

Geometric deep learning

Michael Bronstein

Imperial College
London

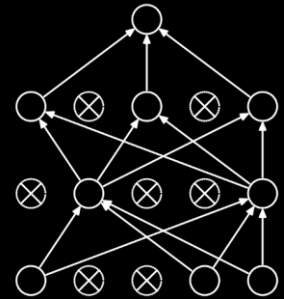
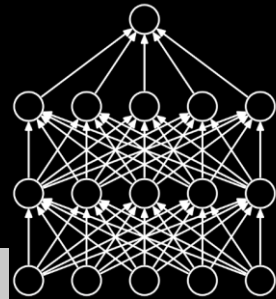




deep learning

Imagenet breakthrough
Krizhevsky

Per
Ros



2010 2012 2014 2015 2016 2017 2018

Visual cortex
Hubel & Wiesel

Neurocognitron
Fukushima

RNN / LSTM
Schmidhuber

Computation

Algorithms

Data



WAYMO



UBER

TESLA

Computer vision

Google



Speech & language



BenevolentAI

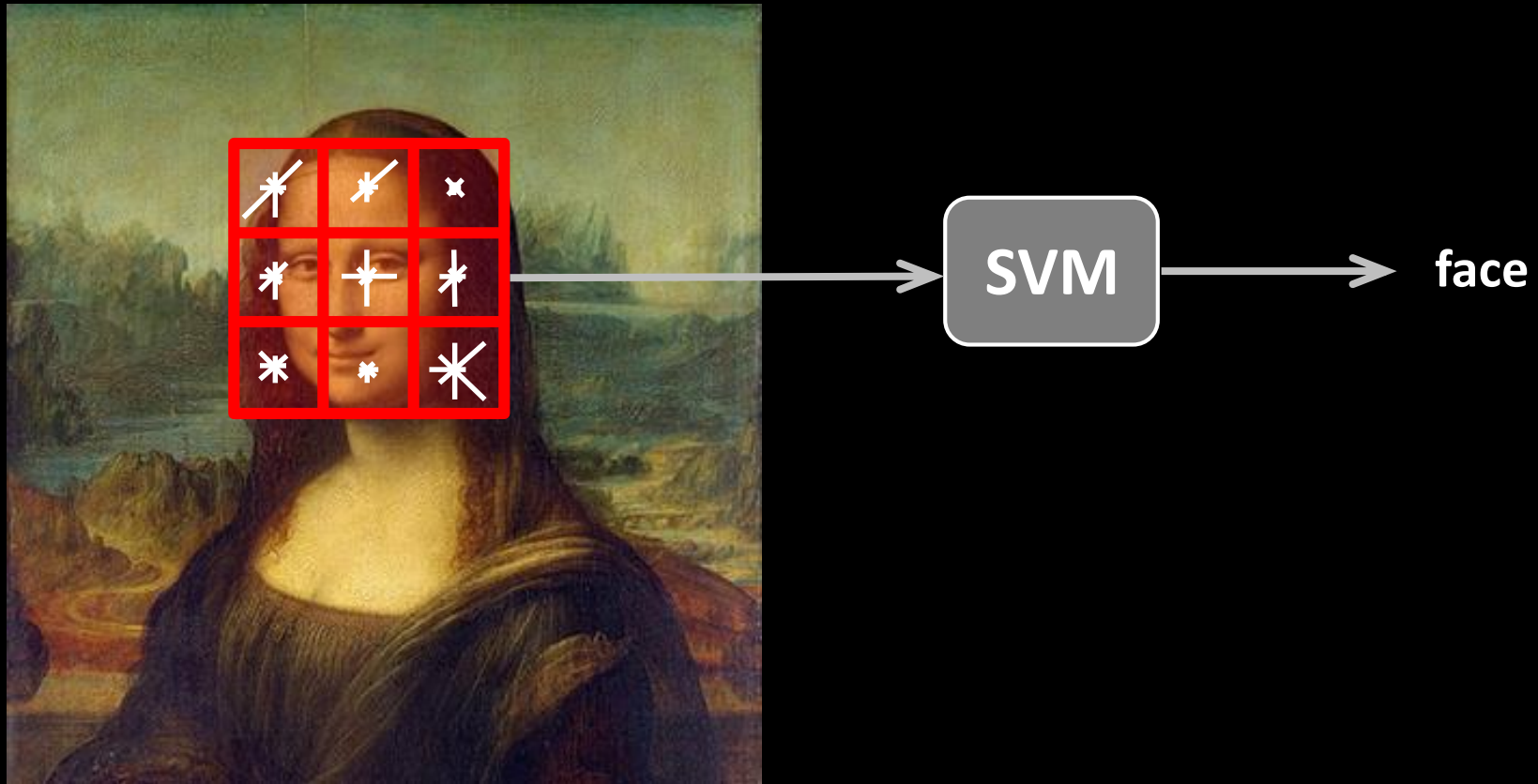


THERAPANACEA



Healthcare

“classical” computer vision

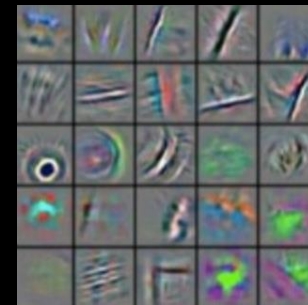


handcrafted features

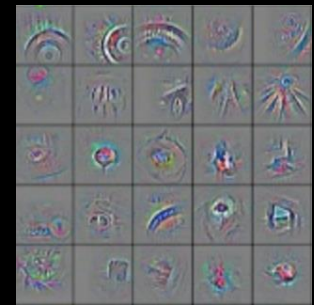
deep learning era



layer 1

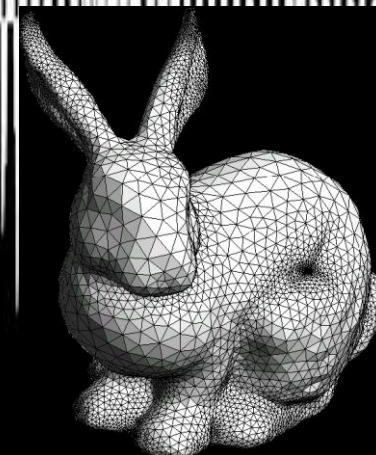
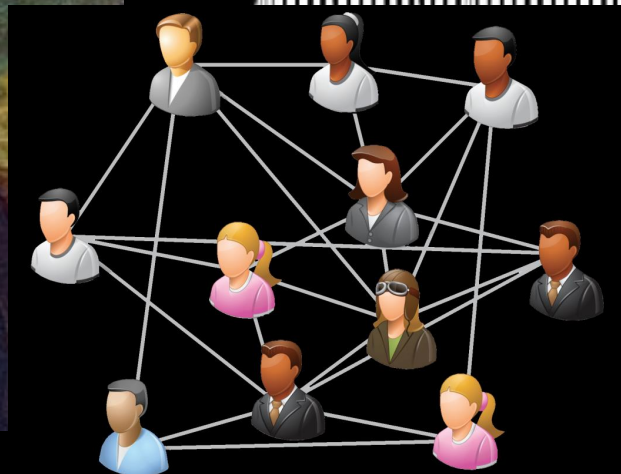
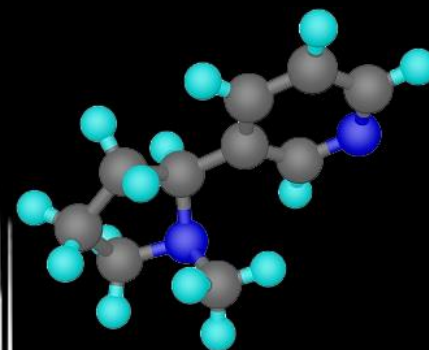
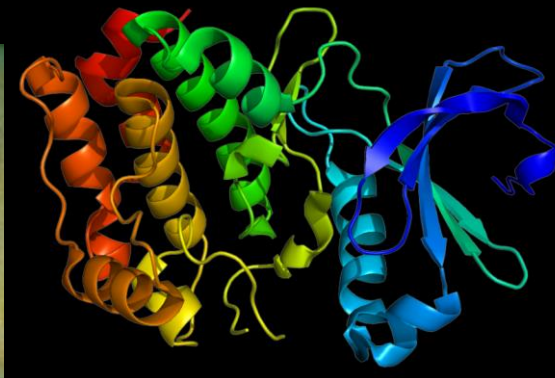


layer 2



layer 3

learnable task-specific features



Euclidean

Non-Euclidean

geometric learning



NIPS 2017 tutorial on geometric deep learning (>2000 participants)



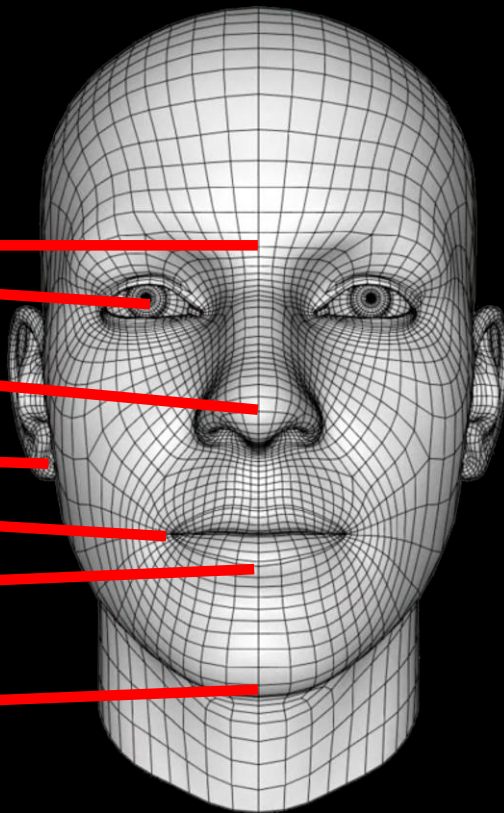
GDC



Faceshift (acquired by Apple in 2015)

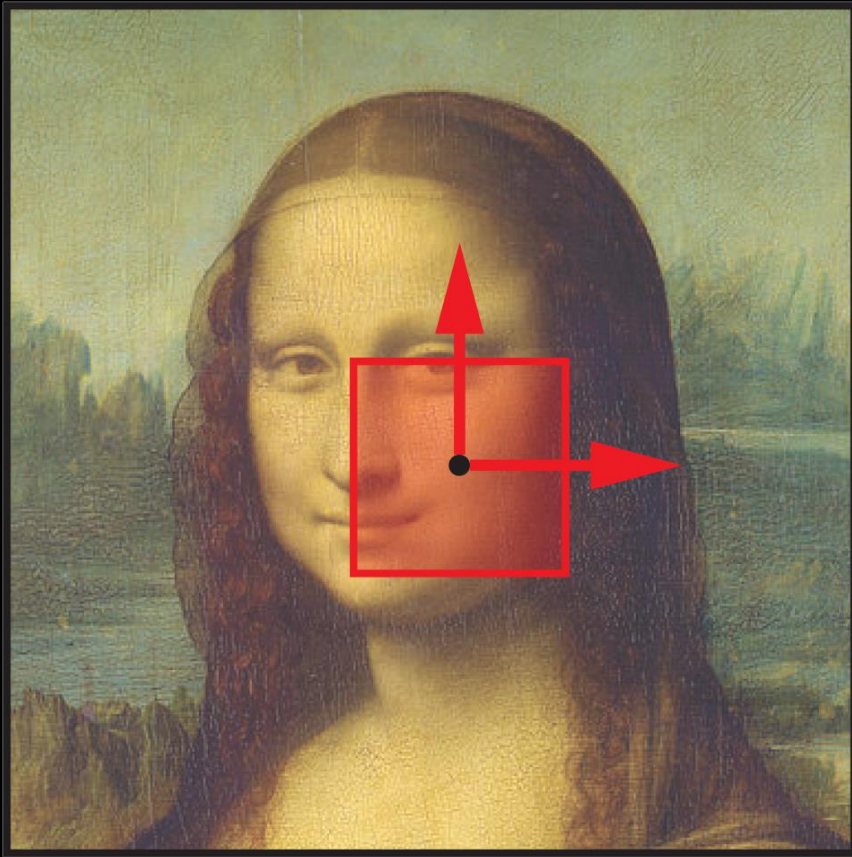


Analysis

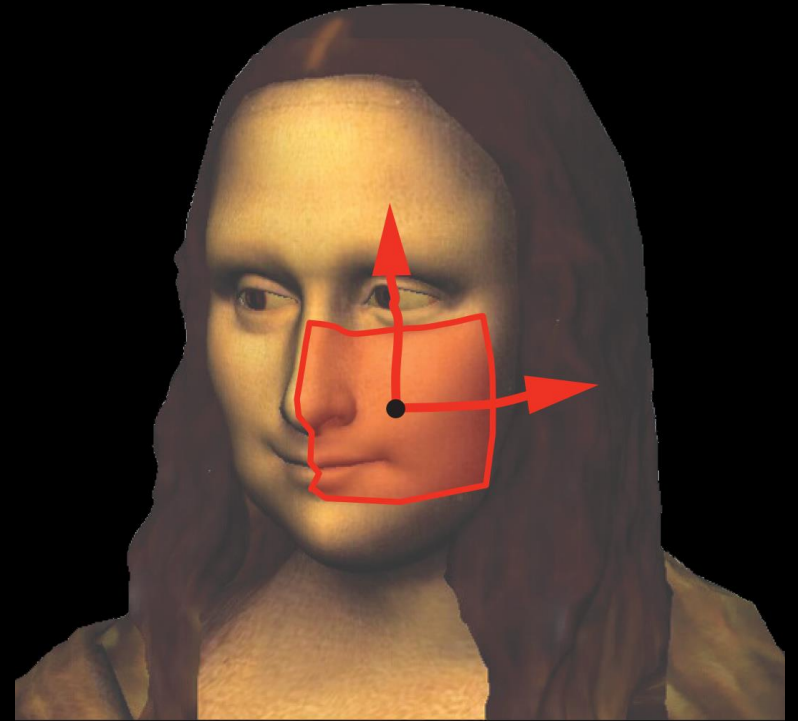


Synthesis

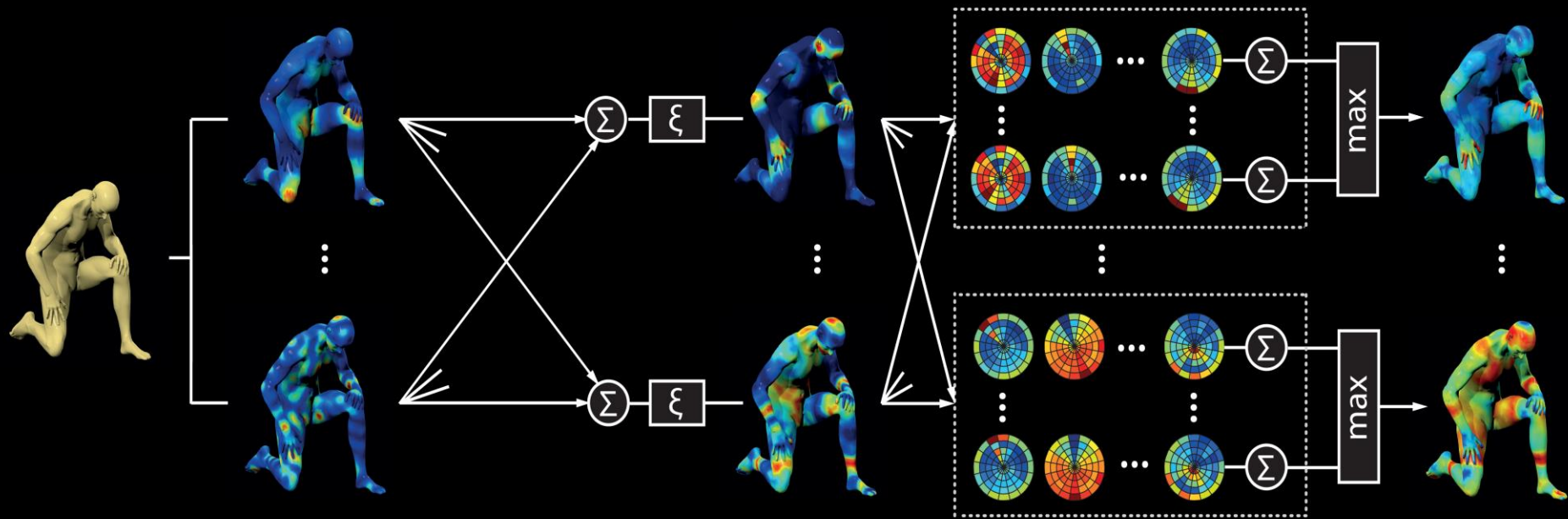




Euclidean



Non-Euclidean

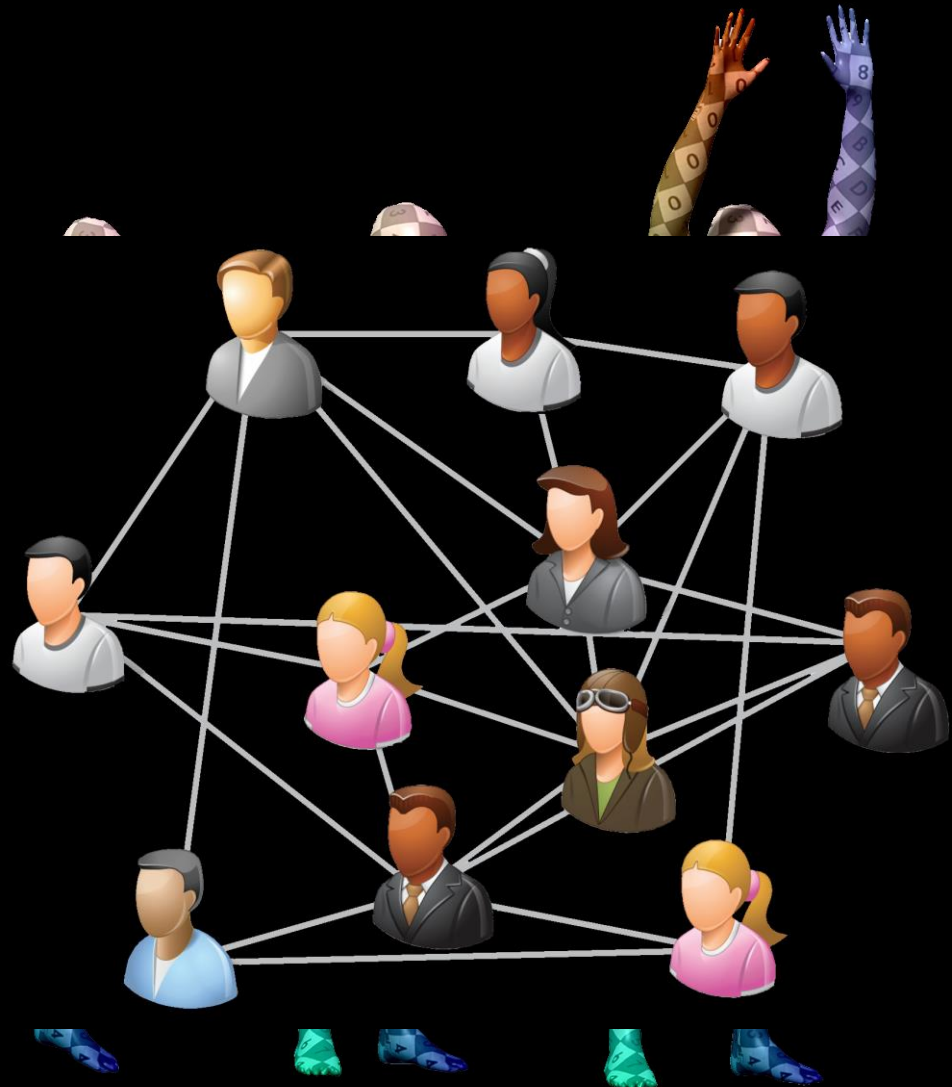


Convolutional neural network on surfaces



Deformable 3D shape correspondence learned with intrinsic CNN

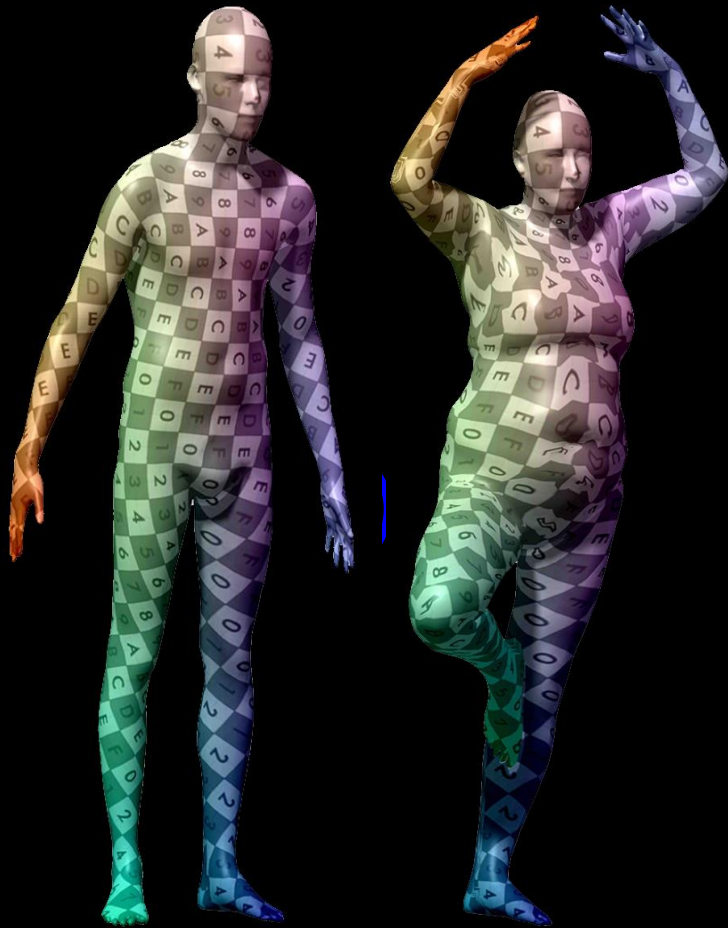
Monti, Boscaini, Masci, Rodola, Svoboda, B 2017



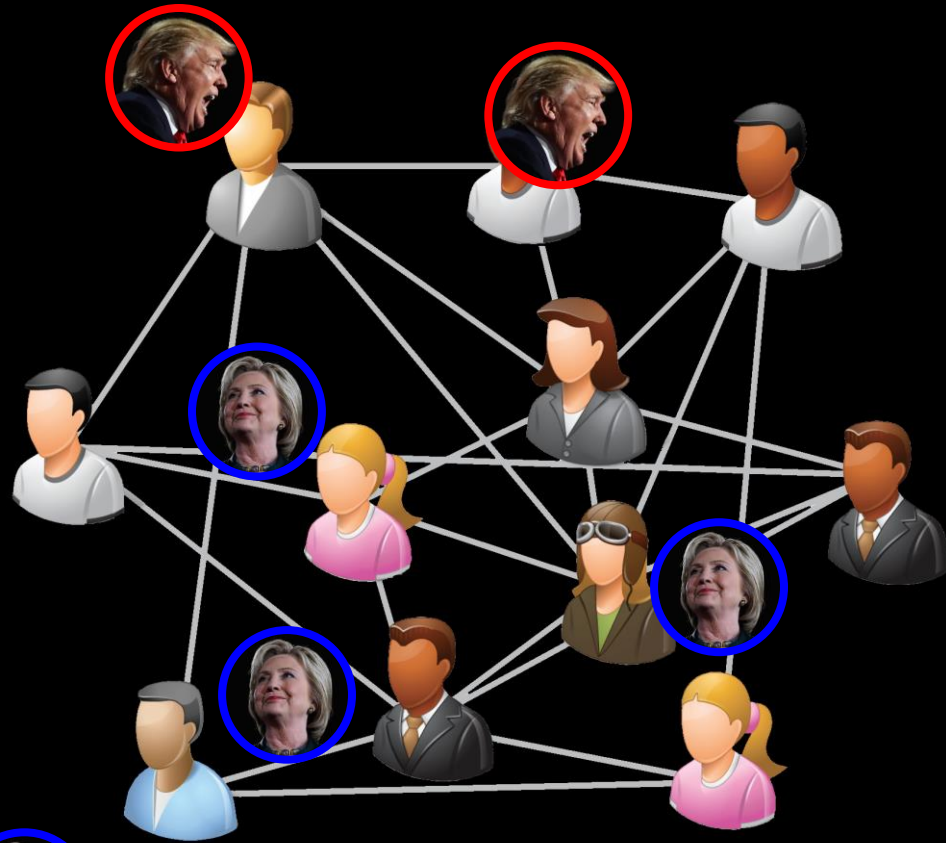
Surfaces
Deformable 3D shape correspondence learned with intrinsic CNN

Graphs & networks

m
a
v
h
e
r



Surfaces



Graphs & networks



Safe spaces for South
Asia's vultures *p. 1086*

Synthetic Notch receptors
enhance T cell therapies *p. 1112*

Dietary fiber fights
diabetes *p. 1151*

Science

\$15
9 MARCH 2018
sciencemag.org

AAAS

HOW LIES SPREAD

On social media,
false news beats the truth

pp. 1094 & 1146

Vosoughi et al. 2018

Marine Le Pen [@MLP_officiel](#) [Follow](#)

-6:33

By calling #migrants to desecrate the Basilica of St. Denis, Necropolis of our Kings, "unsubdued France" and the far-left show that, in their immigrationist madness, they are ready to trample our civilization and desecrate a place of historical worship. Unworthy. Mlp

11:58 AM - 19 Mar 2018

2,565 Retweets 4,001 Likes

CAP [@CAP741776](#) [Follow](#)

I am a Conservative American Patriot (CAP) who is totally fed up with Liberalism's screwed up moral compass and erosion of American traditional values.

Pm [@Pmbellamy](#) [Follow](#)

Marine présidente, Macron retourne travailler au guichet de ROTHSCHILD

Vaness' [@van83720](#) [Follow](#)

POLITIFACT

Did 'Muslim Migrants' Attack Catholic Church?

A video of pro-migrant protesters being removed from the Basilica of Saint-Denis in France was shared with the inflammatory and incorrect claim that it shows Muslim immigrants attacking a church.



Federico Monti



Ernesto Schmitt



Damon Mannion



US Patent 15006694; multiple patents pending

Marine Le Pen @MLP_officiel
Follow

By calling #migrants to "unsubdued France" and left show the t, in their immigrationist madness, they are ready to trample our civi. and desecrate a place of al worship. Unworthy. Mlp

11:58 AM - 19 Mar 2018

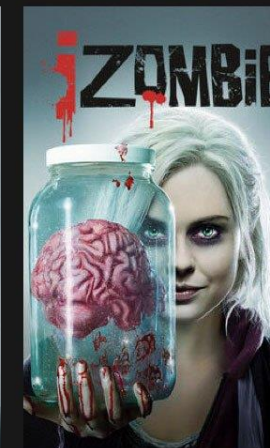
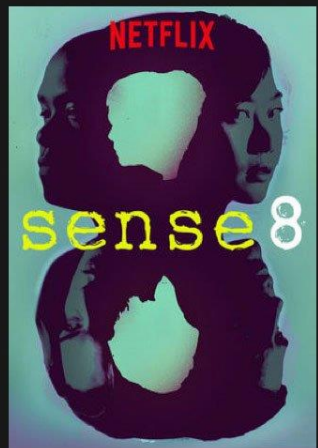
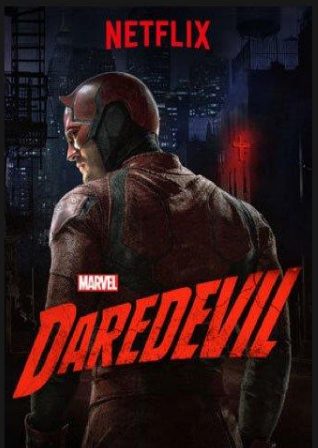
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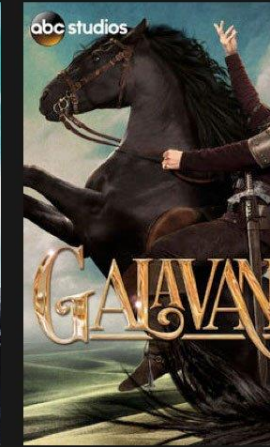
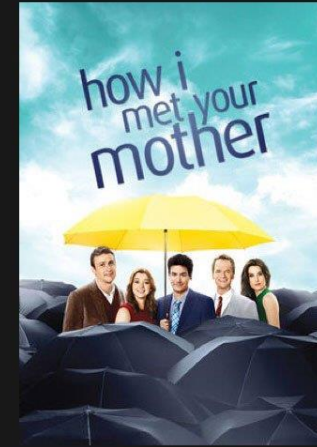
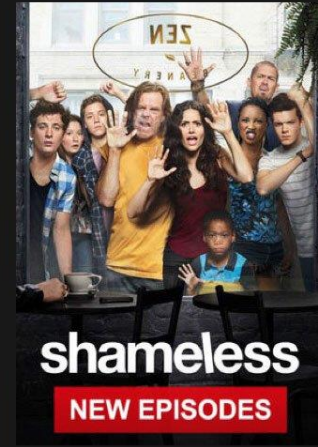
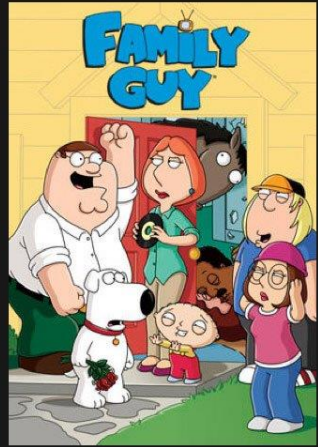
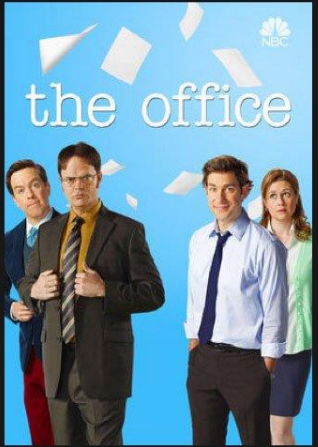
Pm @Pmbellamy
Marine présidente, Macron re travailler au guichet de ROTHSC...

Vaness' @van83720
Follow

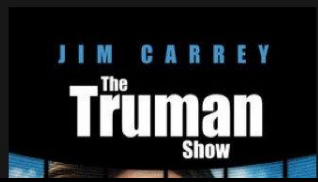
Because you liked Marvel's Jessica Jones



Trending Now



Because you liked Galaxy Quest





1

9

2

10

100K ? 10M

6

8

8

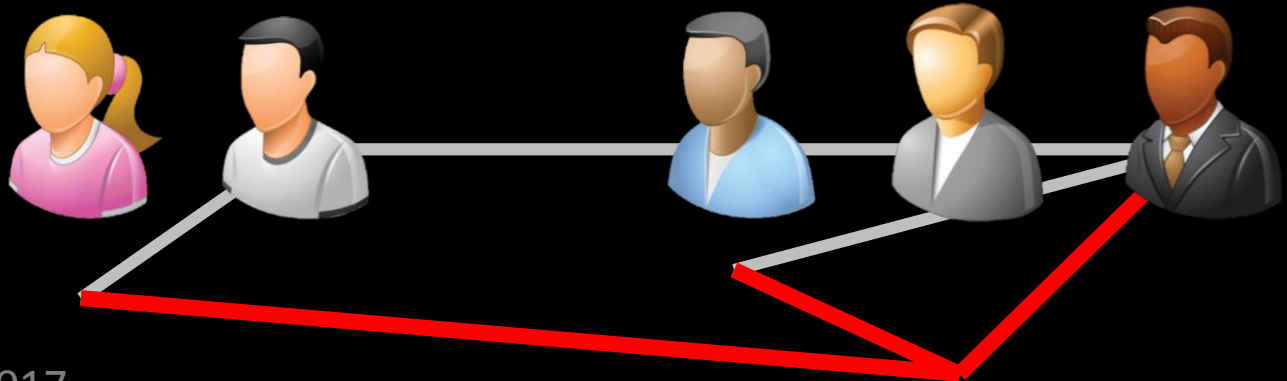
2

1





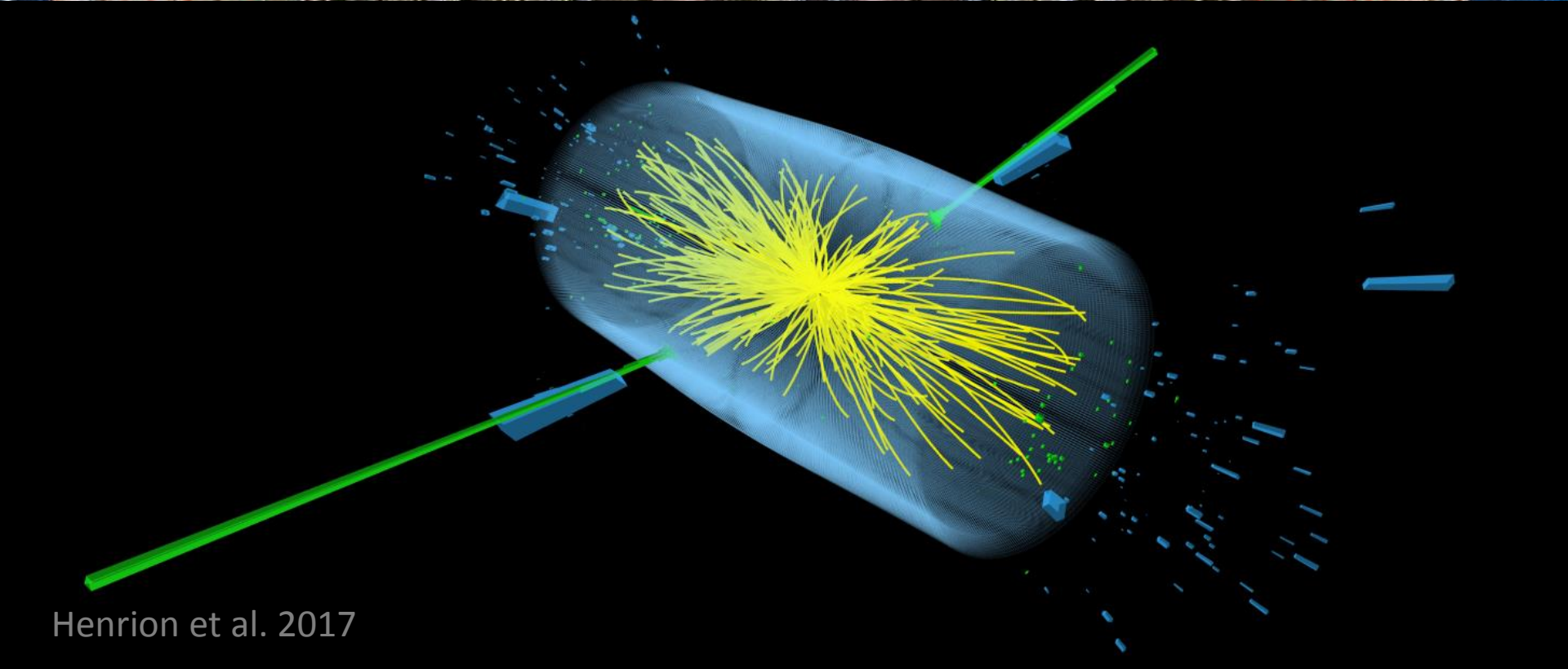
1	2	9	7	9
2	3	7	7	10
6	6	6	6	6
8	8	2	4	1

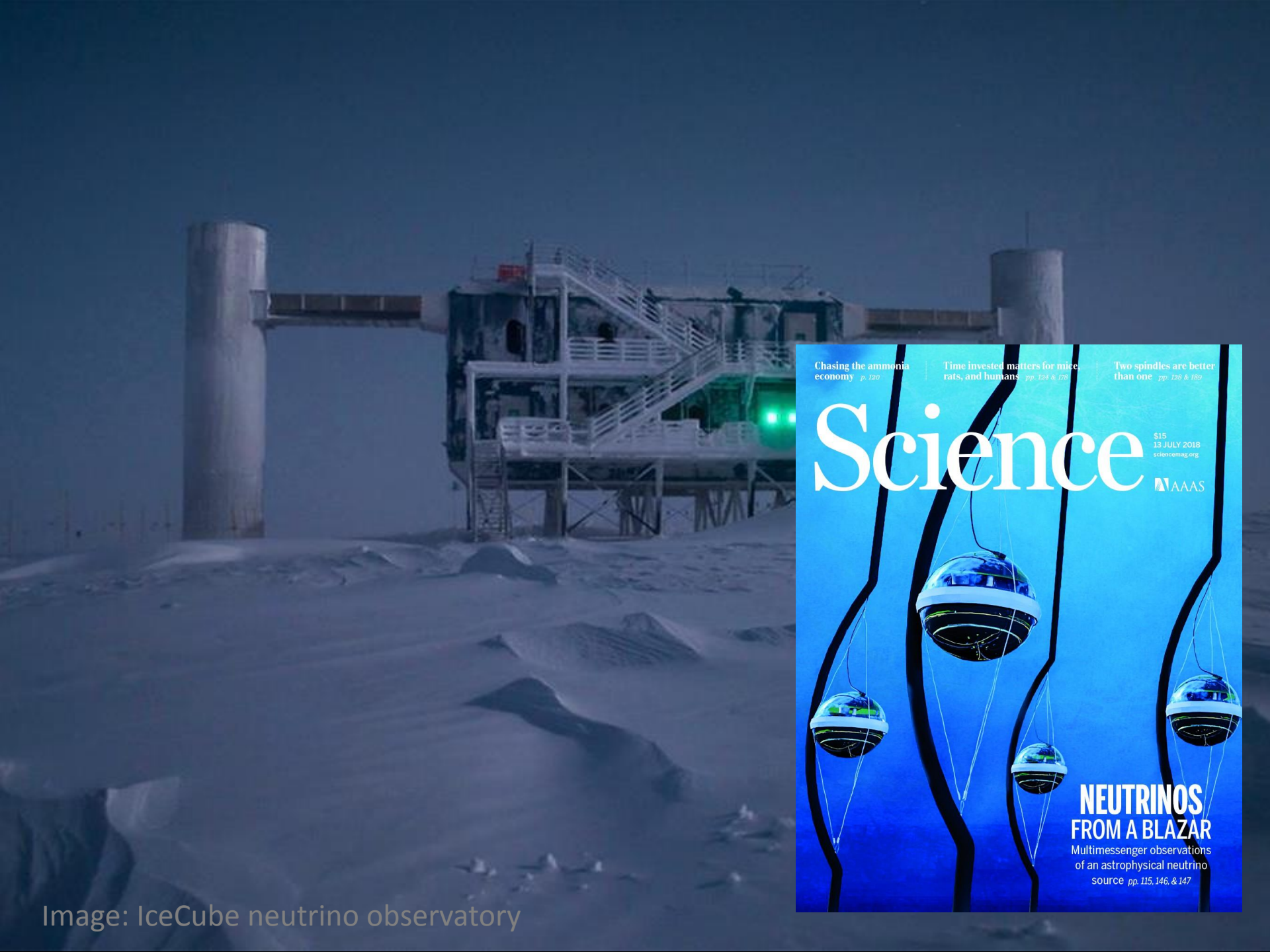




3B nodes
18B edges







Chasing the ammonia economy p. 120

Time invested matters for mice, rats, and humans pp. 124 & 179

Two spindles are better than one pp. 126 & 189

Science

\$15
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AAAS



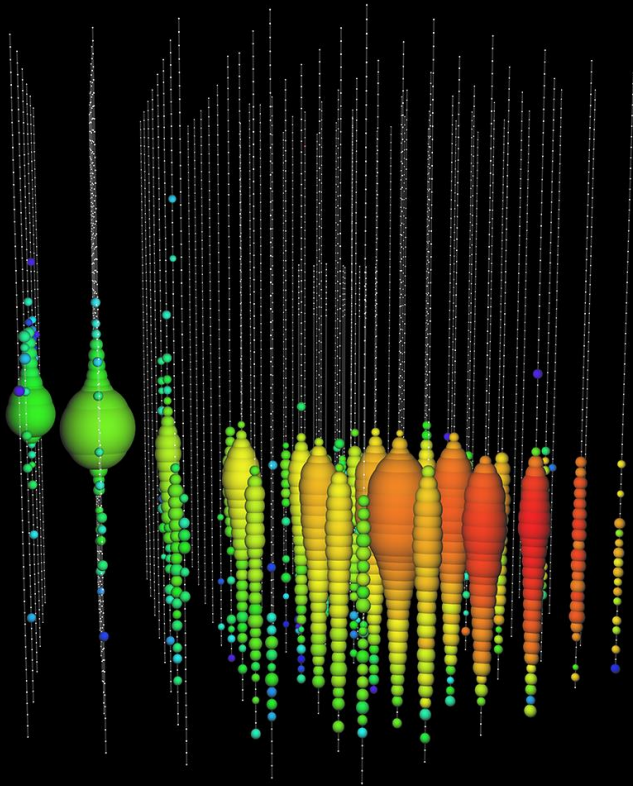
NEUTRINOS FROM A BLAZAR

Multimessenger observations of an astrophysical neutrino

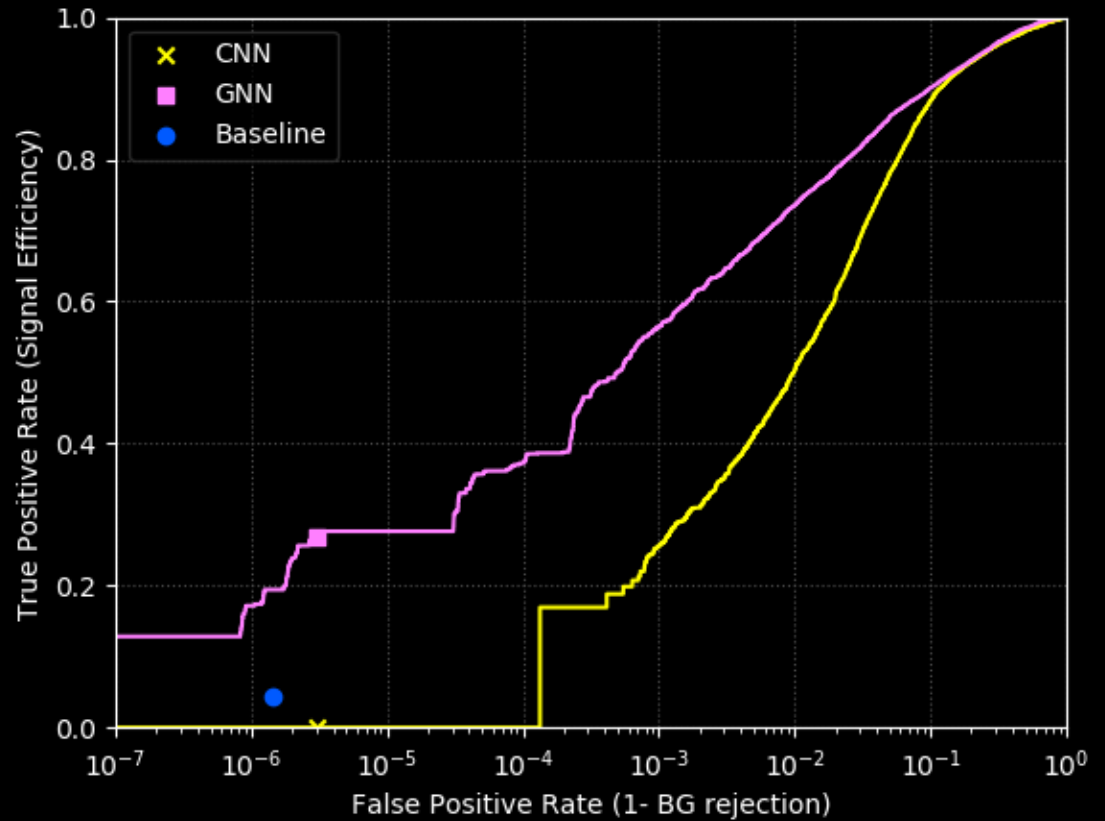
source pp. 115, 146, & 147

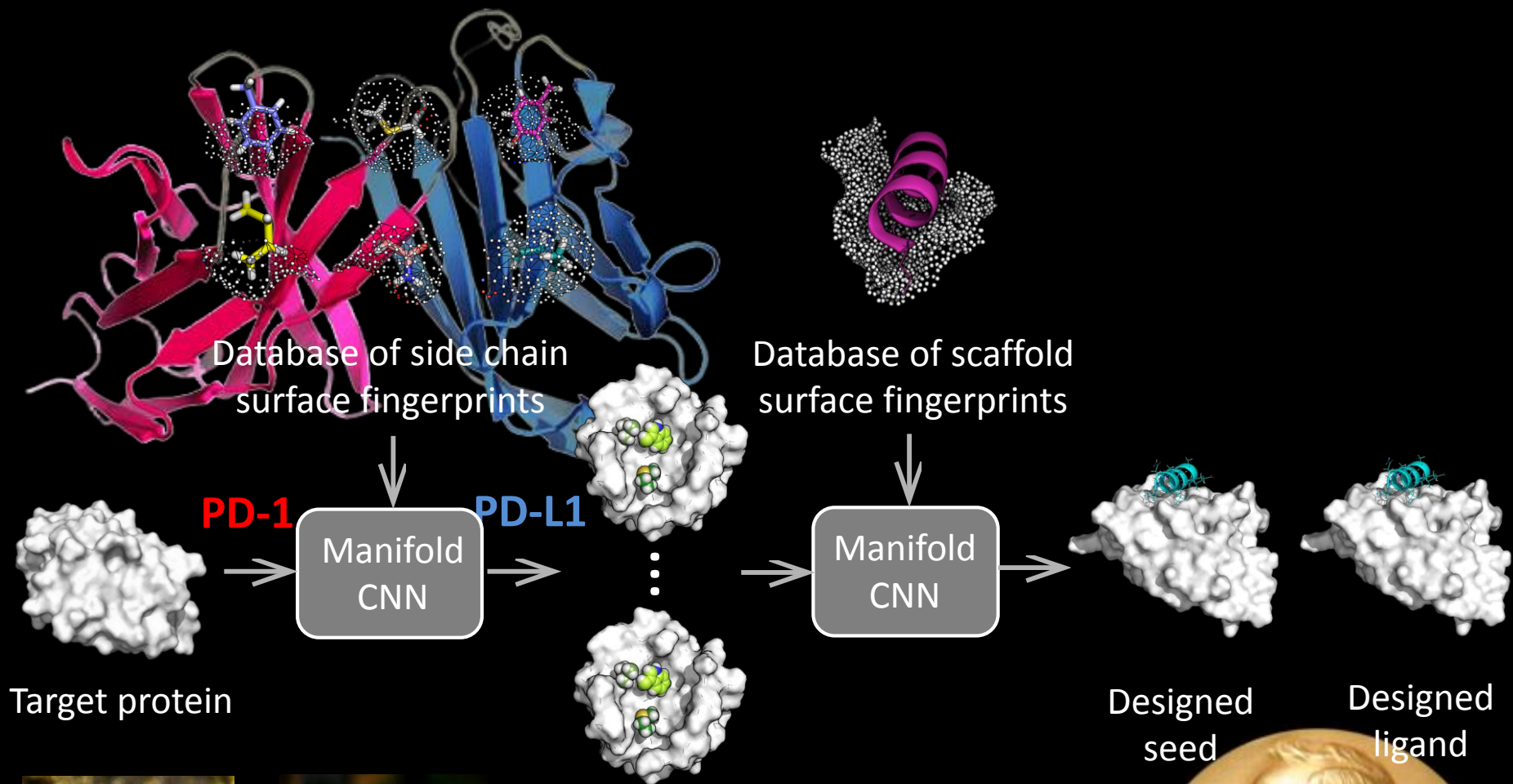
Image: IceCube neutrino observatory





Example of IceCube detected event





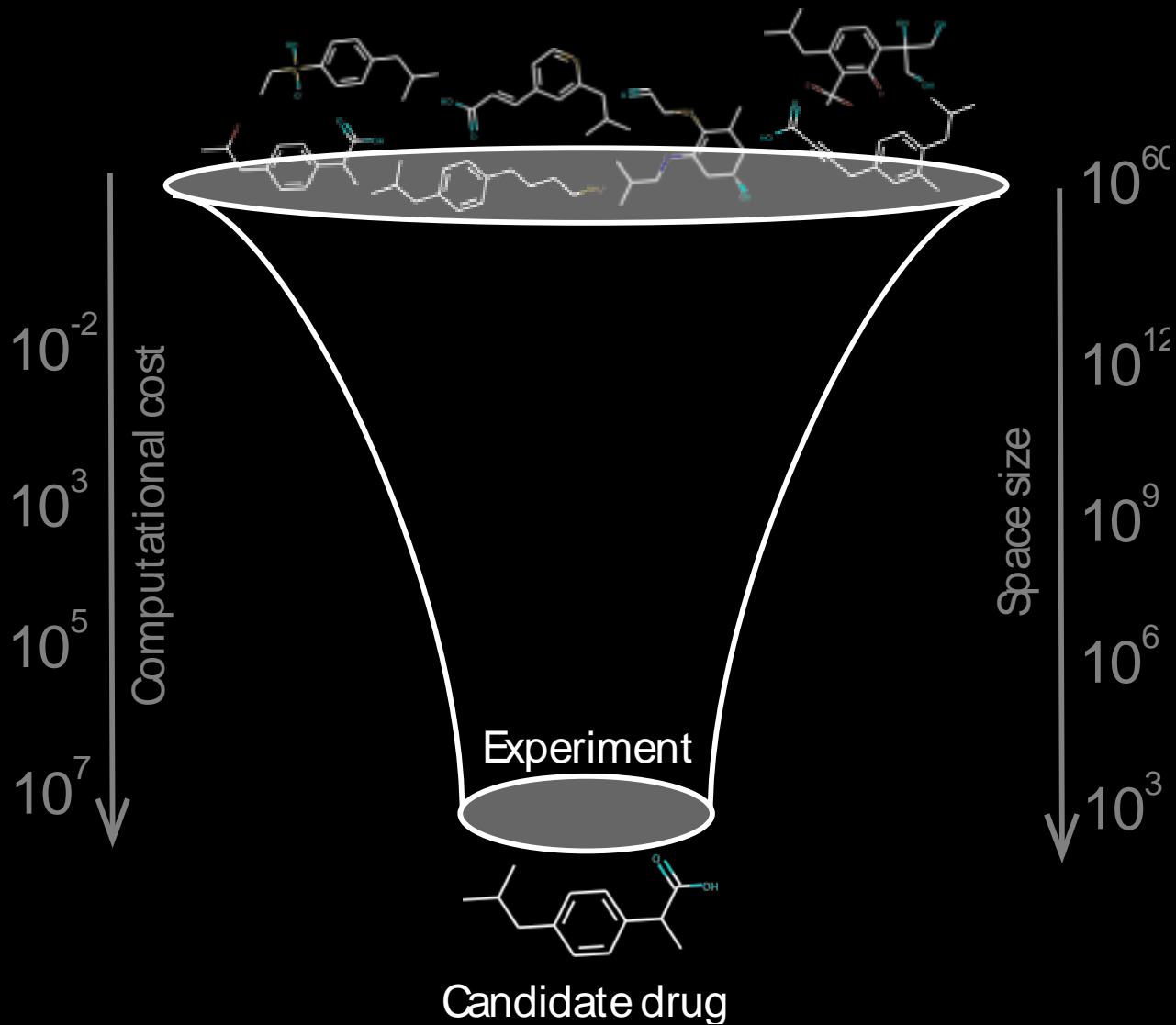
Bruno Correia



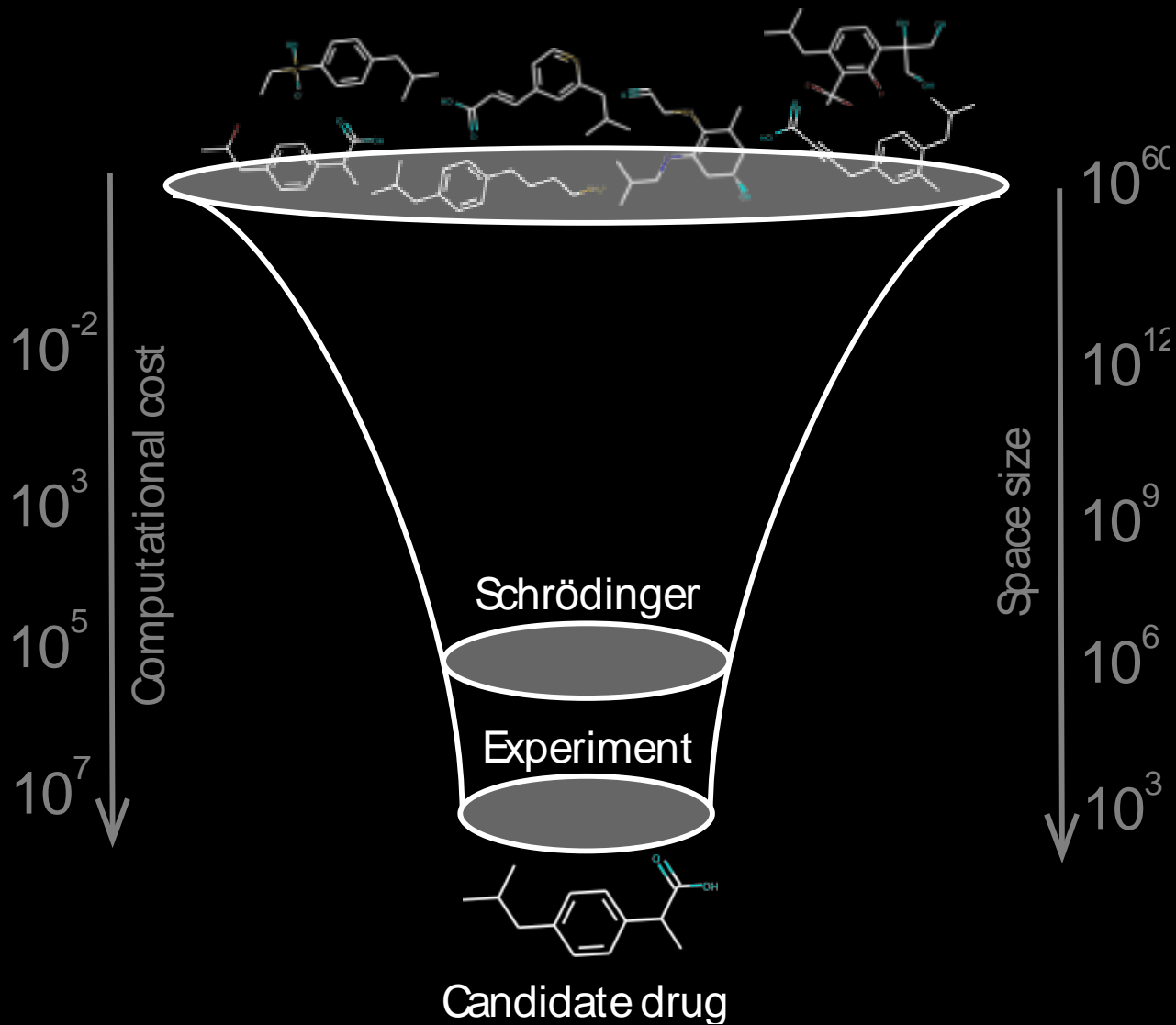
Pablo Gainza



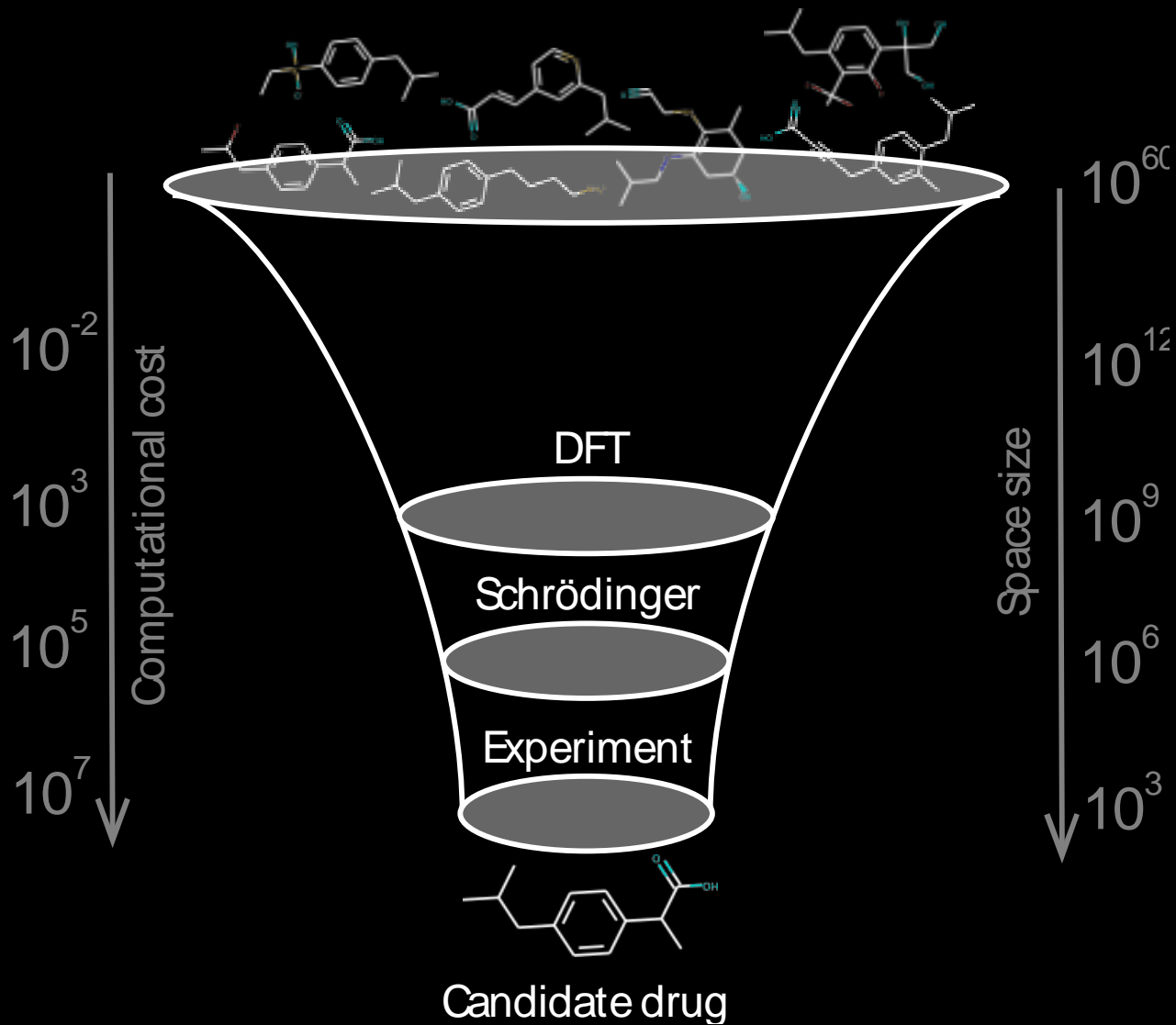
All synthesizable mid-size molecules



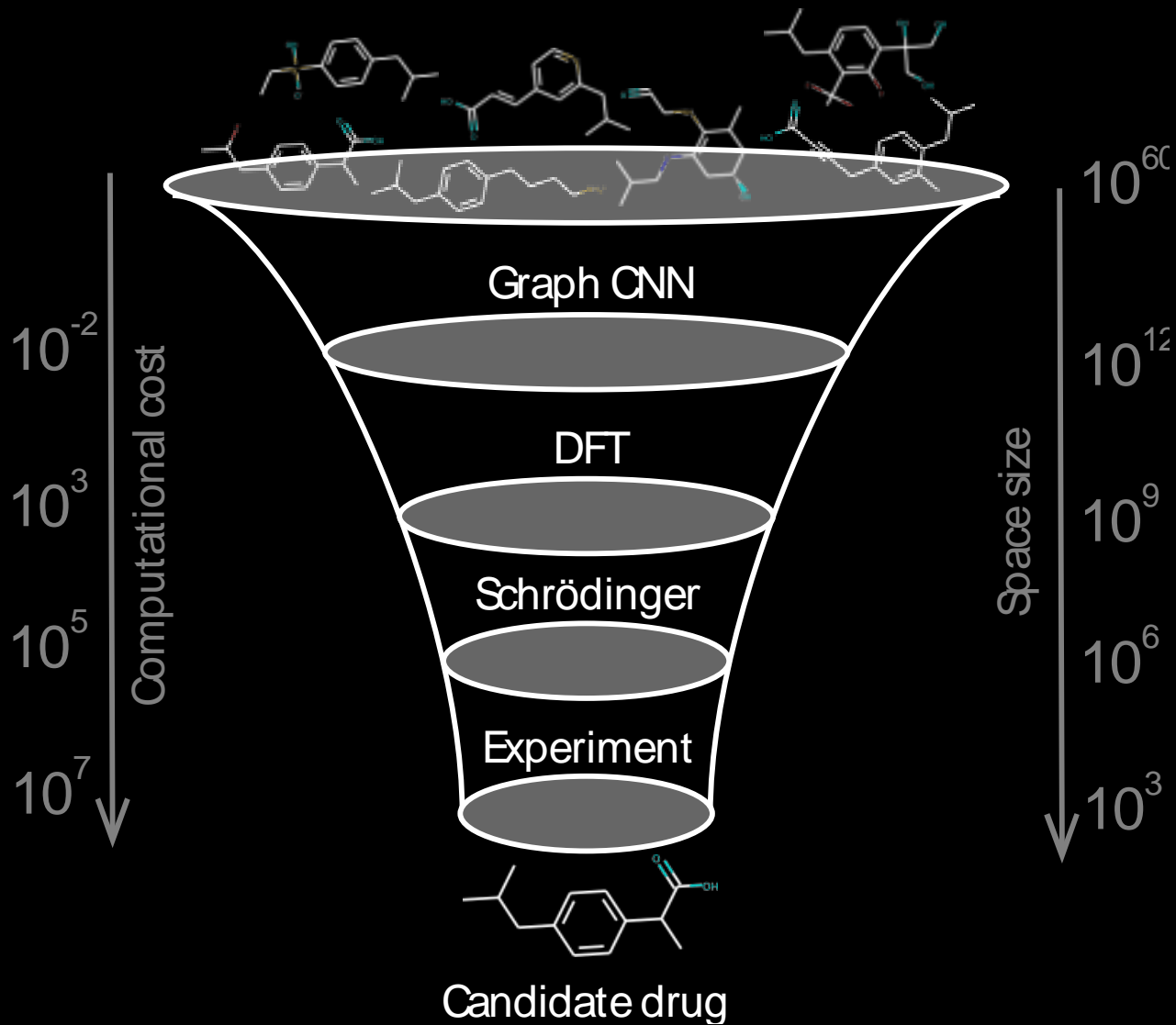
All synthesizable mid-size molecules

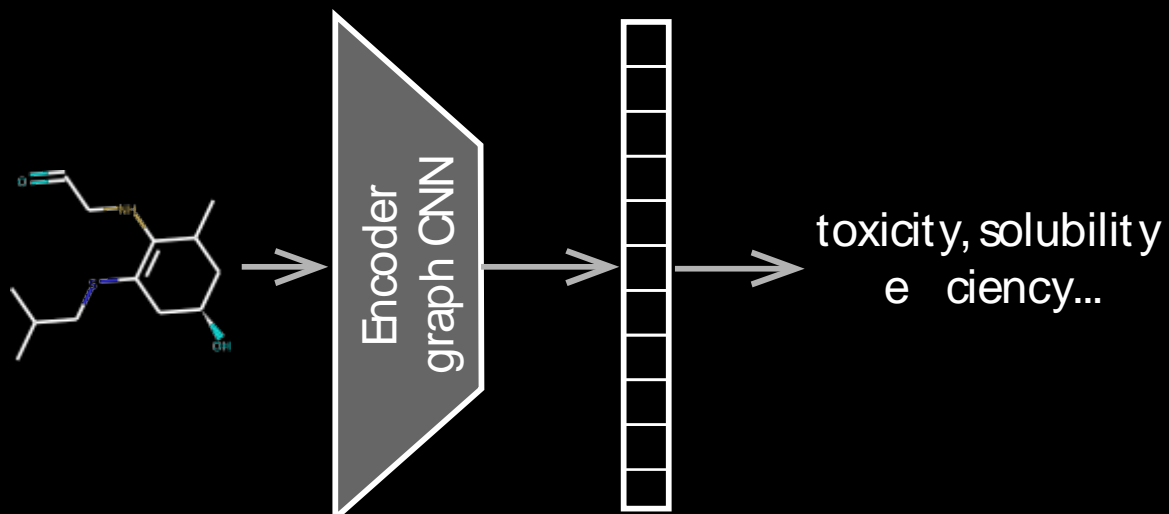


All synthesizable mid-size molecules

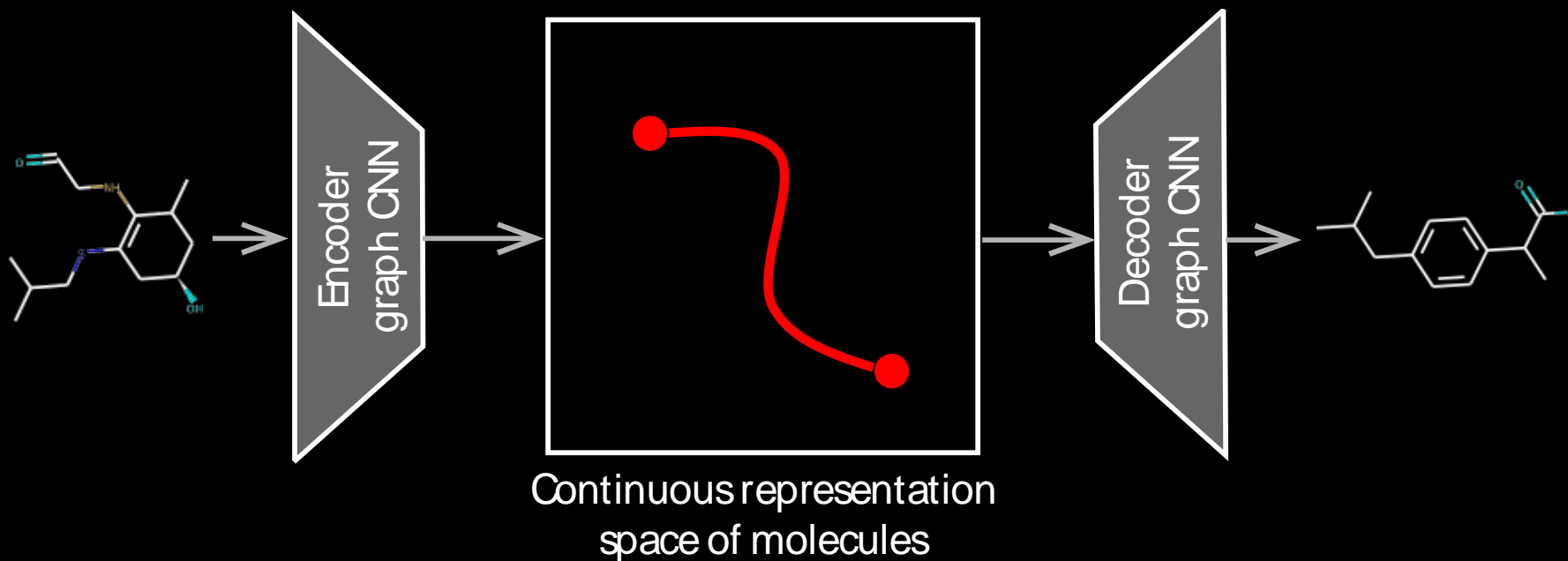


All synthesizable mid-size molecules





Analysis: predicting physical and chemical properties



Synthesis: generating molecules with desired properties

5000 drugs

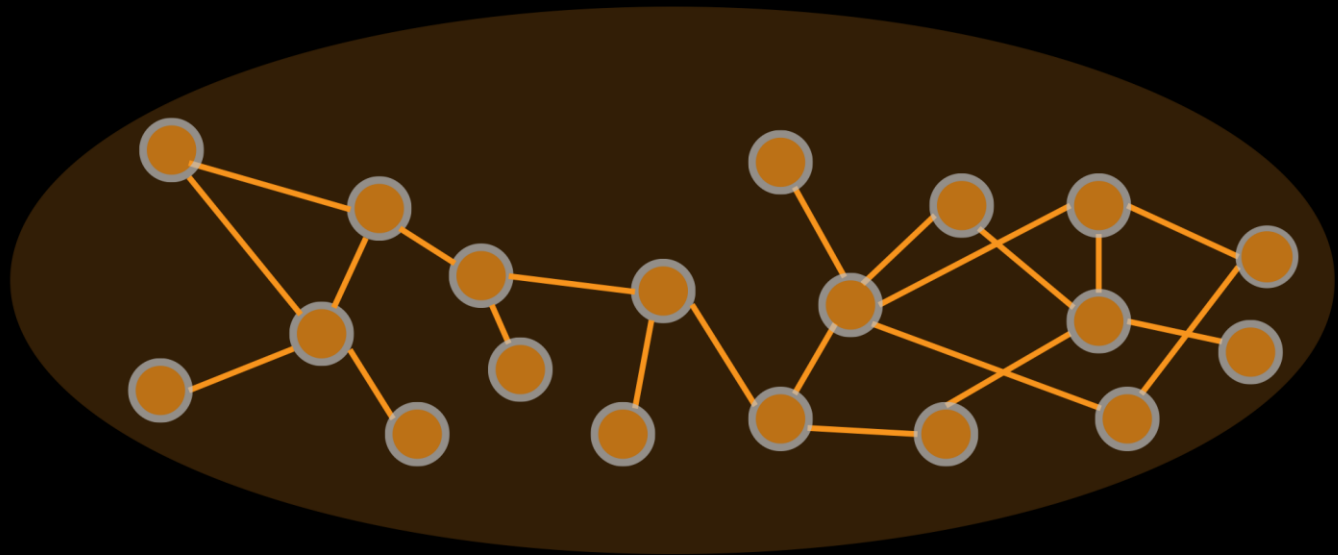
>10¹¹ drug pairs

Serious side effects include:

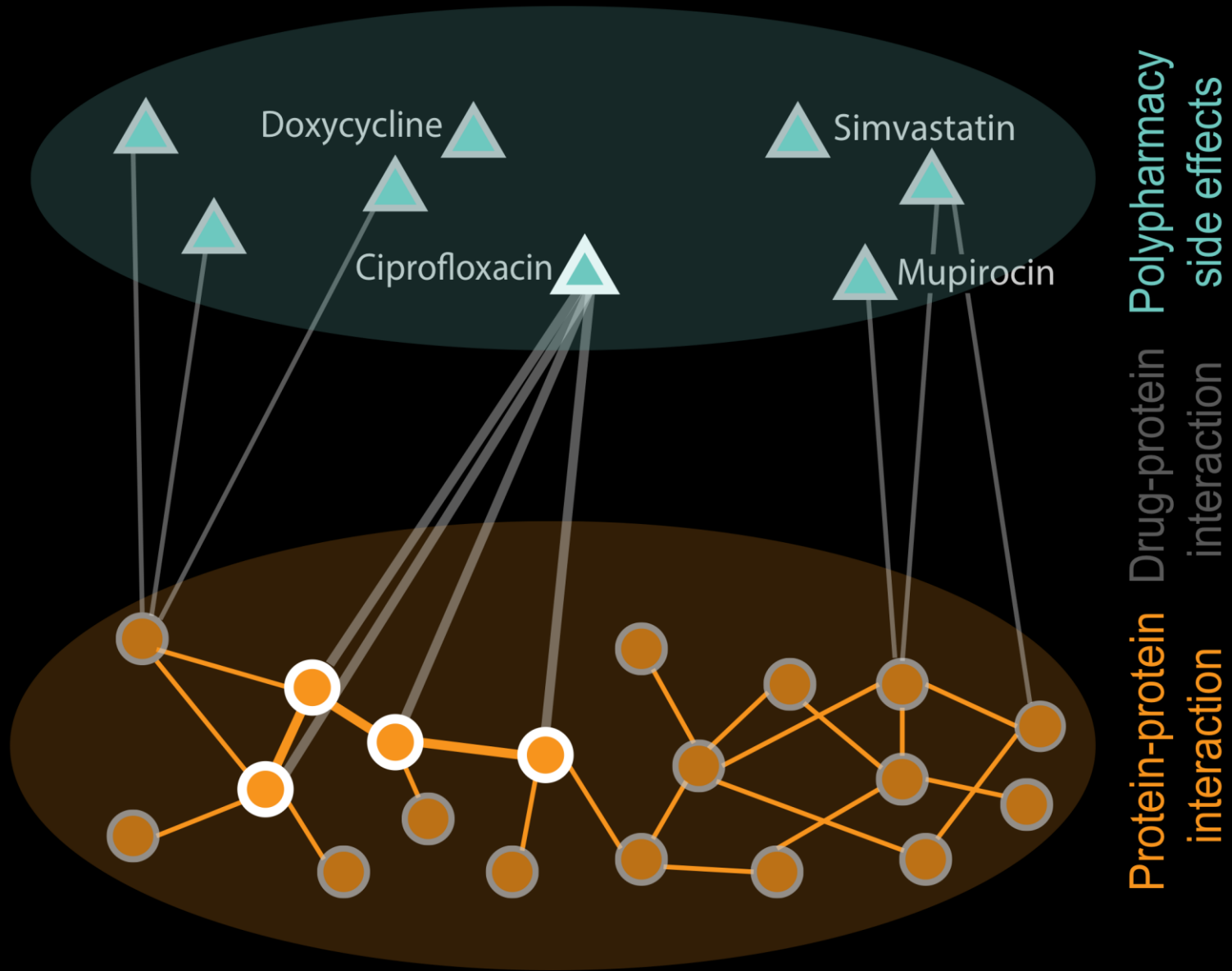
- heart attack
- stroke
- high blood pressure
- heart failure from body swelling (fluid retention)
- kidney problems including kidney failure
- bleeding and ulcers in the stomach and intestine
- low red blood cells (anemia)
- life-threatening skin reactions
- life-threatening allergic reactions
- liver problems including liver failure
- asthma attacks in people who have asthma

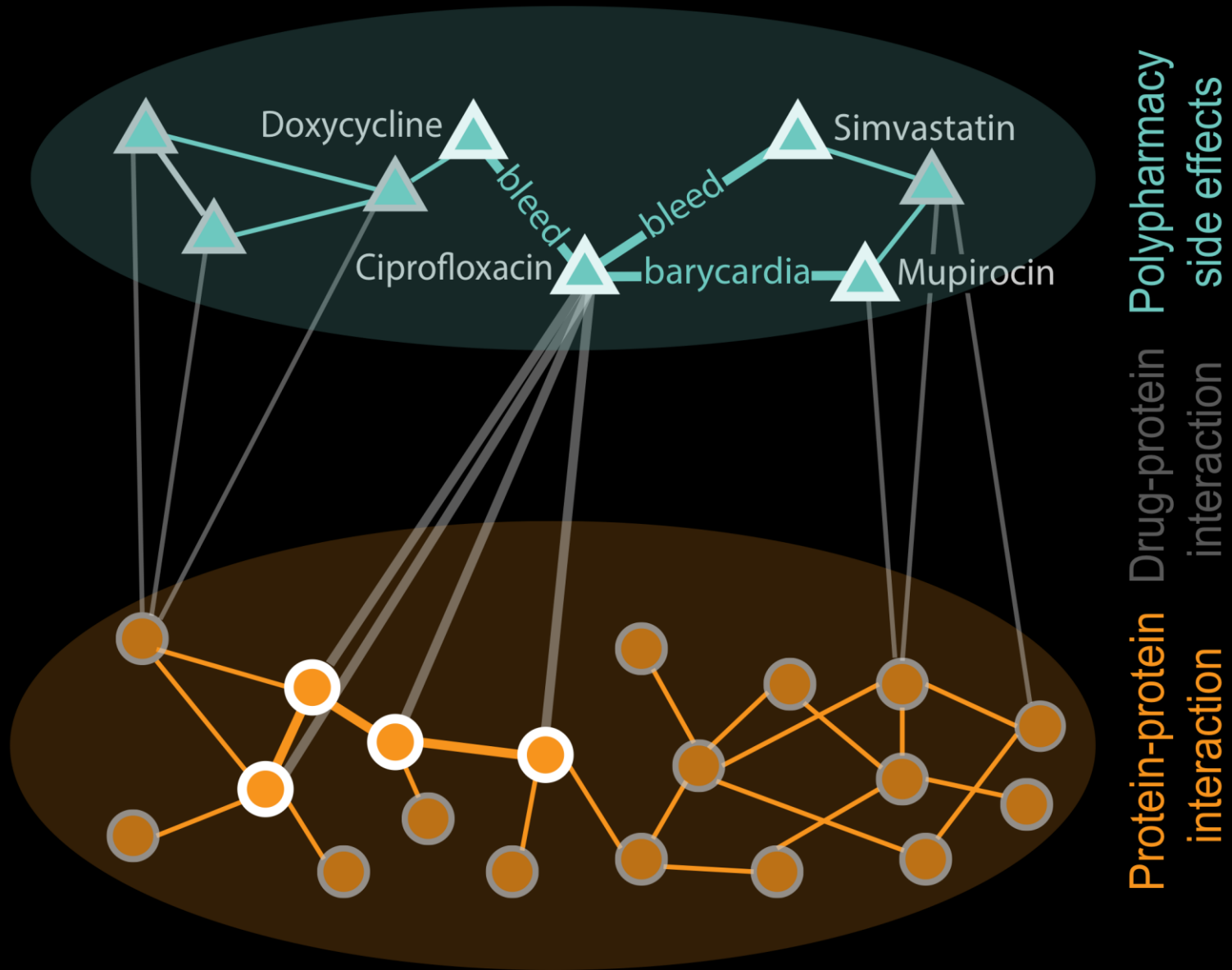
Other side effects include:

- stomach pain
- constipation
- diarrhea
- gas
- heartburn
- nausea
- vomiting
- dizziness



Protein-protein
interaction







Kirill Veselkov

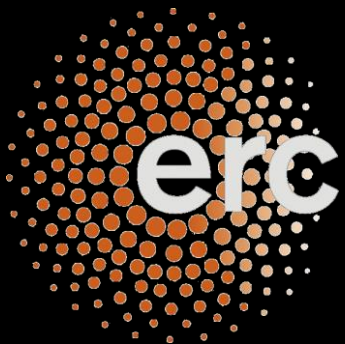


Jozef Youssef

“food passport”

geometric deep learning

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