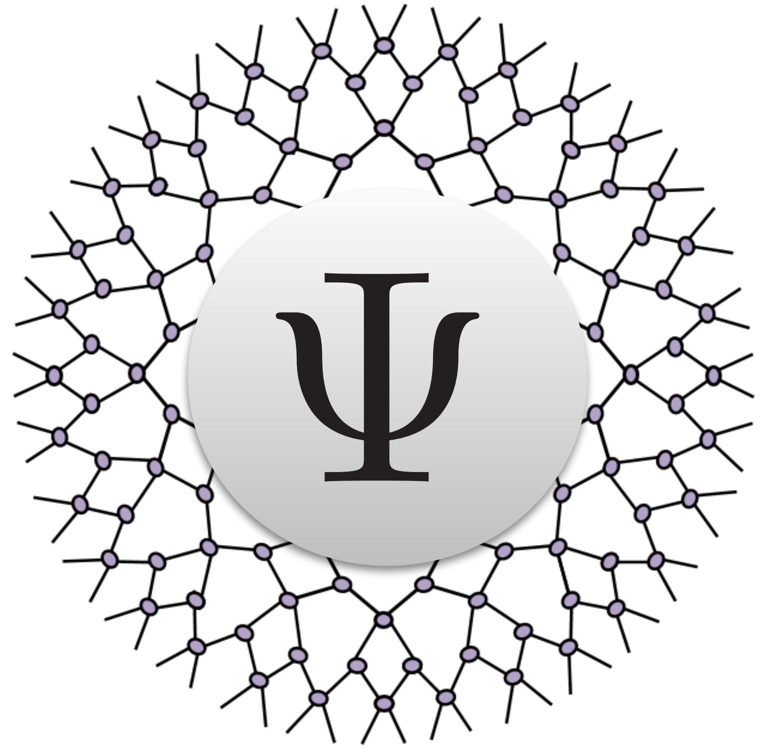
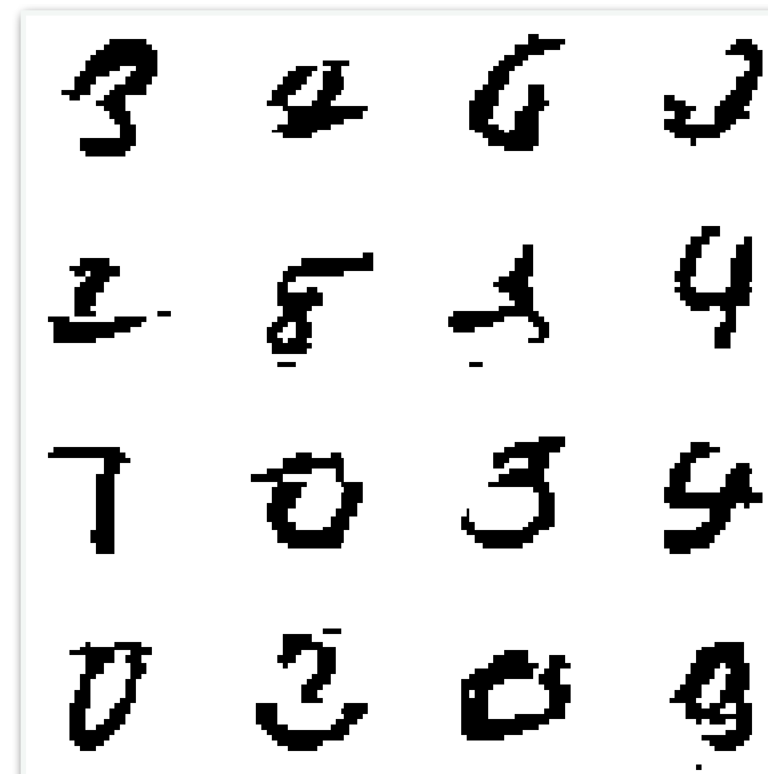




Generate

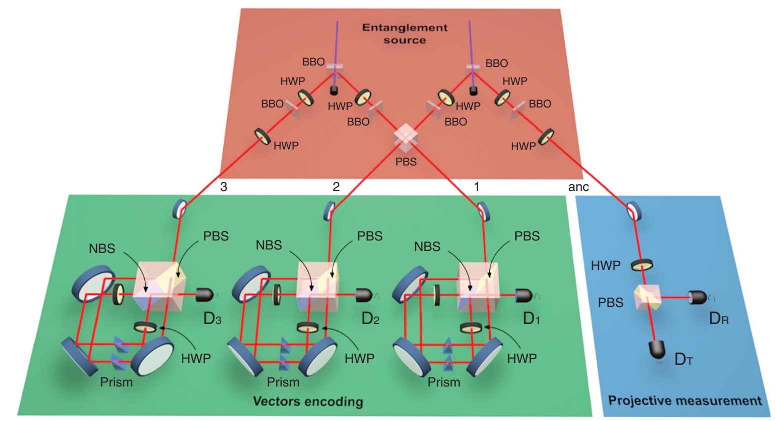


“Teach a quantum state to write digits”

Han, Wang, LW, Zhang, arXiv 2017   cf. Stoudenmire and Schwab, NIPS 2016

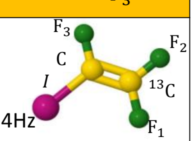
Quantum Machine Learning

- Search
- Sampling
- Clustering
- Optimization
- Linear system solver
- Support vector machines
- Principal component analysis



Cai et al, PRL **114**, 110504 (2015)

	^{13}C	F_1	F_2	F_3
^{13}C	15479.9Hz			
F_1	-297.7Hz	-33130.1Hz		
F_2	-275.7Hz	64.6Hz	-42681.4Hz	
F_3	39.1Hz	51.5Hz	-129.0Hz	-56443.5Hz
T_2^*	1.22s	0.66s	0.63s	0.61s
T_2	7.9s	4.4s	6.8s	4.8s



Li et al, PRL **114**, 140504 (2015)

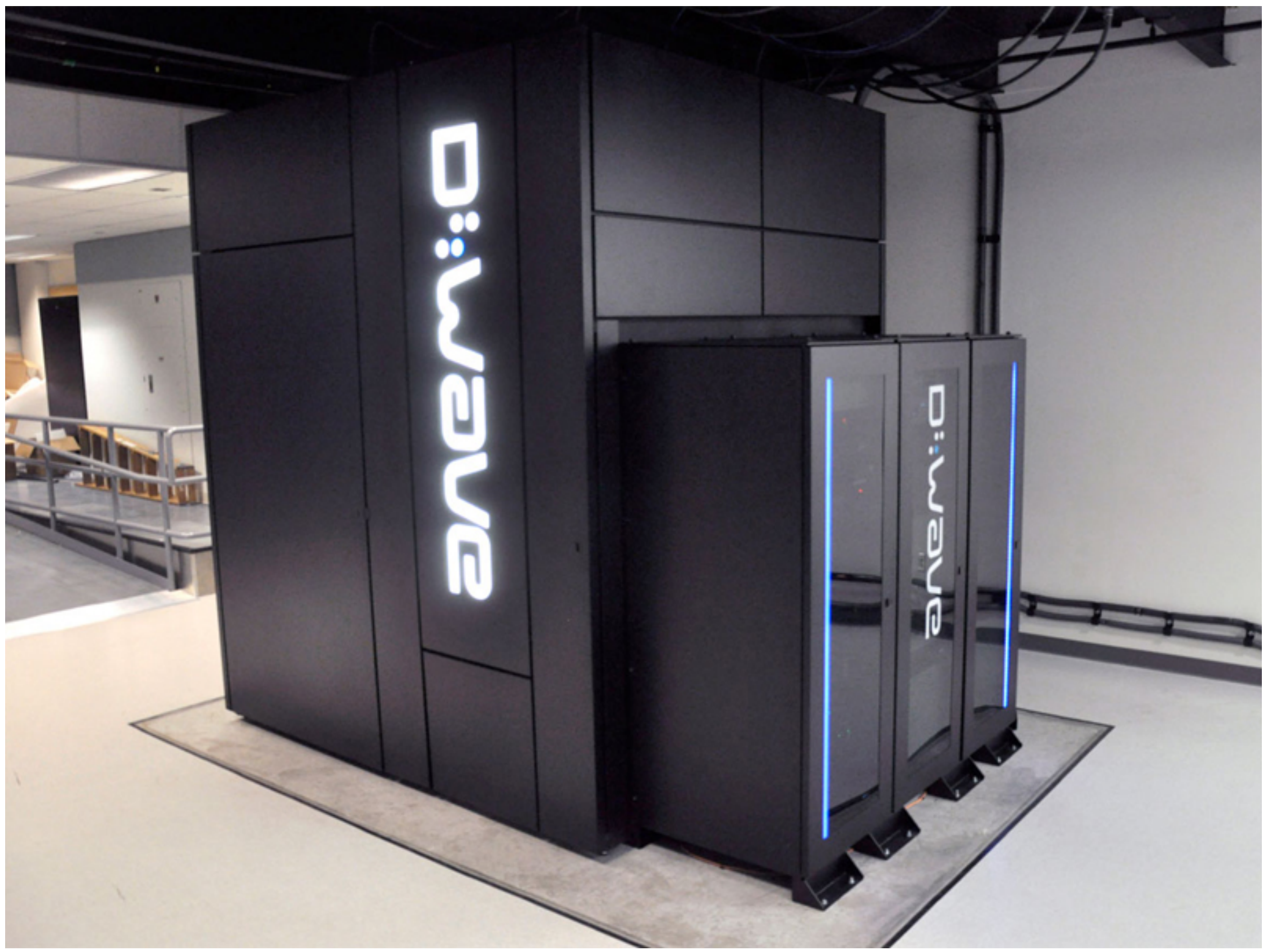
few qubits demo

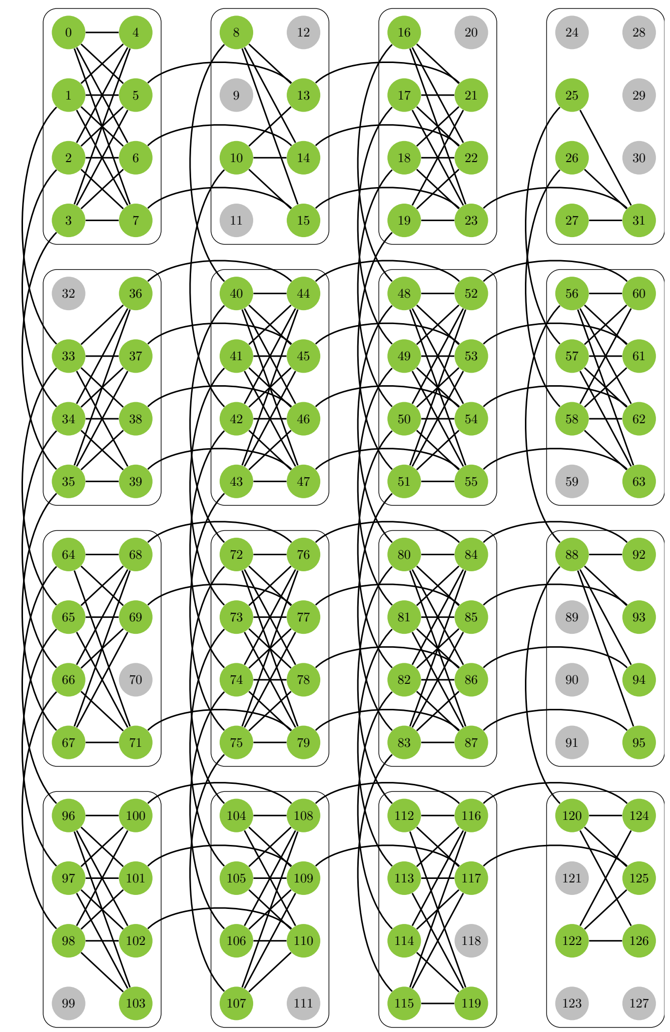
"Use a quantum computer to speed up ML subroutines"

Review "Quantum machine learning", Biamonte et al, Nature 2017

Quantum Boltzmann Machines

$15 million “analog quantum device”





~2000 “qubits”

Is there any advantage of this quantum architecture?

Amin et al, 1601.02036   Perdomo-Ortiz et al, 1708.09757

Do Androids dream of Schrödinger's cat ?

Thank you!