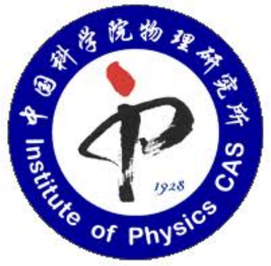
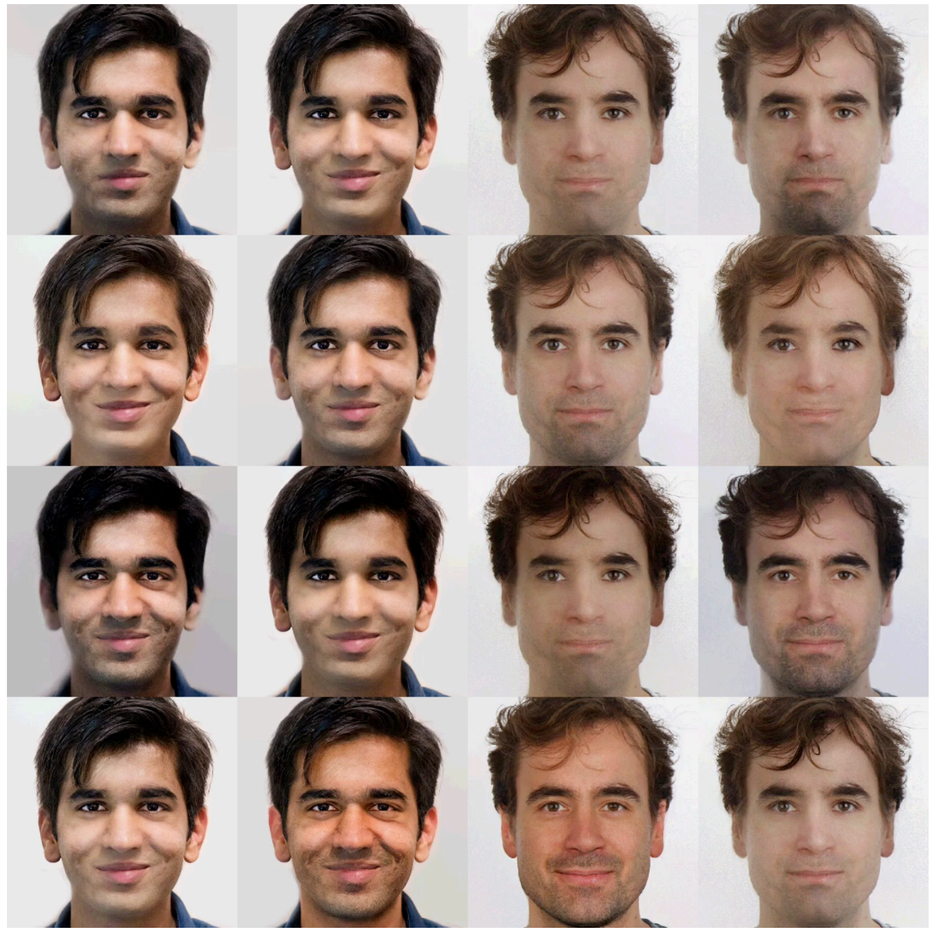
Generative Models for Physicists

Lei Wang (王磊)
https://wangleiphy.github.io

Institute of Physics, Beijing
Chinese Academy of Sciences



Generative Models



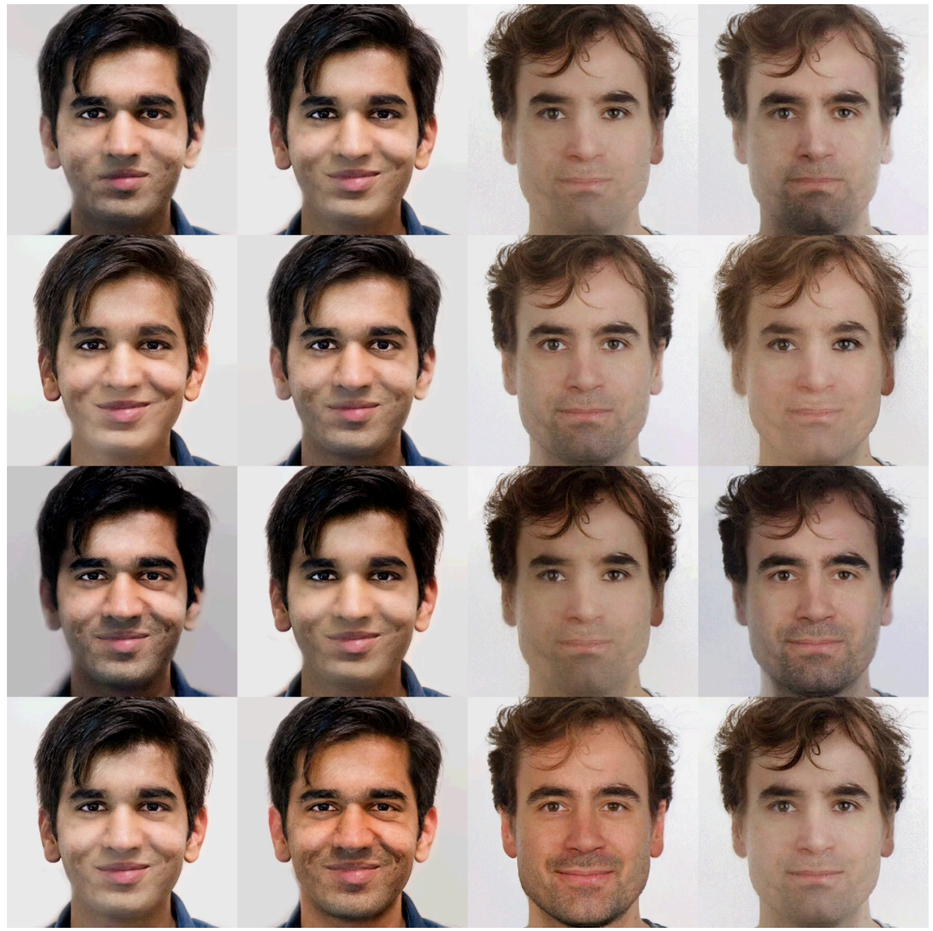
WaveNet 1609.03499 1711.10433

https://deepmind.com/blog/wavenet-generative-model-raw-audio/
https://deepmind.com/blog/high-fidelity-speech-synthesis-wavenet/
https://deepmind.com/blog/wavenet-launches-google-assistant/

Glow 1807.03039

https://blog.openai.com/glow/

Generative Models



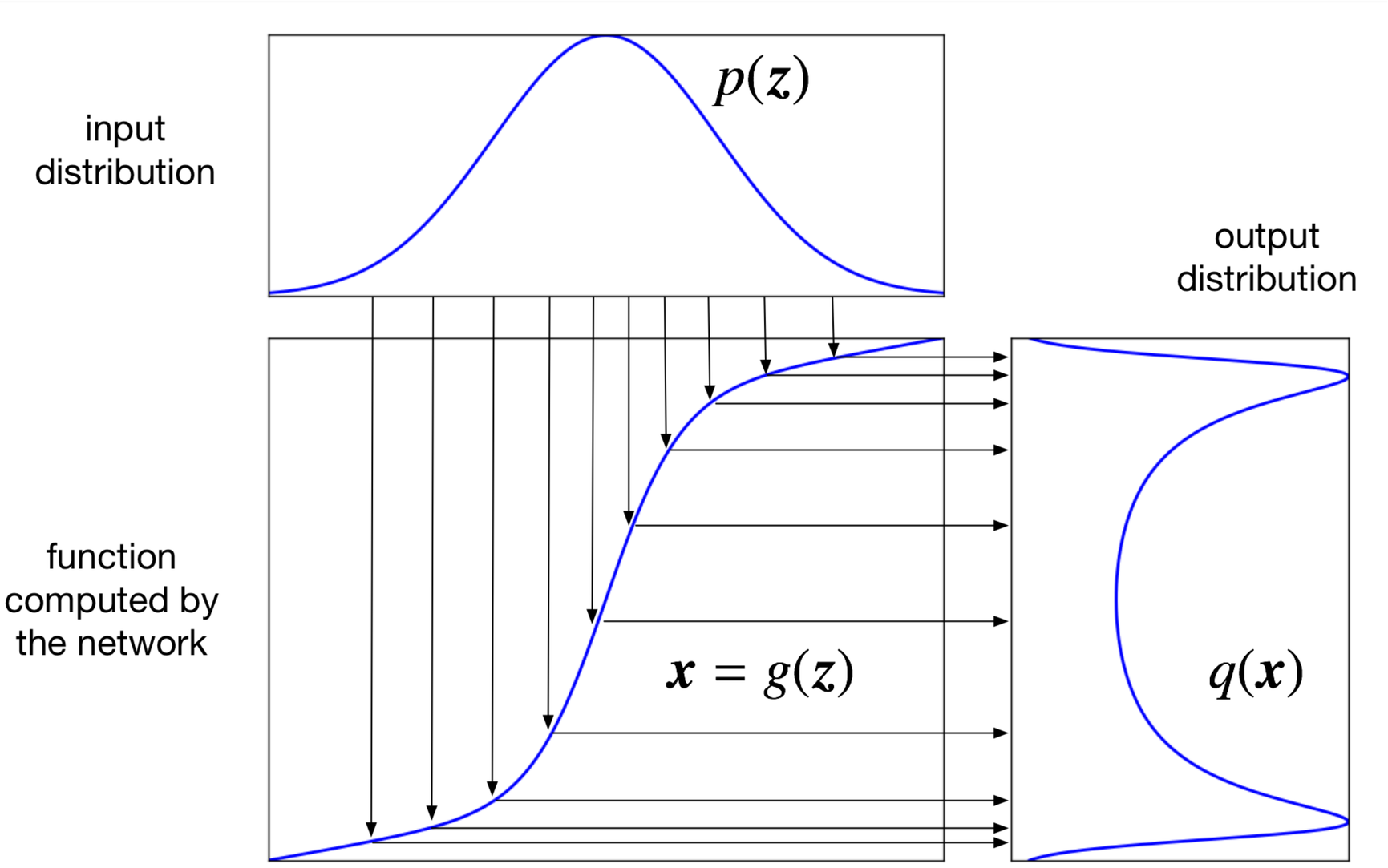
WaveNet 1609.03499 1711.10433

https://deepmind.com/blog/wavenet-generative-model-raw-audio/
https://deepmind.com/blog/high-fidelity-speech-synthesis-wavenet/
https://deepmind.com/blog/wavenet-launches-google-assistant/

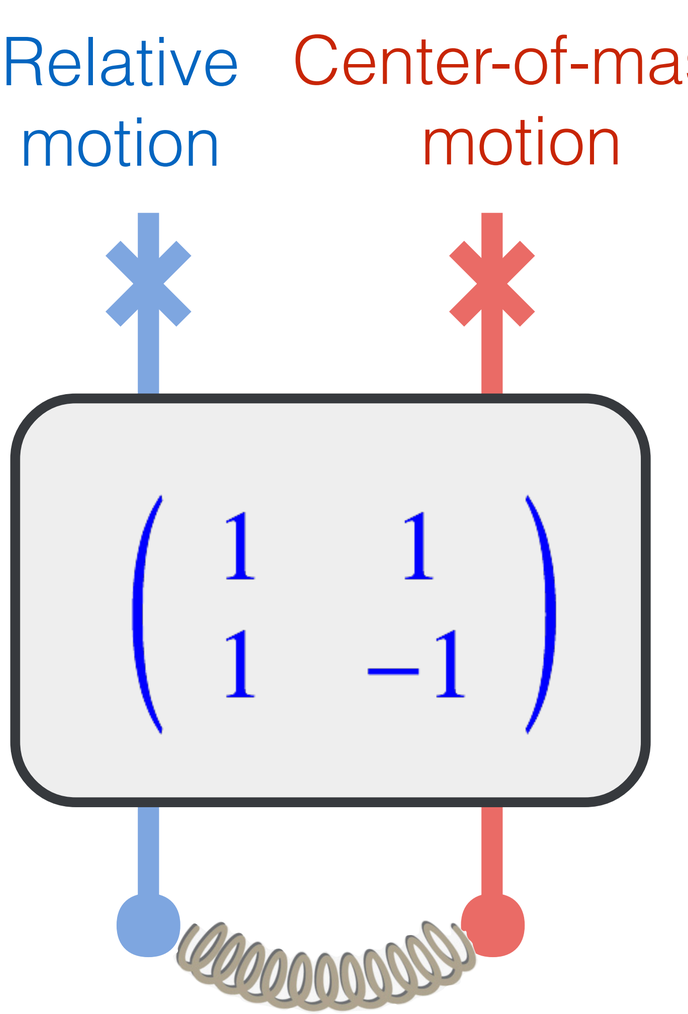
Glow 1807.03039

https://blog.openai.com/glow/

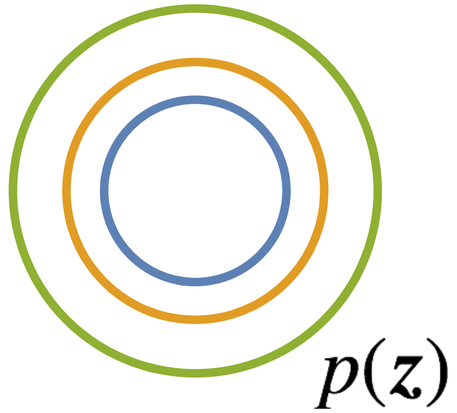
Probability transformation in picture

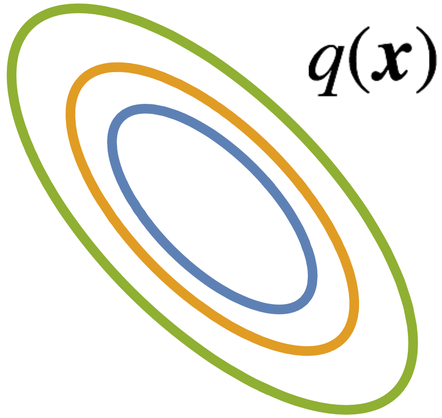


A Toy problem: Harmonic oscillator



Coupled harmonic oscillator

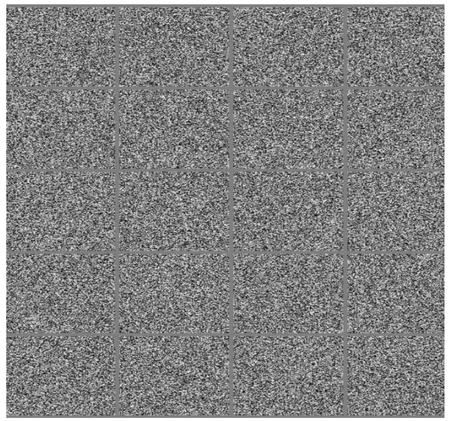




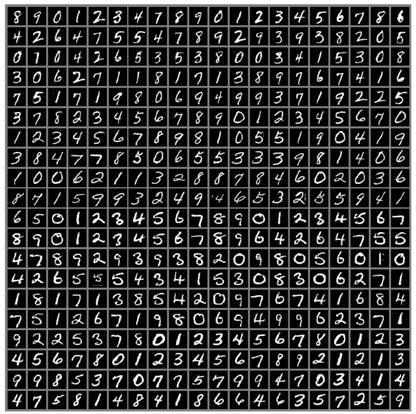
Probabilistic Generative Modeling

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

How to express, learn, and sample from a high-dimensional probability distribution ?



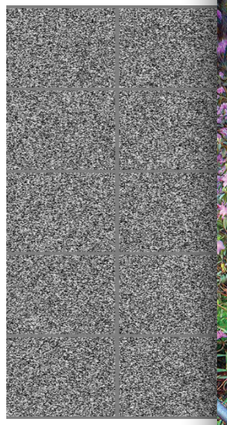
“random” images



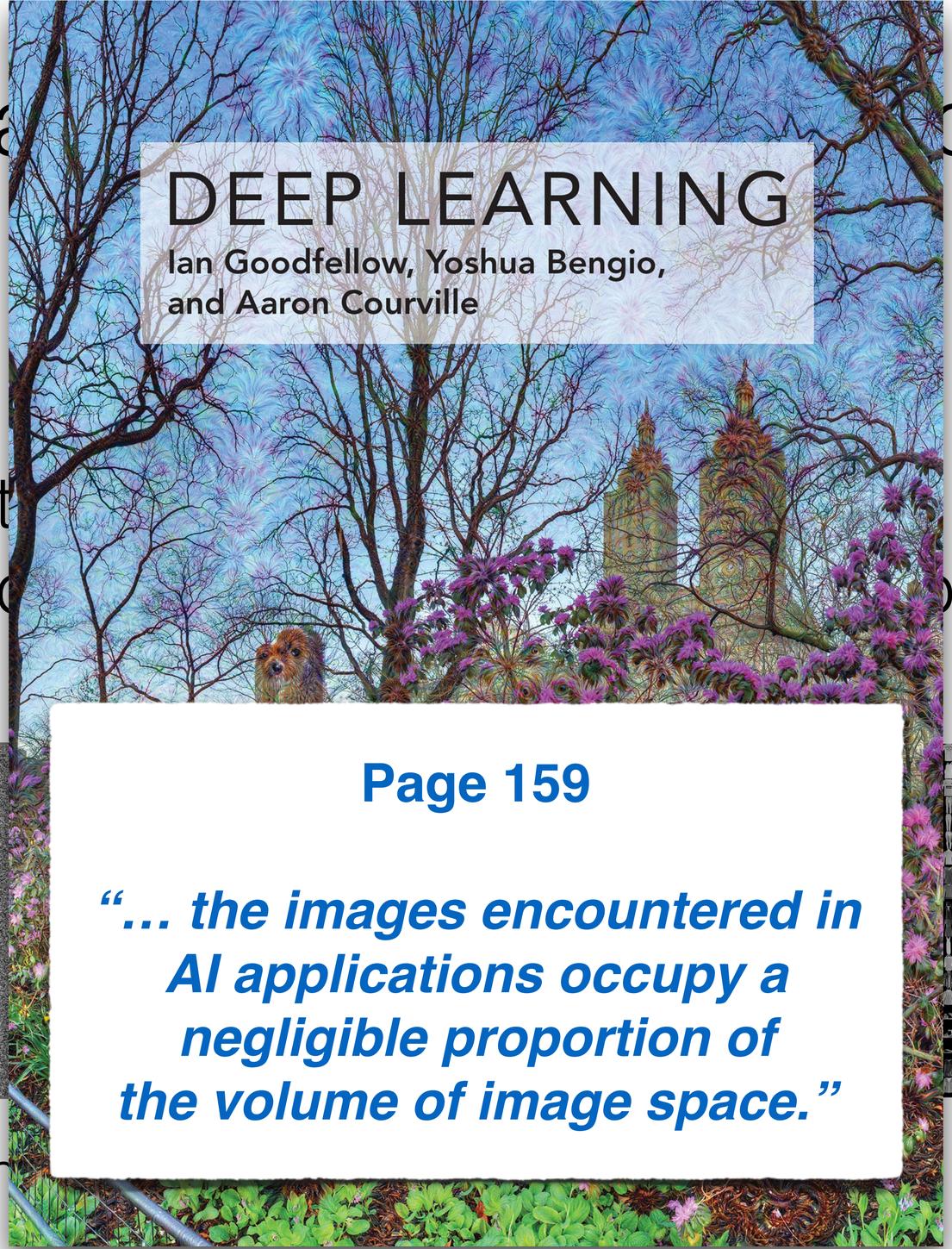
“natural” images

Proba odeling

How t from a
high-d ution ?



“random



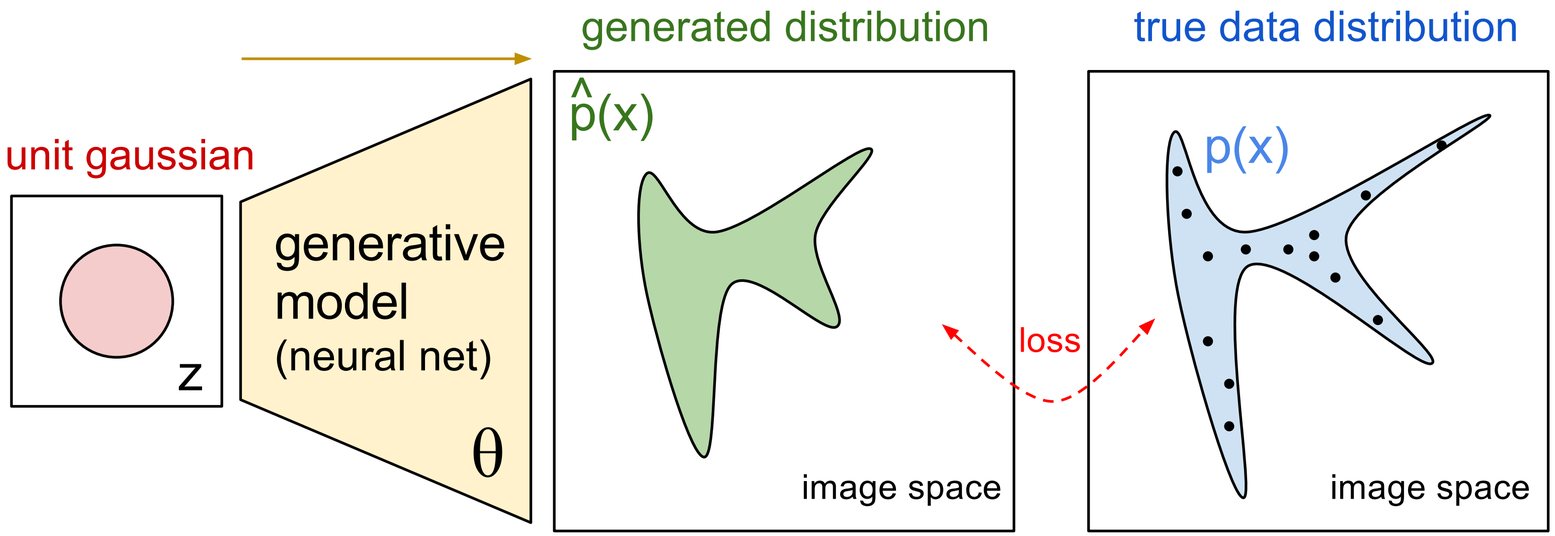
Page 159

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

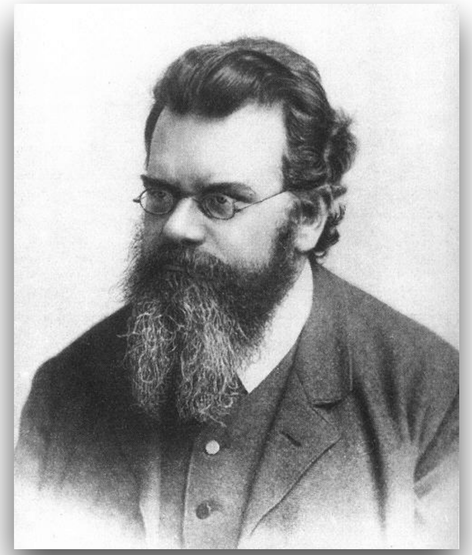
Probabilistic Generative Modeling

$$p(x)$$

How to express, learn, and sample from a high-dimensional probability distribution ?



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



Boltzmann Machines

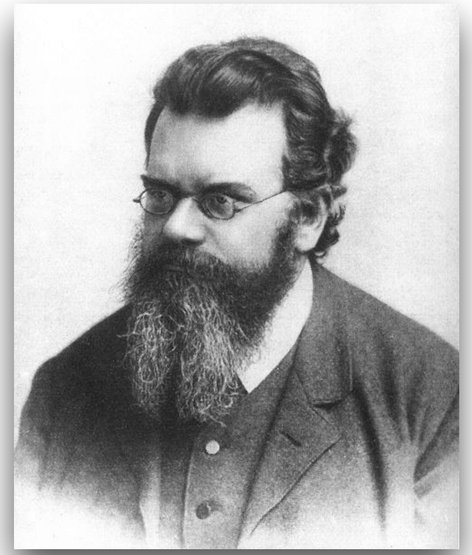
$$p(\boldsymbol{x}) = \frac{e^{-E(\boldsymbol{x})}}{Z}$$

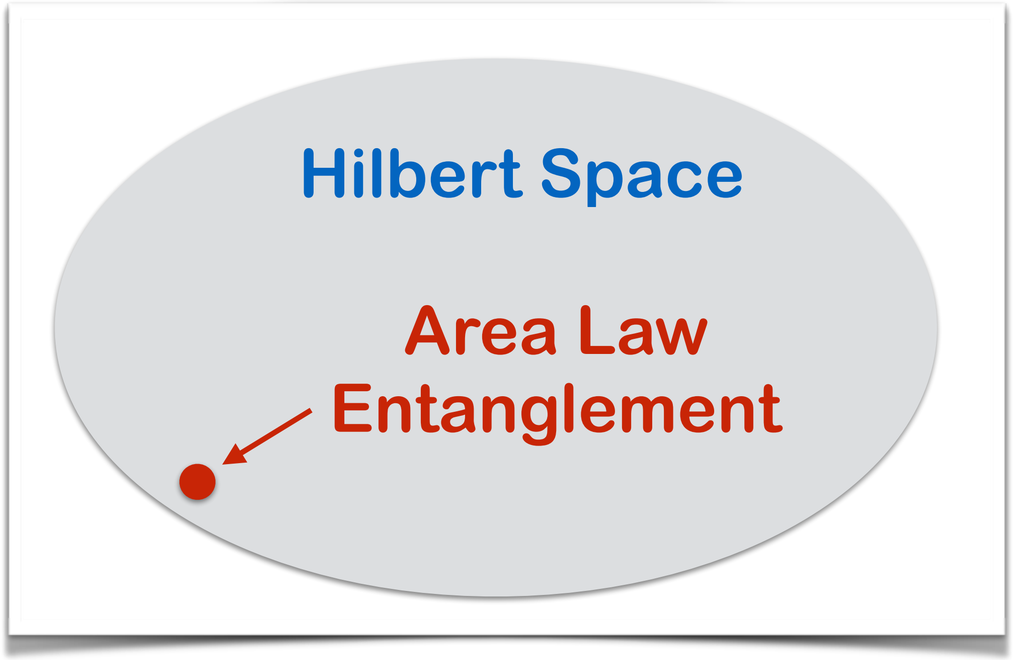
statistical physics

Born Machines

$$p(\boldsymbol{x}) = \frac{|\Psi(\boldsymbol{x})|^2}{Z}$$

quantum physics





Boltzmann Machines

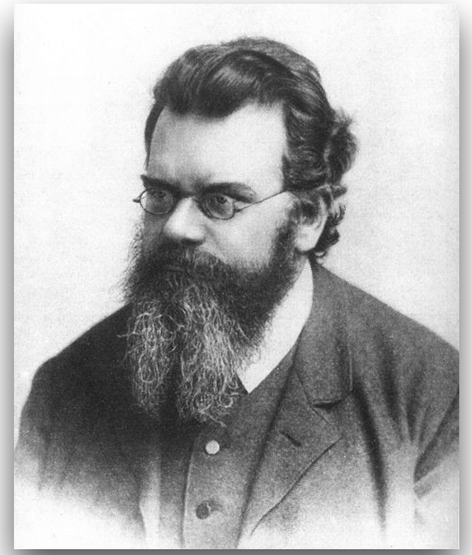
$$p(\boldsymbol{x}) = \frac{e^{-E(\boldsymbol{x})}}{Z}$$

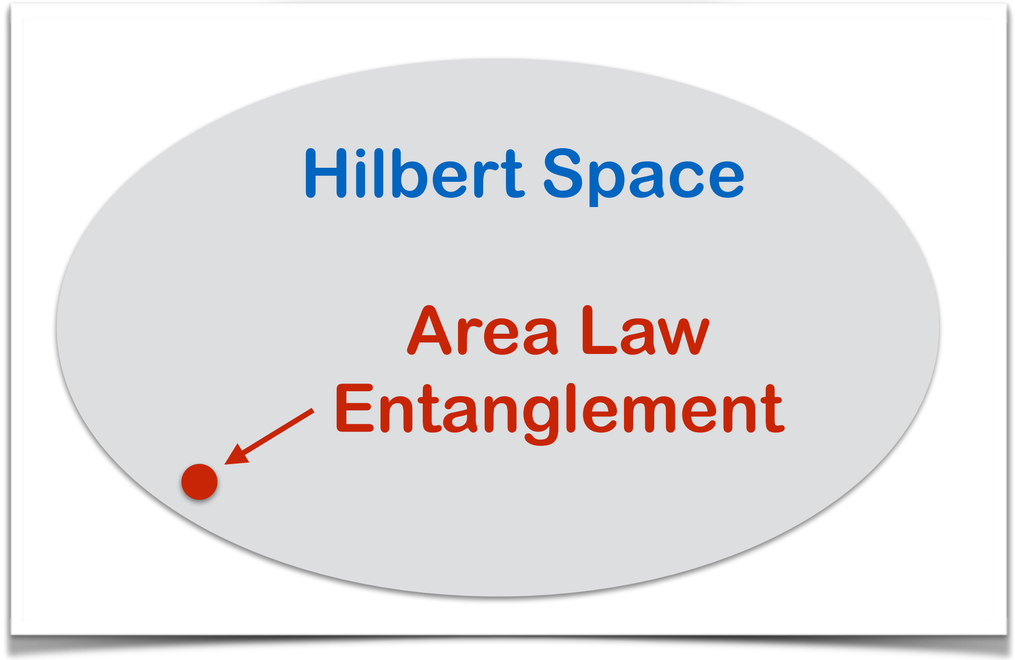
statistical physics

Born Machines

$$p(\boldsymbol{x}) = \frac{|\Psi(\boldsymbol{x})|^2}{Z}$$

quantum physics



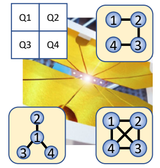


Boltzmann Machines

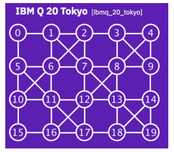
$$p(\boldsymbol{x}) = \frac{e^{-E(\boldsymbol{x})}}{Z}$$

statistical physics

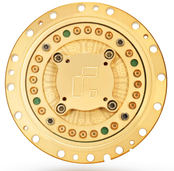
Born Machines



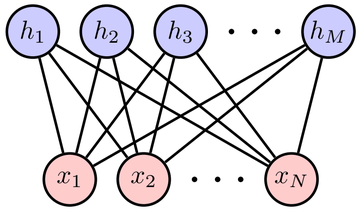
$$p(\boldsymbol{x}) = \frac{|\Psi(\boldsymbol{x})|^2}{Z}$$

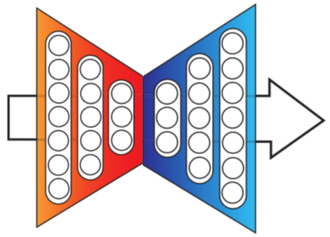


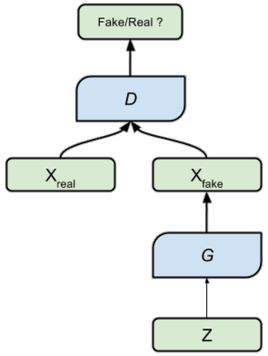
quantum physics

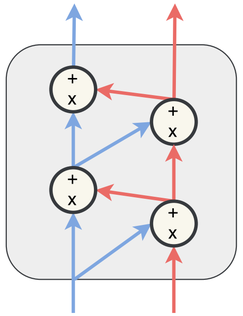


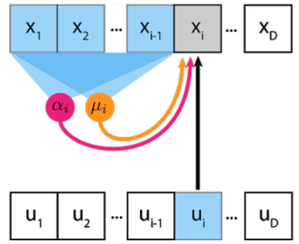
Timeline of Generative Models

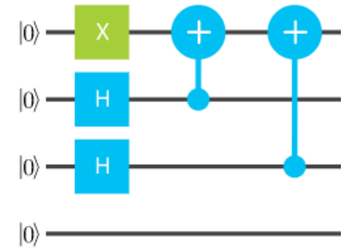












Boltzmann Machines 1980s

Variational Autoendoer 2013

Adversarial Network 2014

Normalizing Flows 2015

Autoregressive Flows 2016

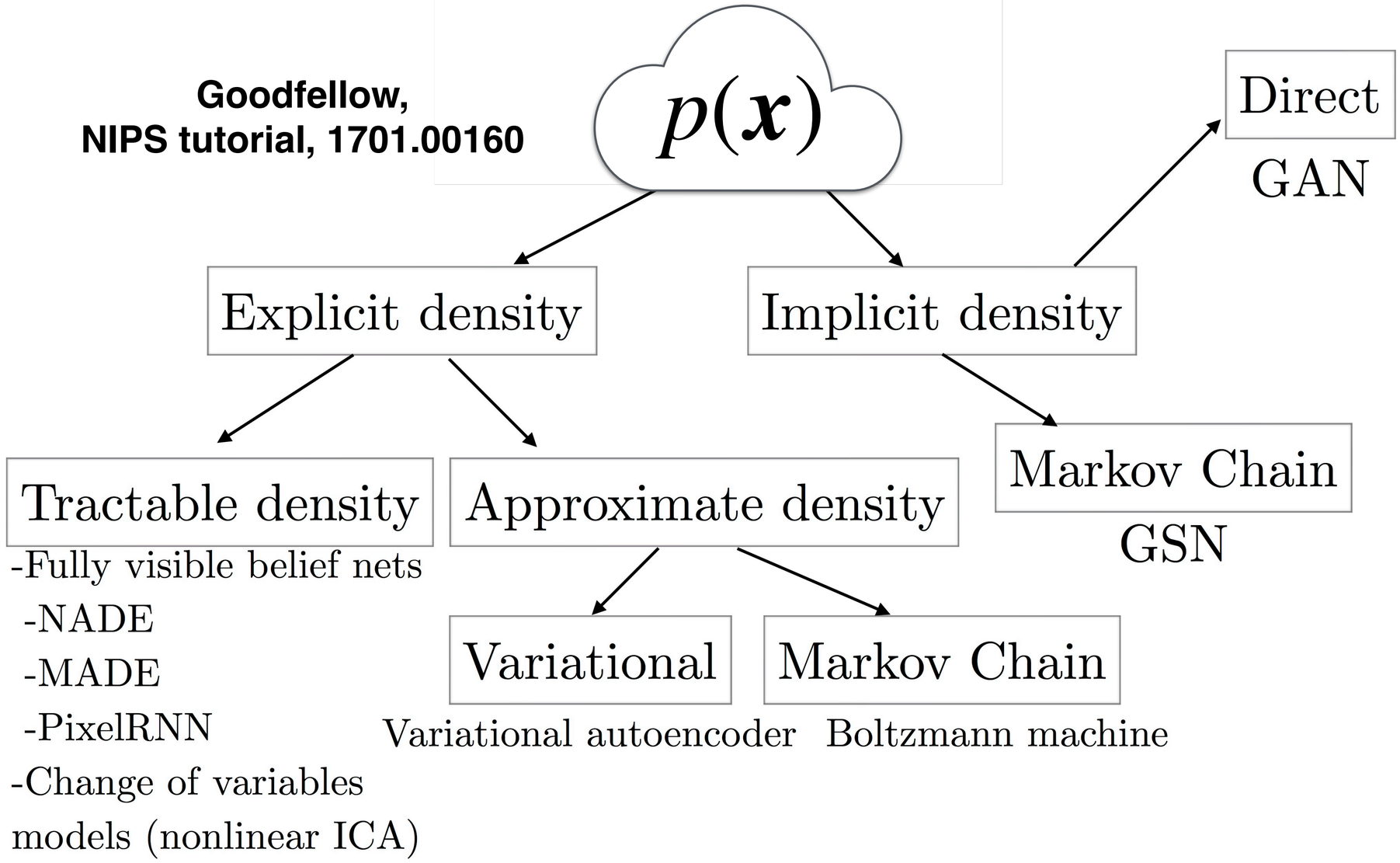
Born Machines 2017

1. **Leverage the power of modern generative models for physics**
2. **Statistical, quantum, and fluid mechanics inspired generative models**

Switch to iPad

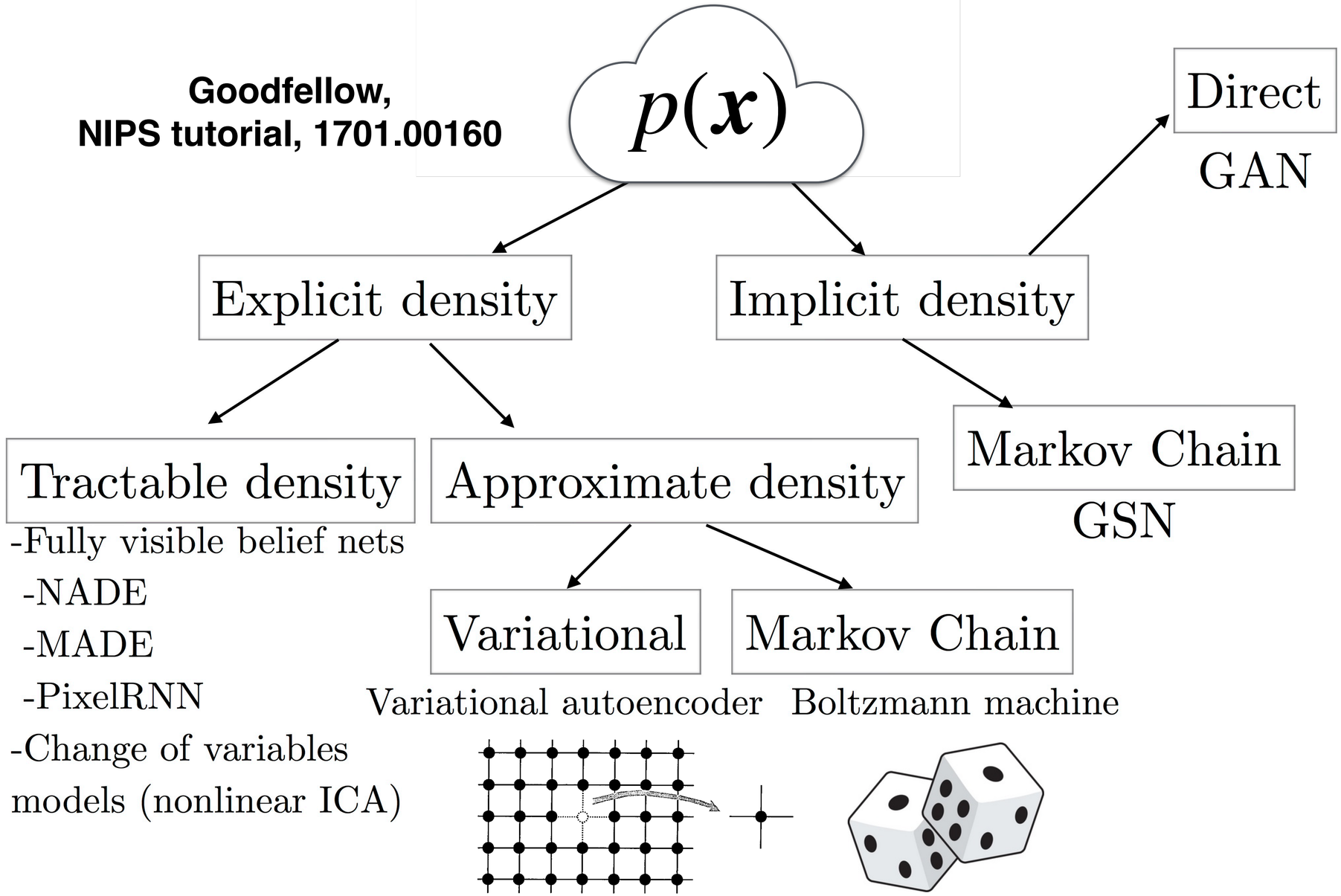
Physics genes of generative models

Goodfellow,
NIPS tutorial, 1701.00160



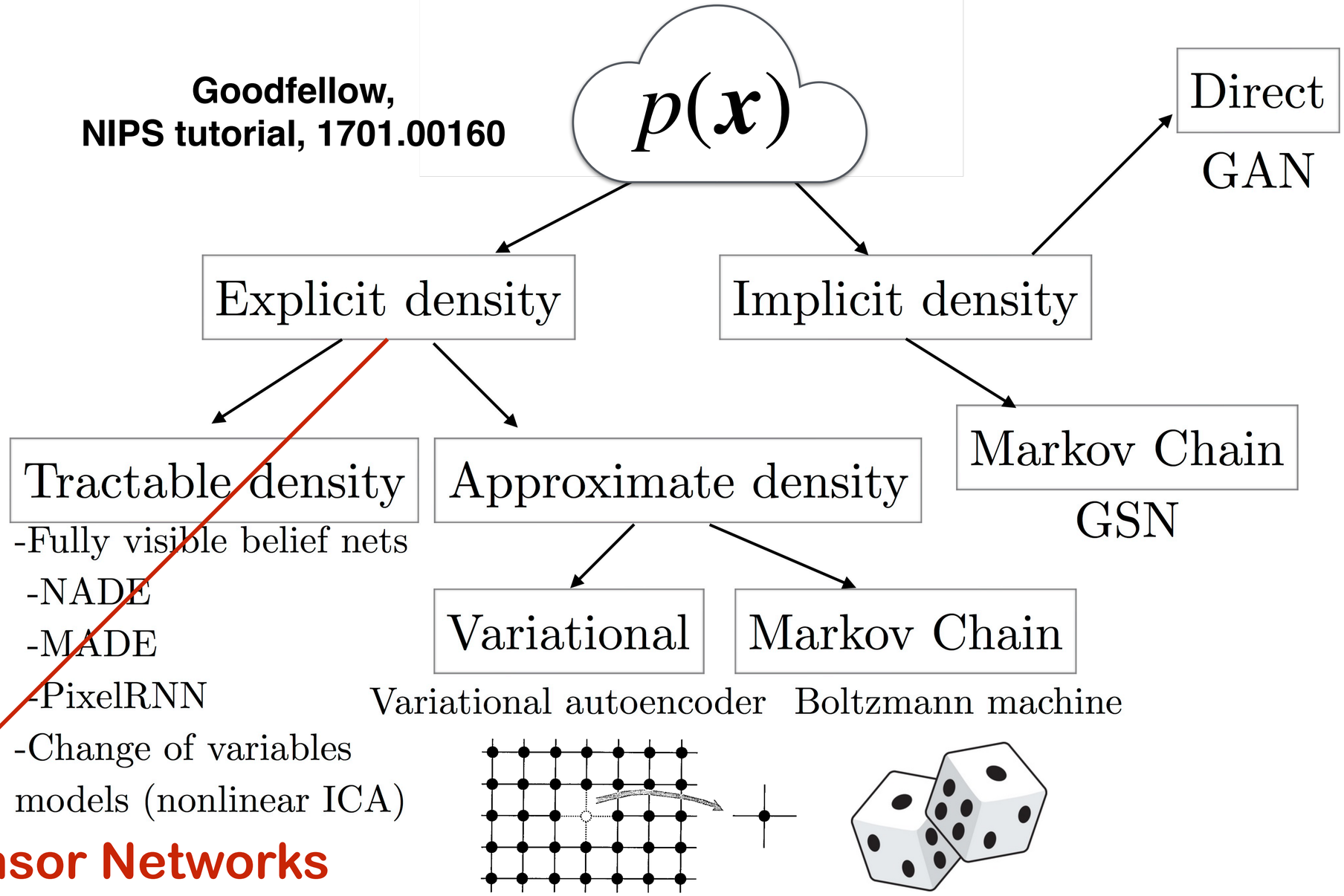
Physics genes of generative models

Goodfellow,
NIPS tutorial, 1701.00160



Physics genes of generative models

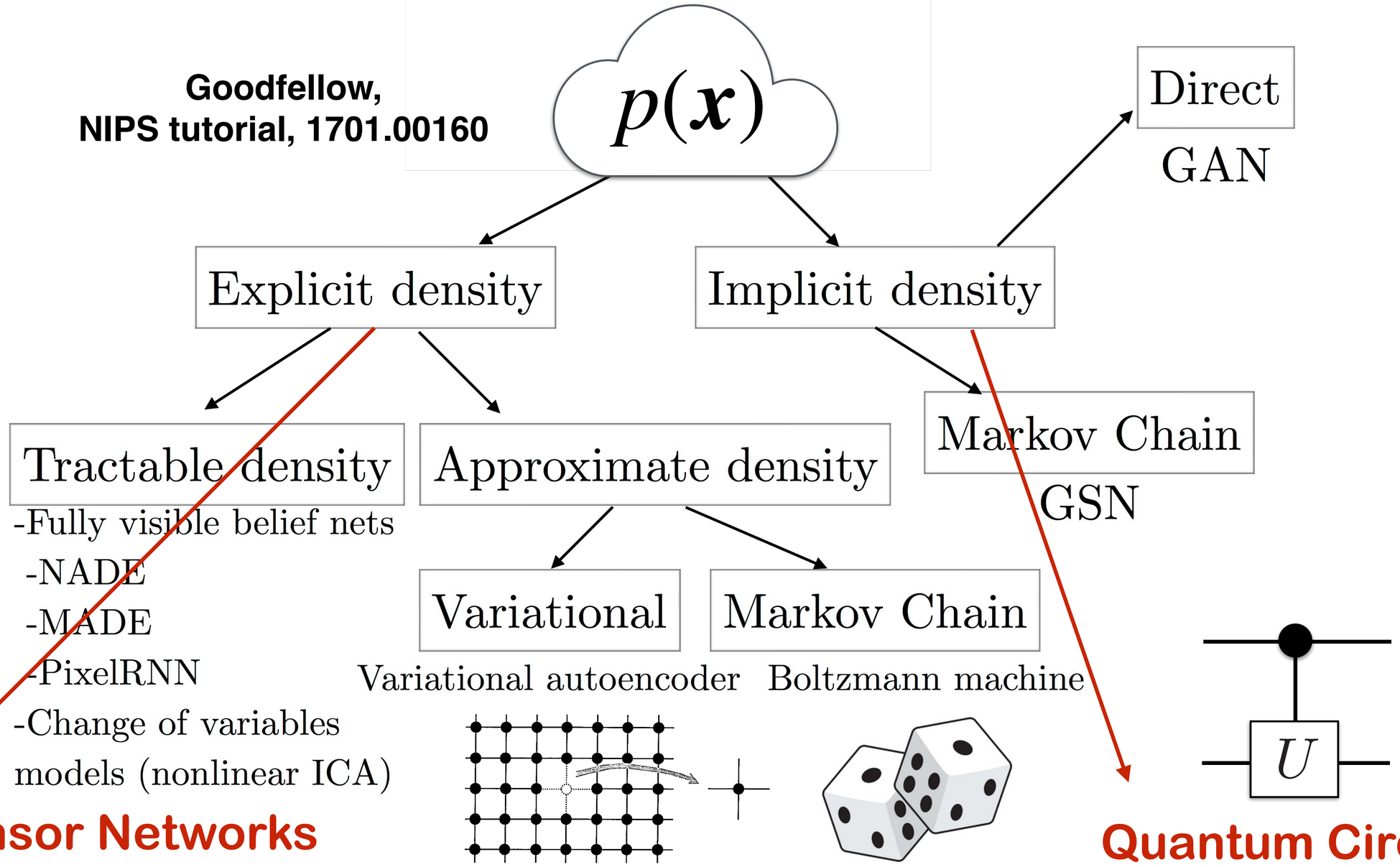
Goodfellow,
NIPS tutorial, 1701.00160



Tensor Networks

Physics genes of generative models

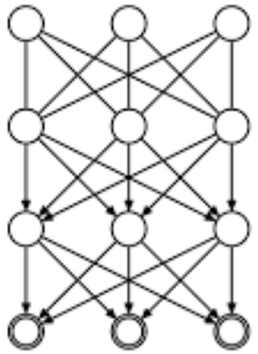
Goodfellow,
NIPS tutorial, 1701.00160



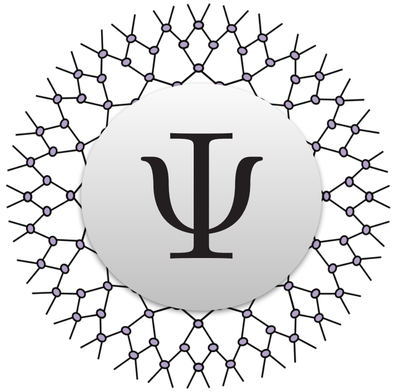
Tensor Networks

Quantum Circuits

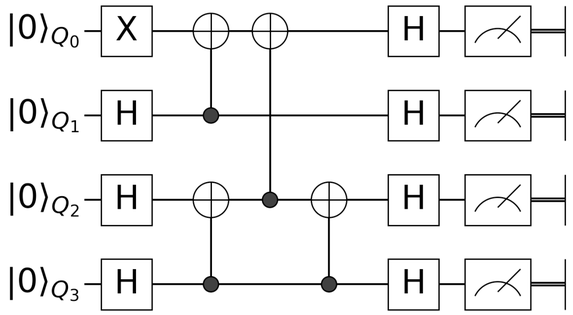
Neural Networks



Tensor Networks



Quantum Circuits



“三重境界”

1. Function Approximation
2. Probabilistic Transformation
3. Information Processing Device