Deep Learning

Introduction
Unreasonable Effectiveness of DL
Theory
How DL Works
Building Deep
Machine Vision
TensorFlow
TensorFlow Intro
DL with TensorFlow
Advanced
NLP
GANs
Deep RL
AI Revolution

The Fundamentals of Deep Learning

with Applications

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jon@untapt.com

Chief Data Scientist at untapt

Columbia University
E6885 001: Reinforcement Learning
February 28th, 2017
(slides available at jonkrohn.com/talks)

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4 Advanced Topics
Natural Language Processing
Generative Adversarial Networks
10: Deep Reinforcement Learning
5 The AI Revolution

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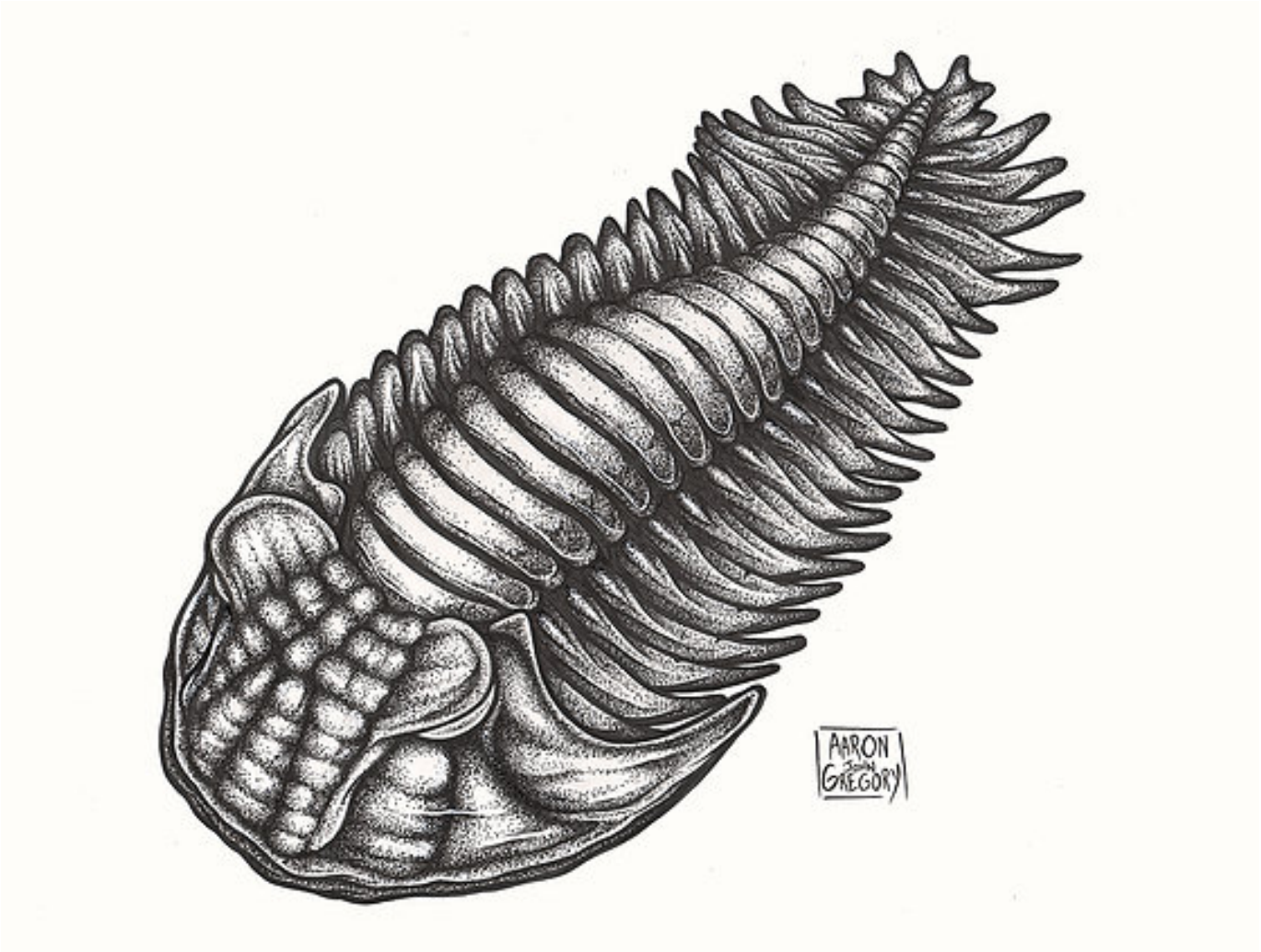
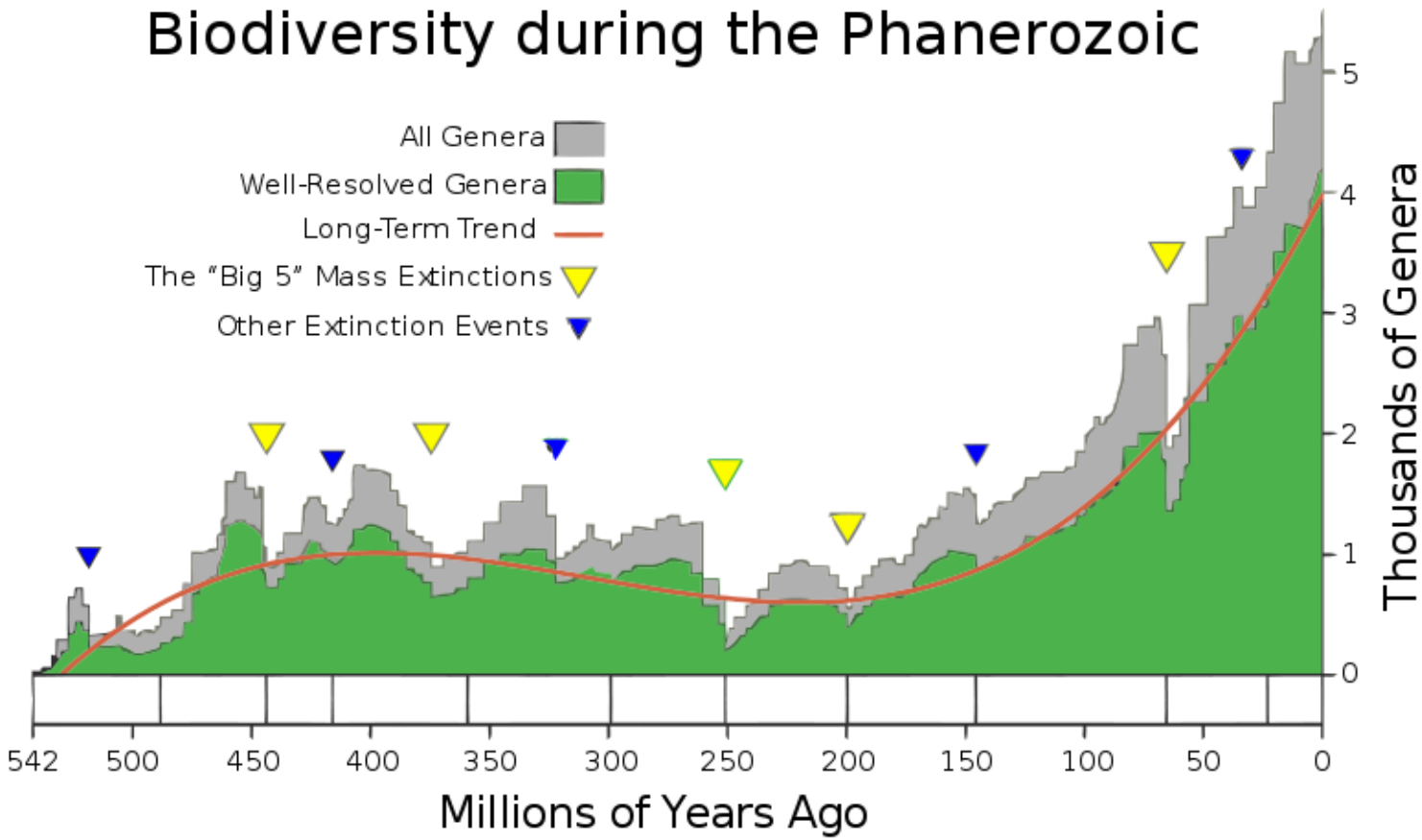
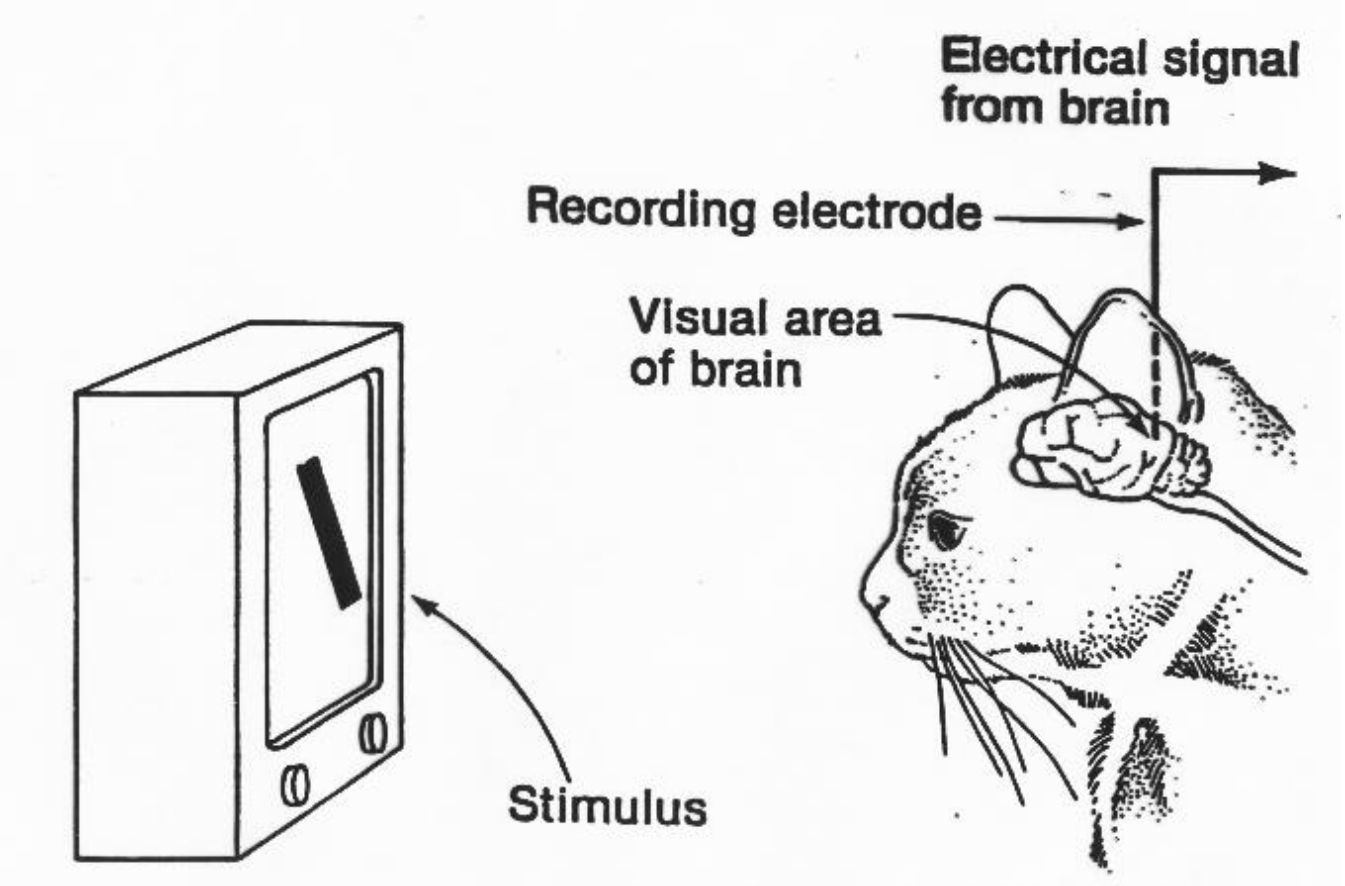
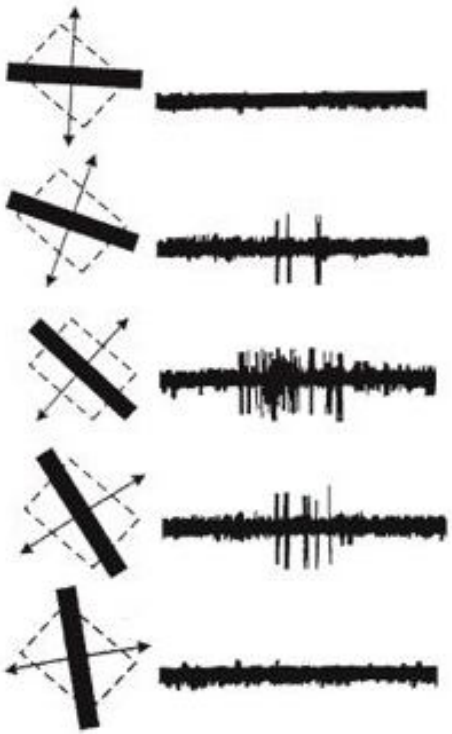
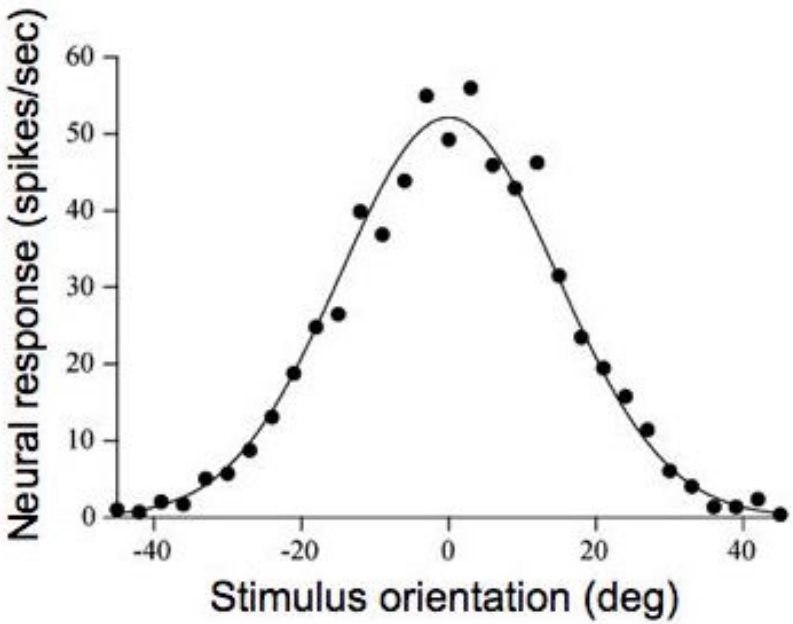

AARON
GREGORY


Biodiversity during the Phanerozoic
All Genera
Well-Resolved Genera
Long-Term Trend
The "Big 5" Mass Extinctions
Other Extinction Events
542
500
450
400
350
300
250
200
150
100
50
0
Millions of Years Ago
0
1
2
3
4
5
Thousands of Genera

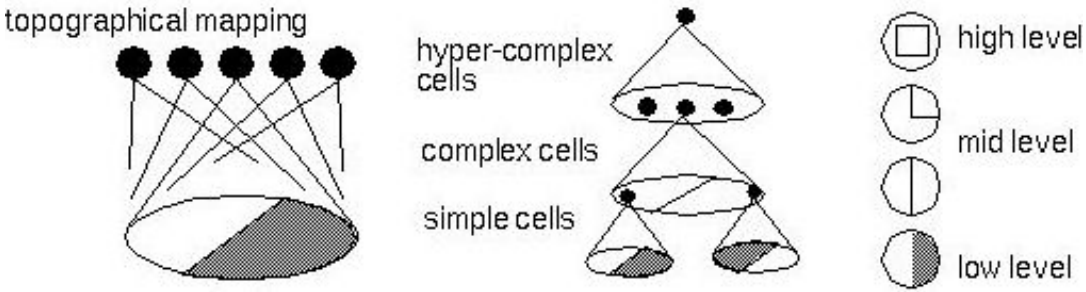
Hubel & Wiesel (1959)

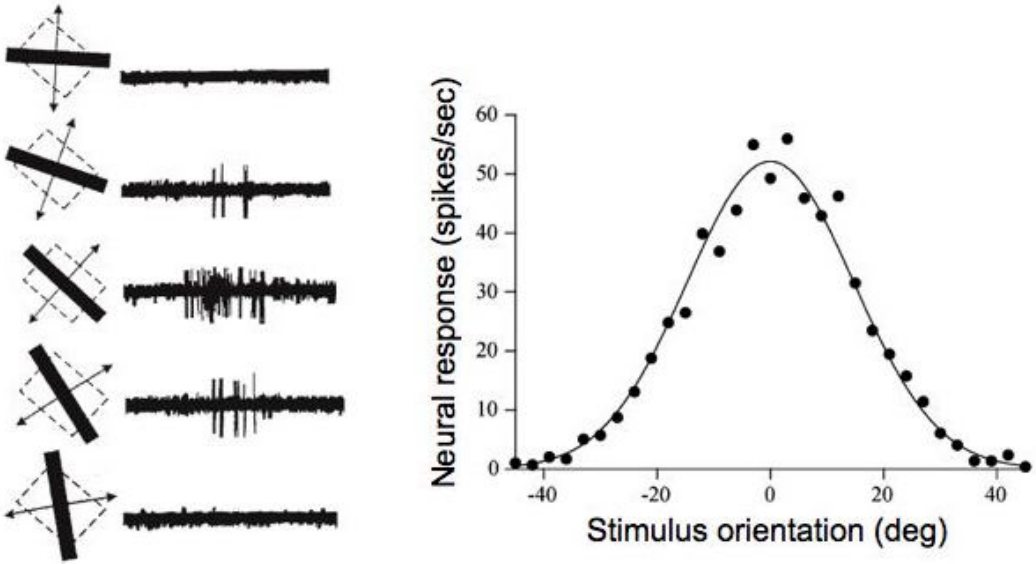






Hubel & Wiesel, 1968





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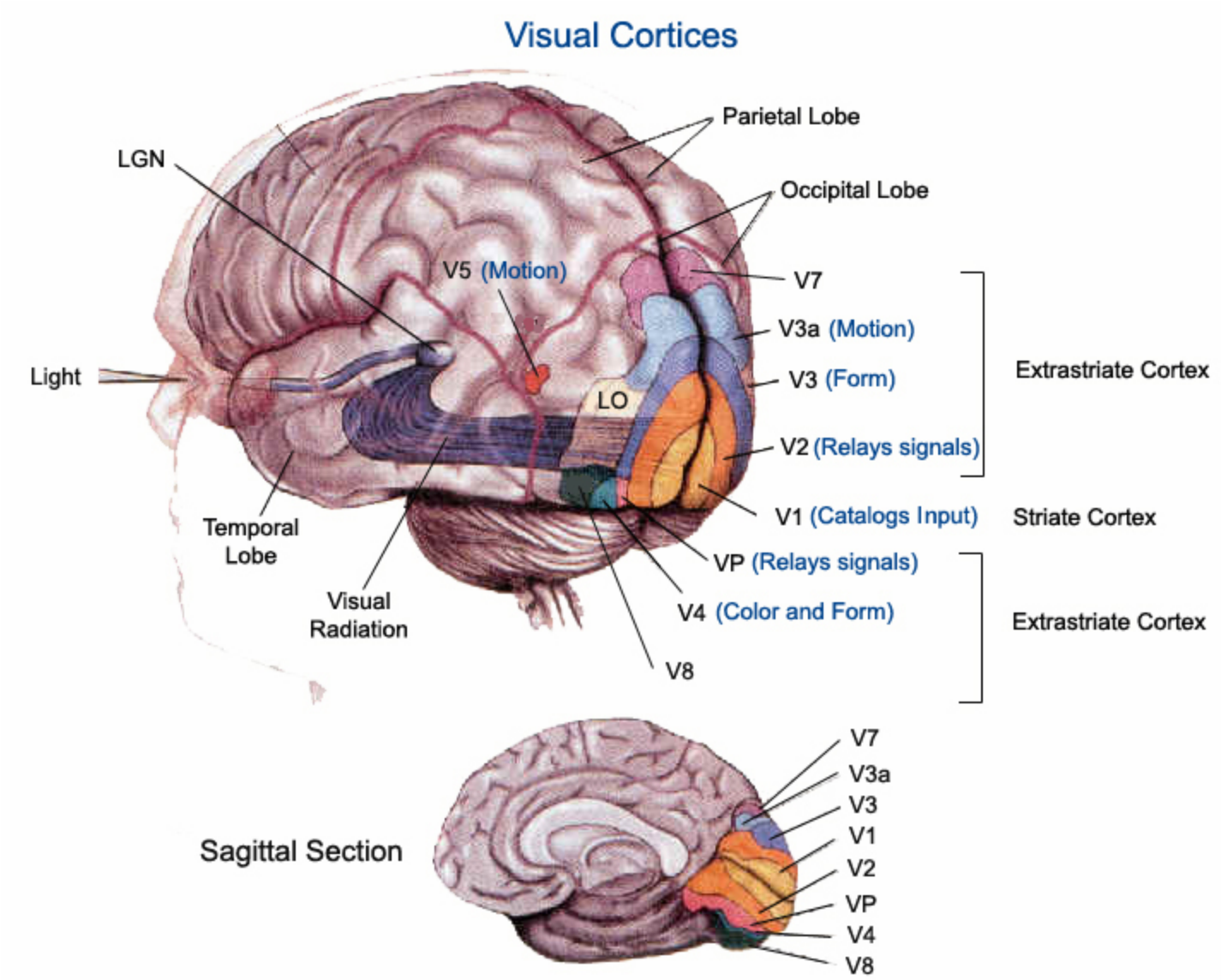
Visual Cortices
Parietal Lobe
LGN
Occipital Lobe
V5 (Motion)
V7
V3a (Motion)
Light
V3 (Form)
LO
Extrastriate Cortex
V2 (Relays signals)
V1 (Catalogs Input)
Striate Cortex
Temporal Lobe
VP (Relays signals)
Visual Radiation
V4 (Color and Form)
Extrastriate Cortex
V8
Sagittal Section
V7
V3a
V3
V1
V2
VP
V4
V8

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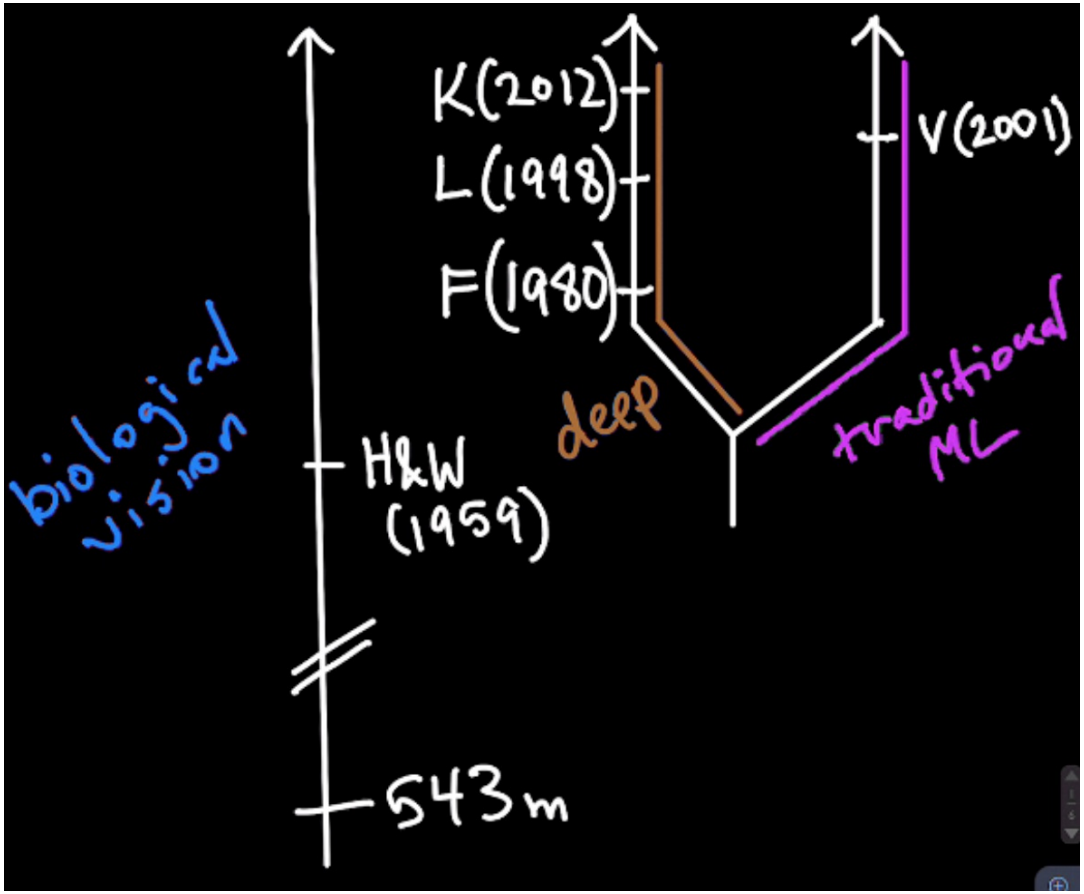
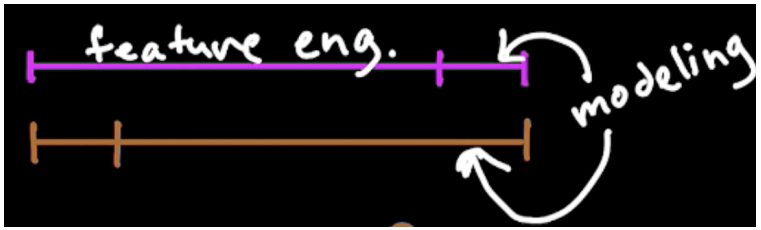
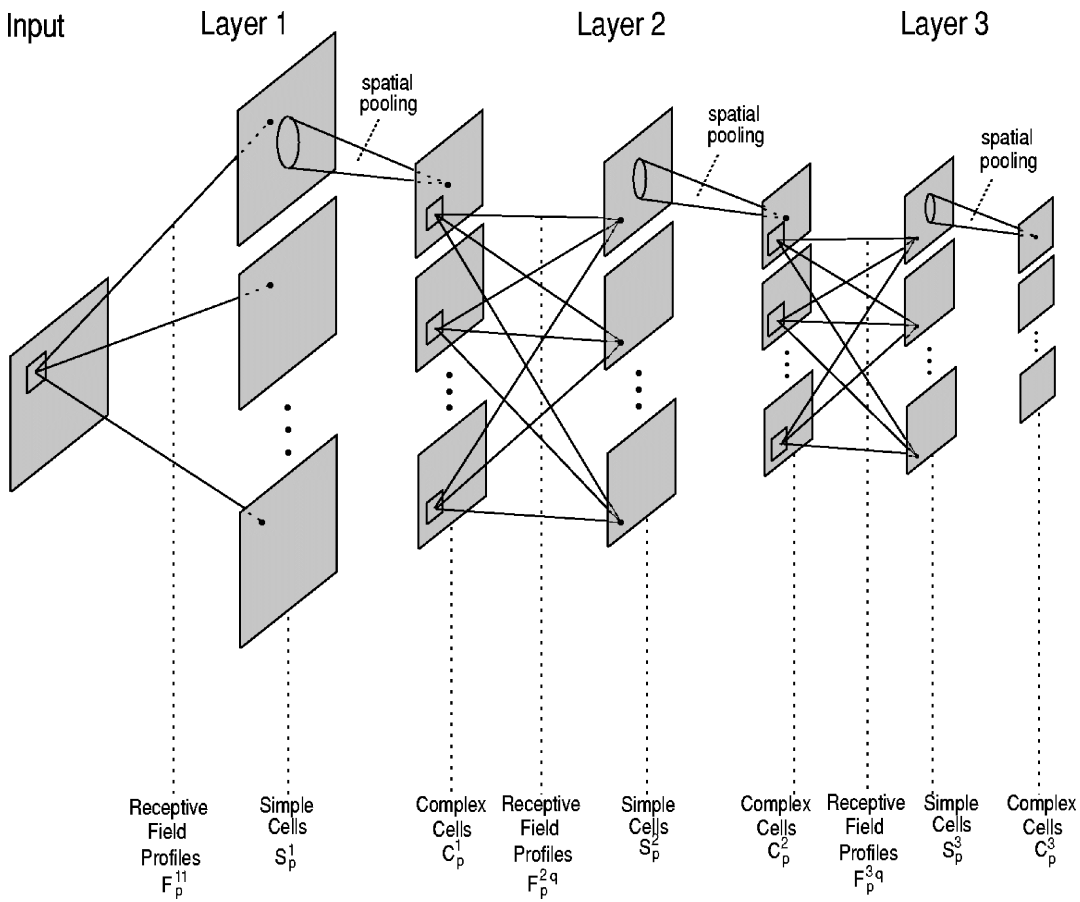




Neurocognitron

Fukushima (1980)



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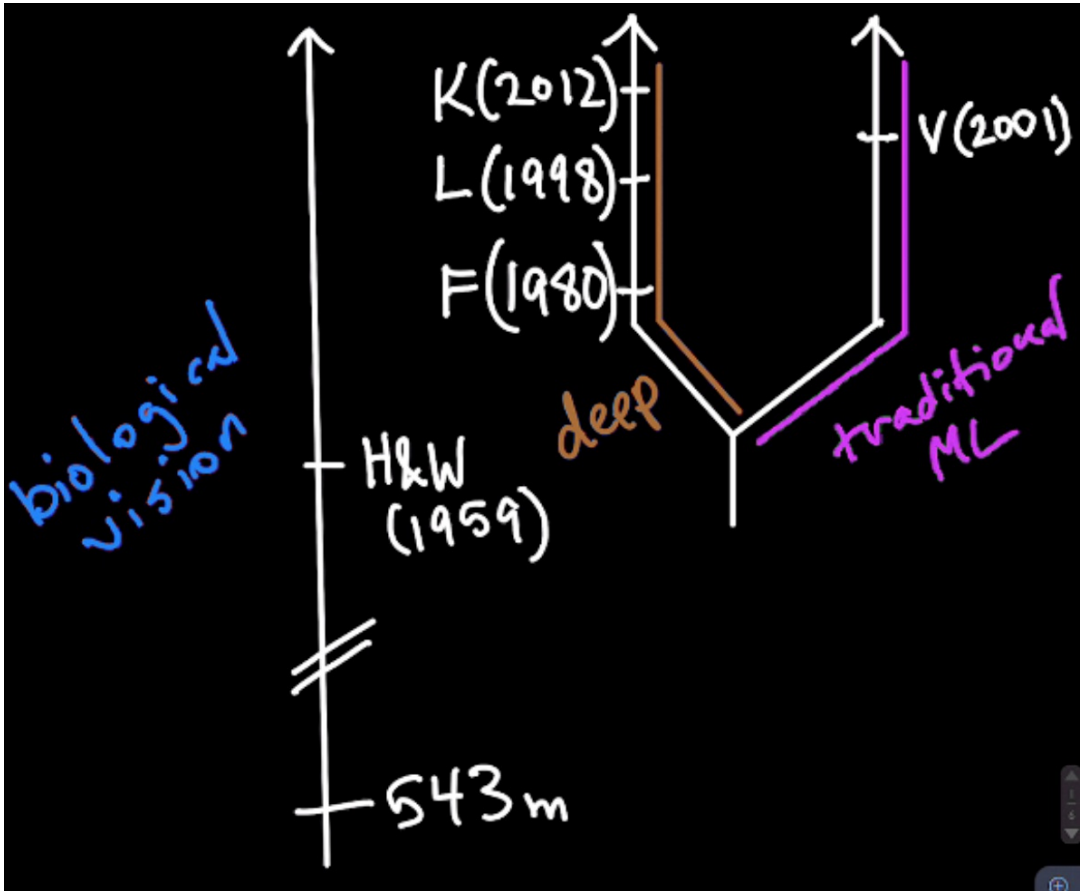
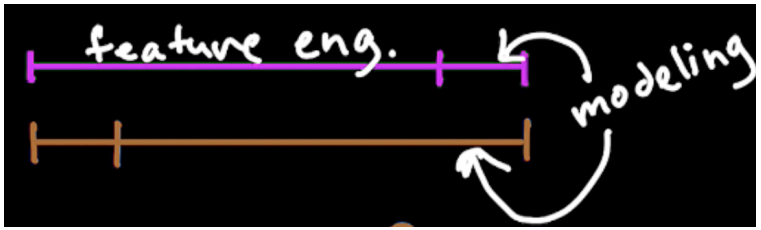
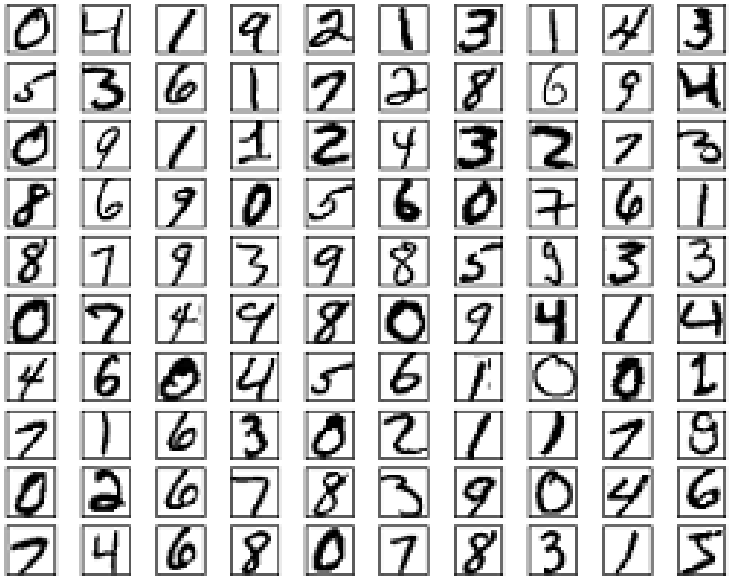




MNIST Digits & LeNet-5

LeCun, Boutou, Bengio & Haffner (1998)



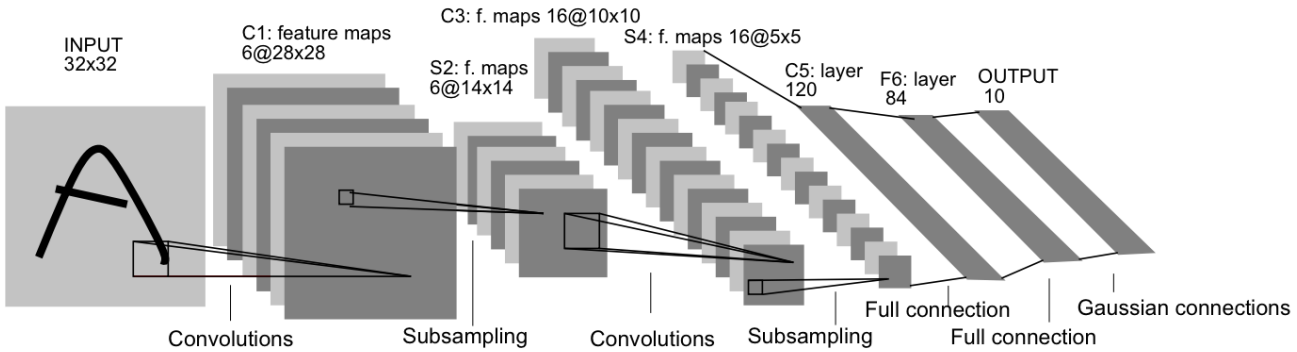
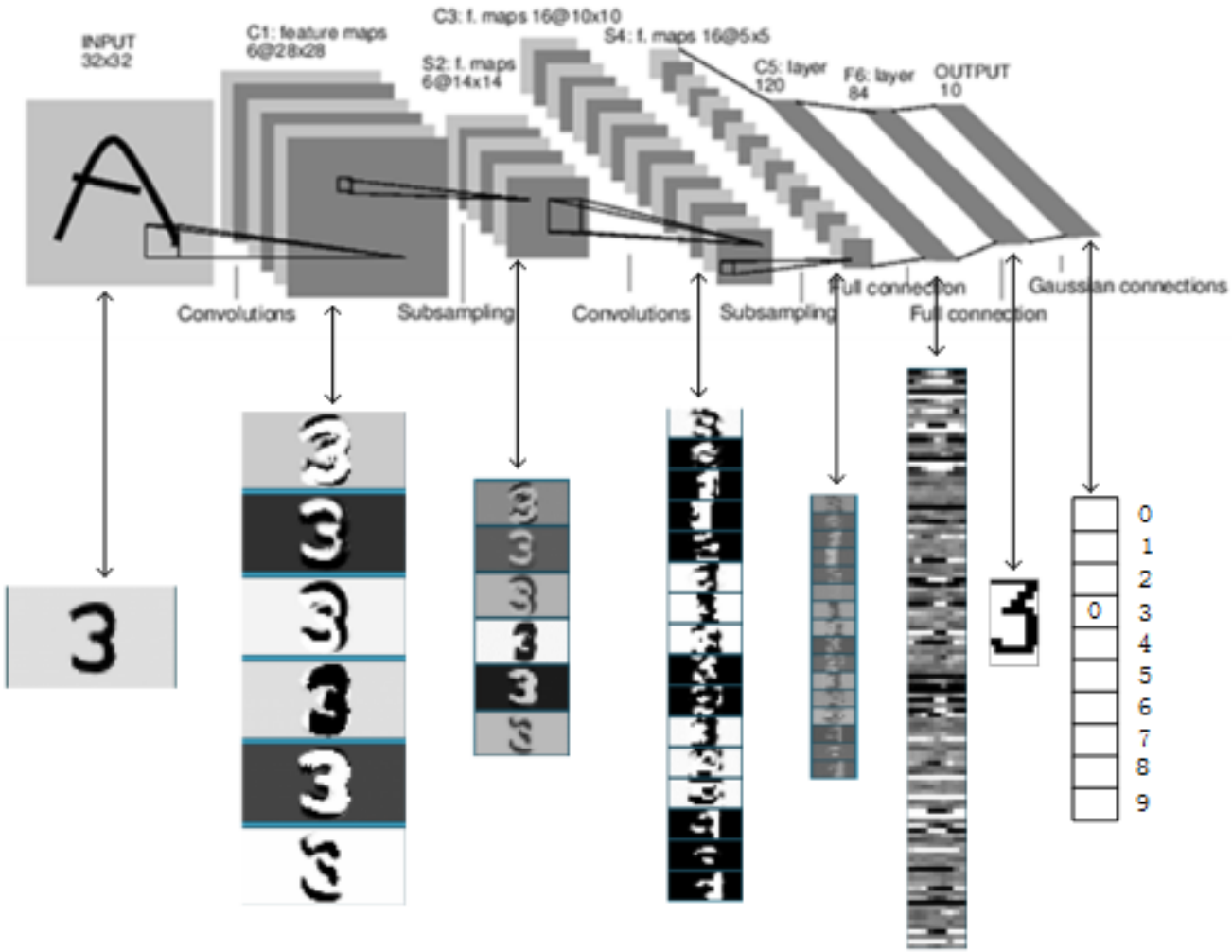


Fig. 2. Architecture of LeNet-5, a Convolutional Neural Network, here for digits recognition. Each plane is a feature map, i.e. a set of units whose weights are constrained to be identical.

LeNet-5

LeCun, Boutou, Bengio & Haffner (1998)



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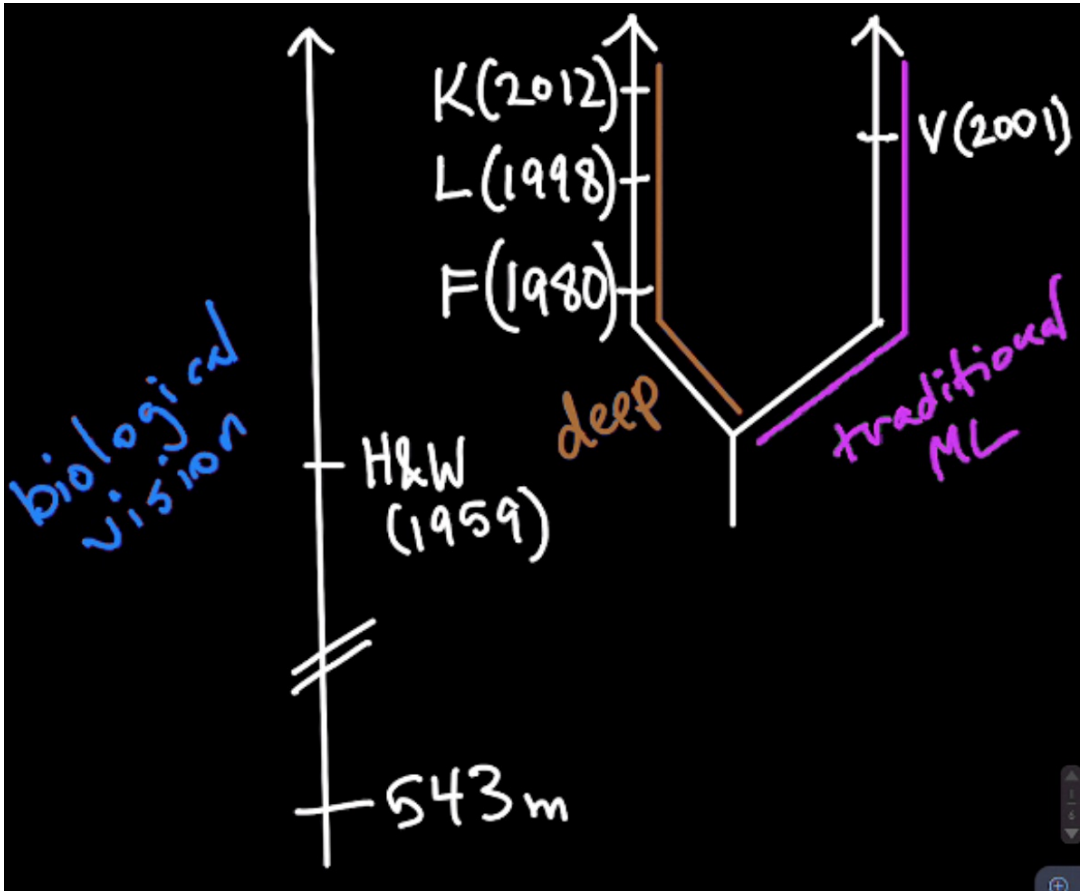
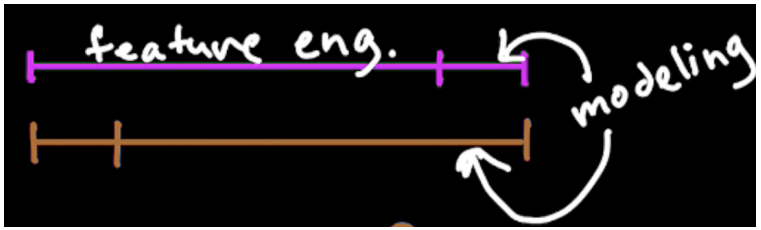
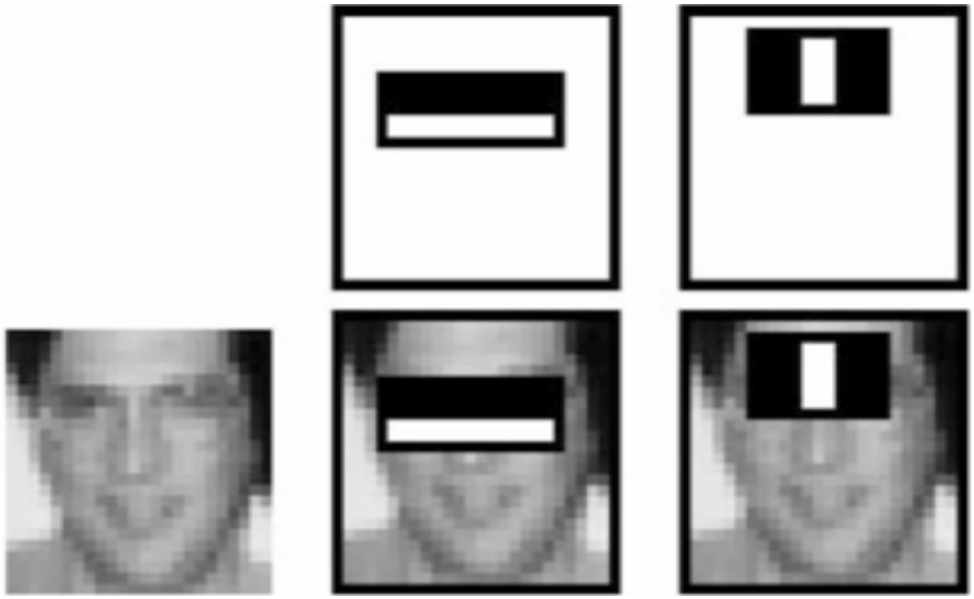




Viola & Jones (2001)



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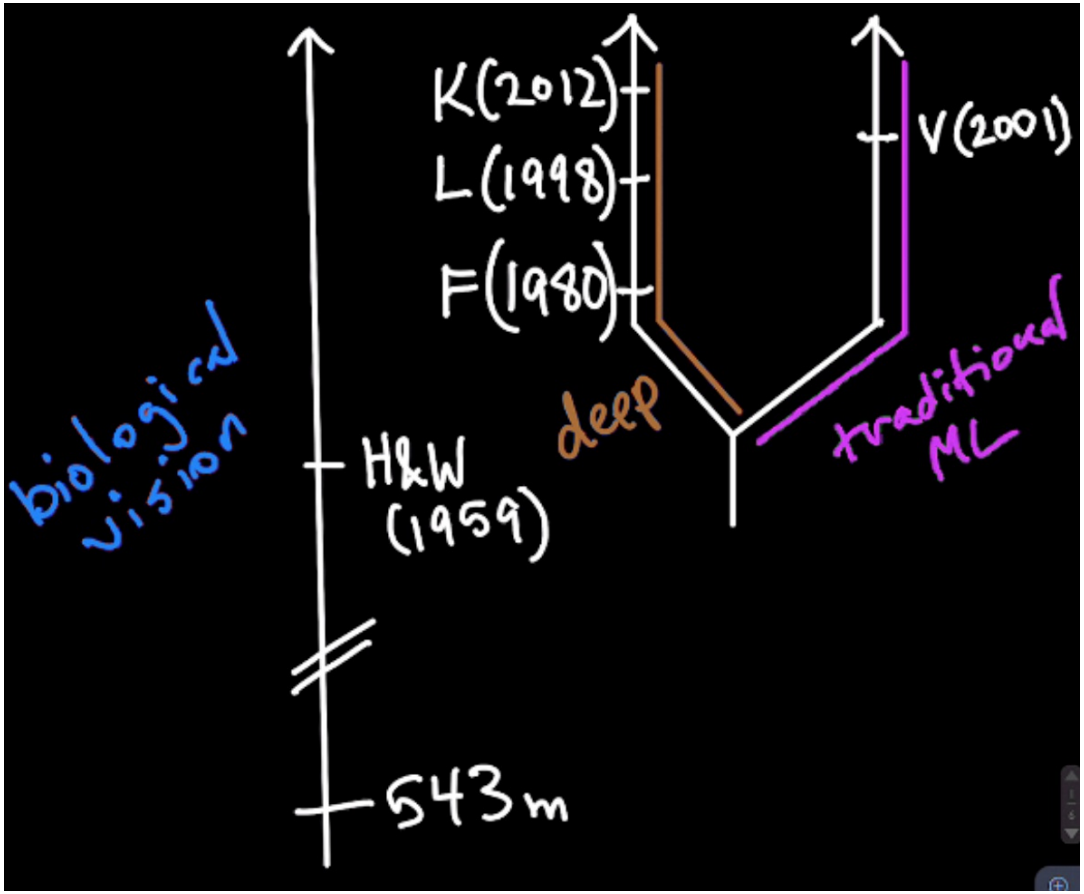
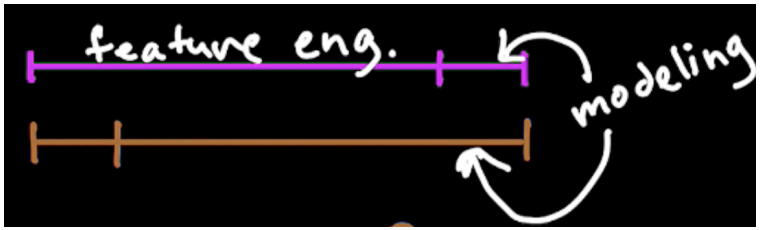
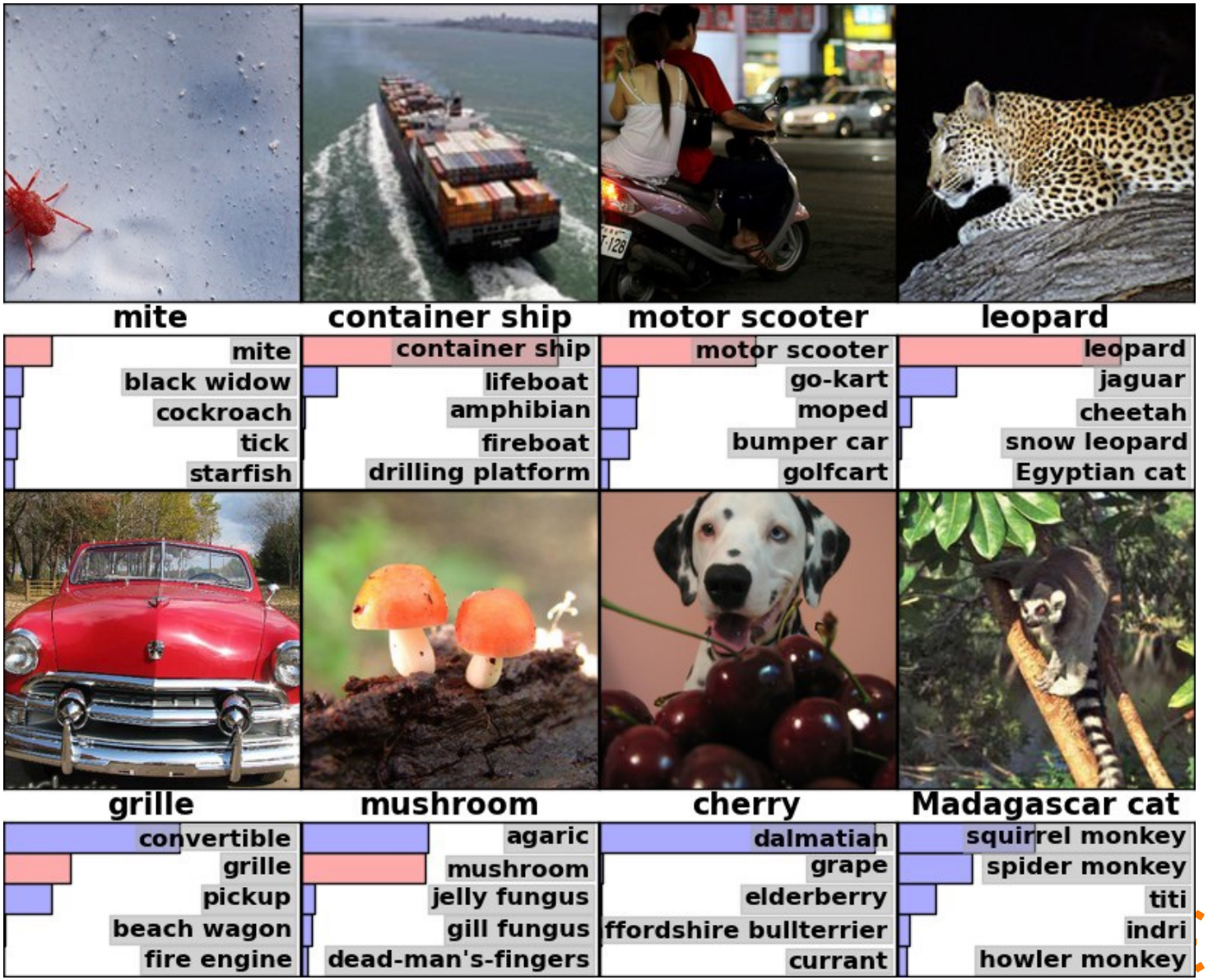




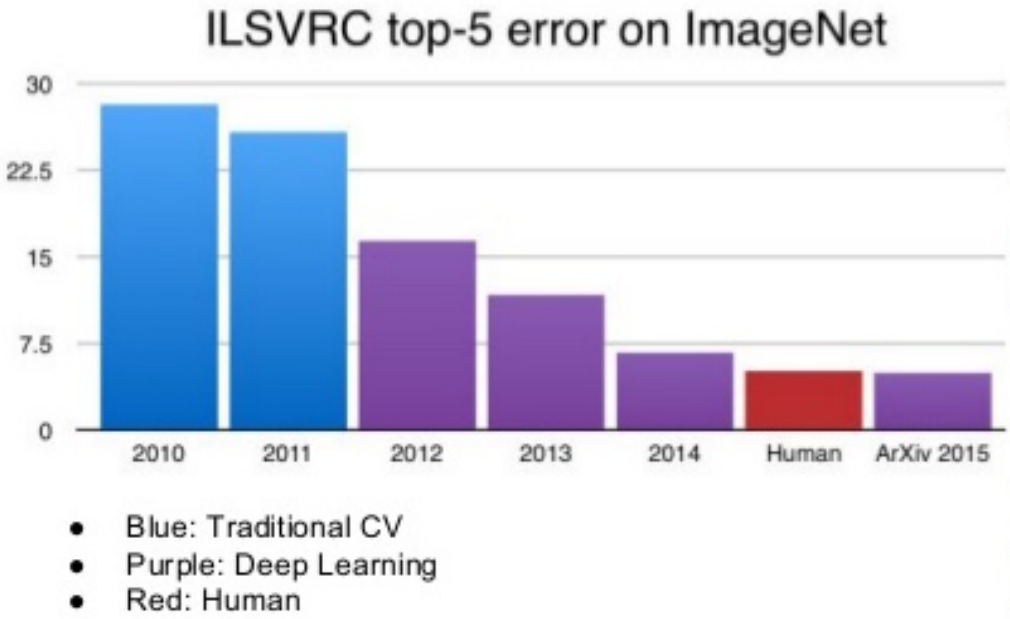
ImageNet

Fei-Fei Li et al. (2009), 14m images, 22k categories

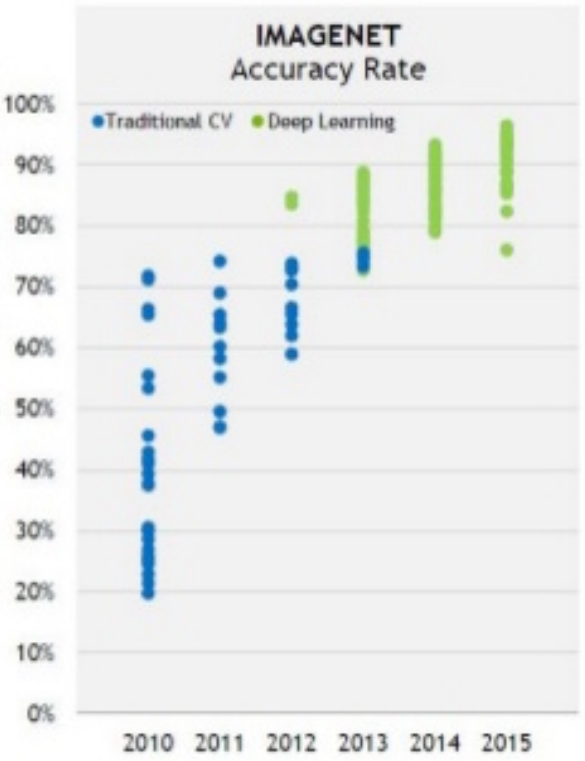


ImageNet Classification Error

ILSVRC: 1.4m, 1k object classes

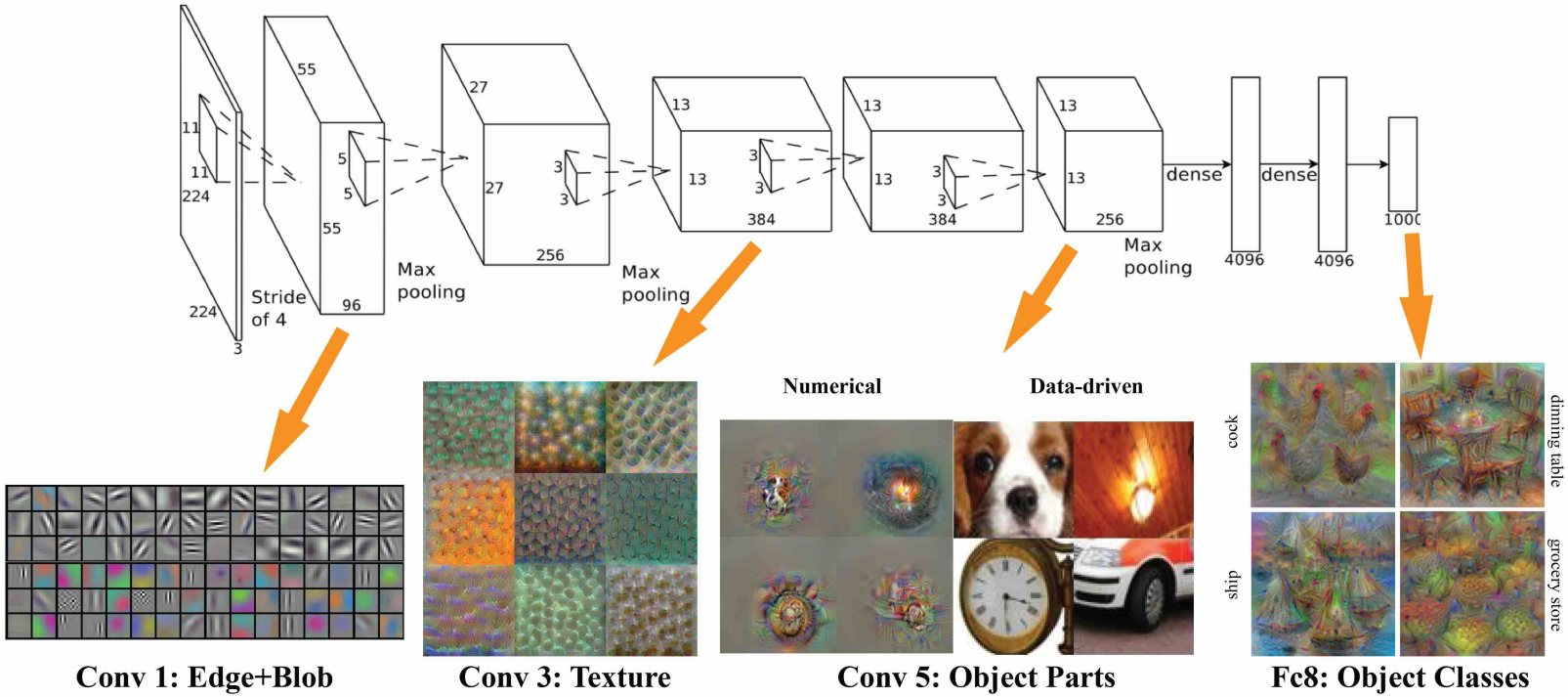


- Blue: Traditional CV
- Purple: Deep Learning
- Red: Human

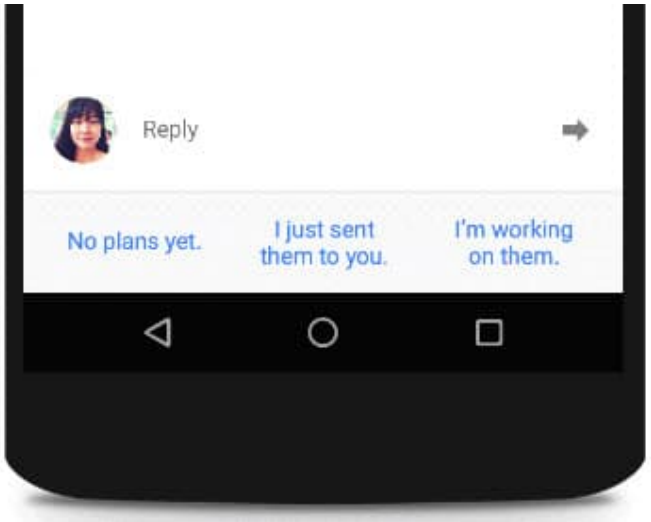


AlexNet

Krizhevsky, Sutskever & Hinton (2012)



mark zuckerberg
Mark Zuckerberg
11,814 like this. · Business P...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No plans yet.
I just sent them to you.
I'm working on them.

"Remind me about this when I get home"
tap to edit
OK, I'll remind you when you arrive at home:
Reminder
11 Hot Beach Escapes - Jetsetter
Arriving: Home
Remove

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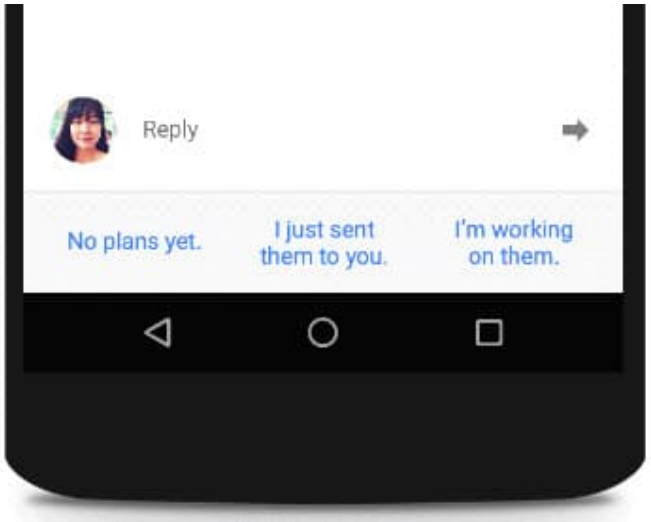
Mark Zuckerberg
11,814 like this. · Business P...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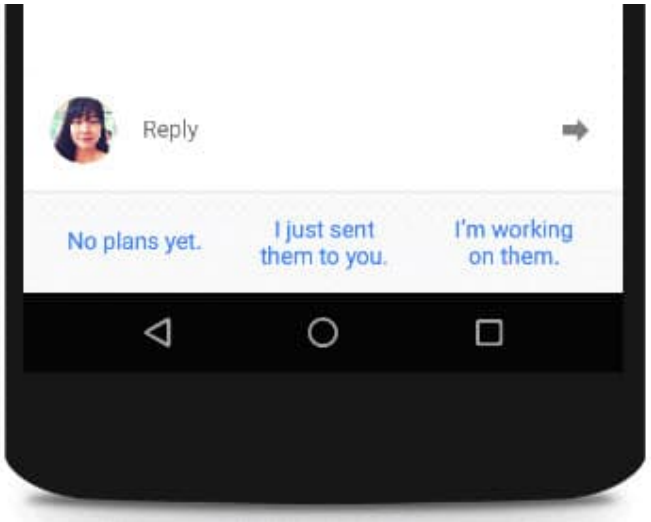
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Interactive Visualization of an Artificial Neural Network

[TensorFlow Playground]

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- local machine
- (Tesla K80 / V100) cloud instance
- (GTX 1080ti) monster box

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[Max's blog post]

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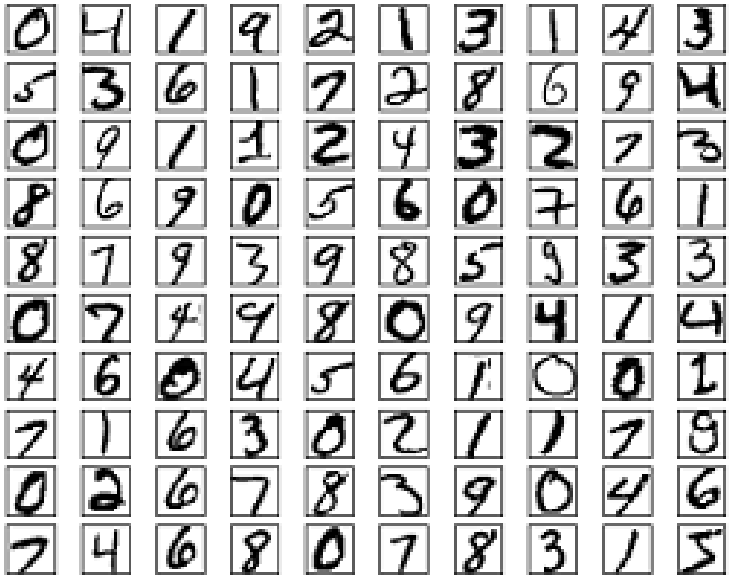
Jupyter Notebooks

+ Docker + Nvidia GPU + TensorFlow

[Dockerfile]

A Shallow Neural Network



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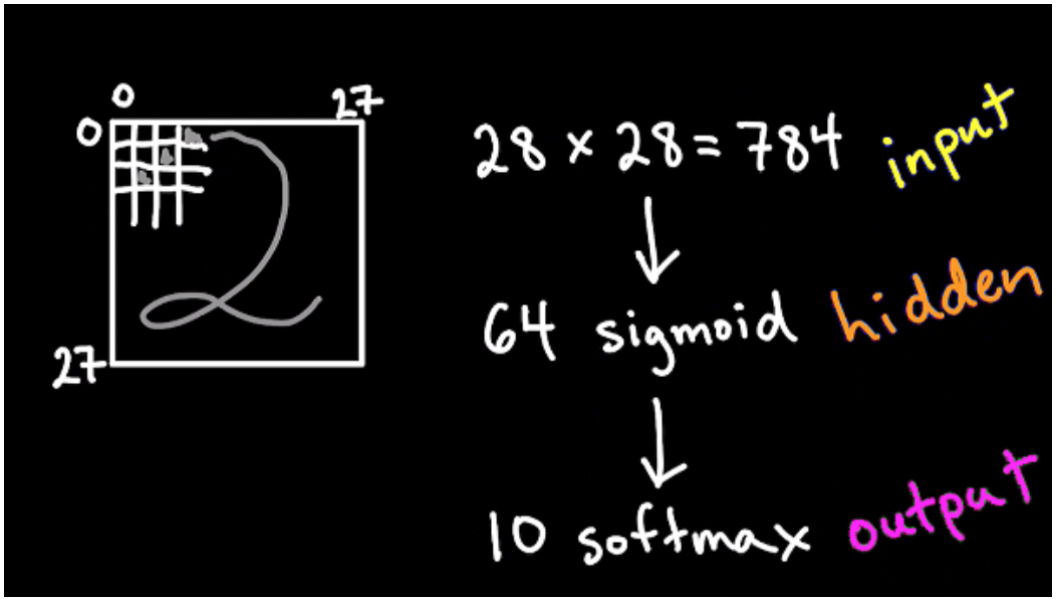

[shallow notebook]

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Essential Theory I

Neural Units

...whiteboard...

Essential Theory II

Cost Functions, Gradient Descent, and Backpropagation

...whiteboard...

An Intermediate Neural Network

[intermediate notebook]

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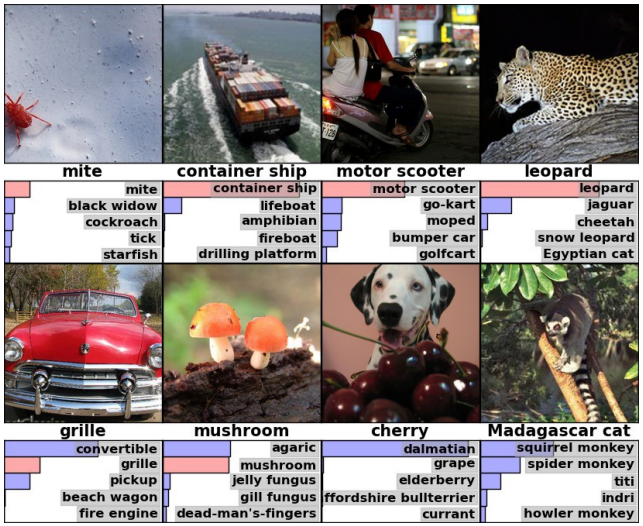
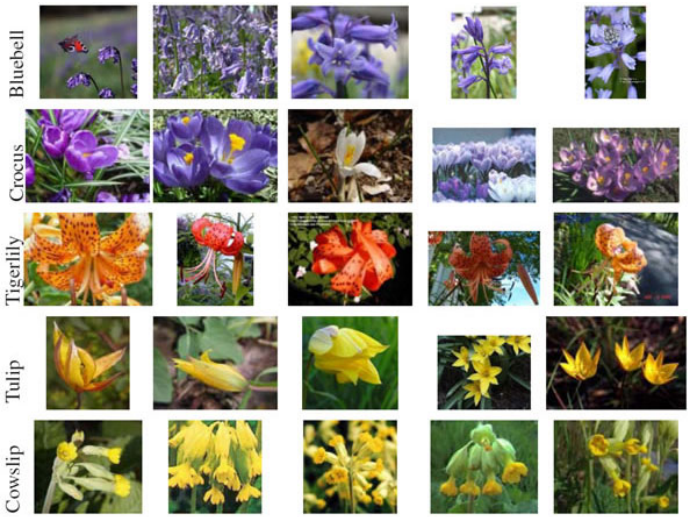
Data Sets for Deep Learning





Dataset	Classes	Train Samples
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Sogou News	5	450,000
DBPedia	14	560,000
Yelp Review Polarity	2	560,000
Yelp Review Full	5	650,000
Yahoo! Answers	10	1,400,000
Amazon Review Full	5	3,000,000
Amazon Review Polarity	2	3,600,000

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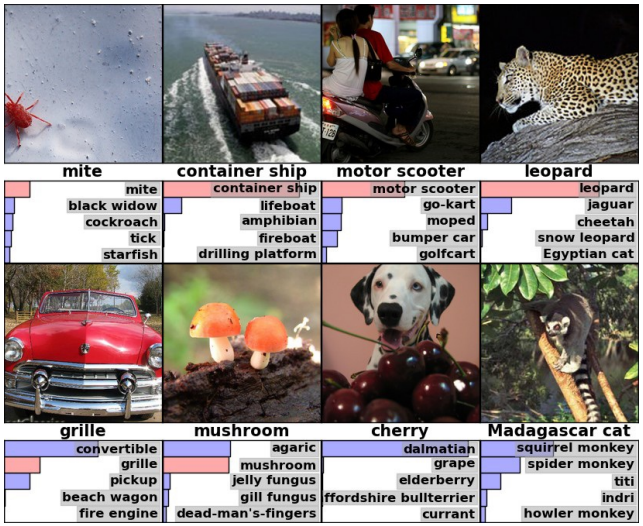

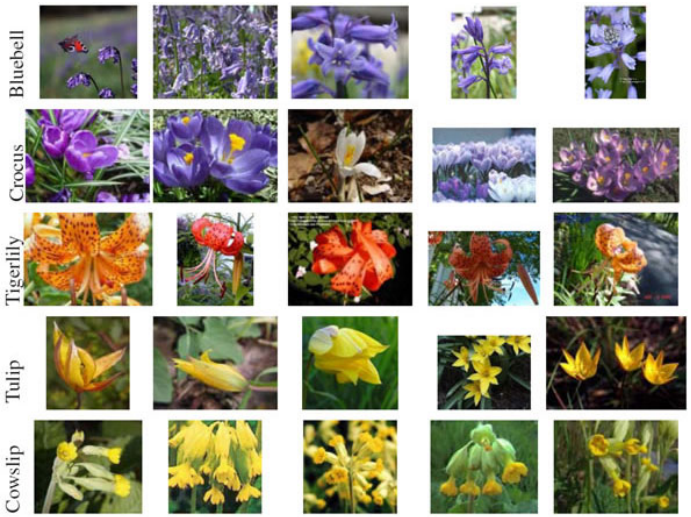

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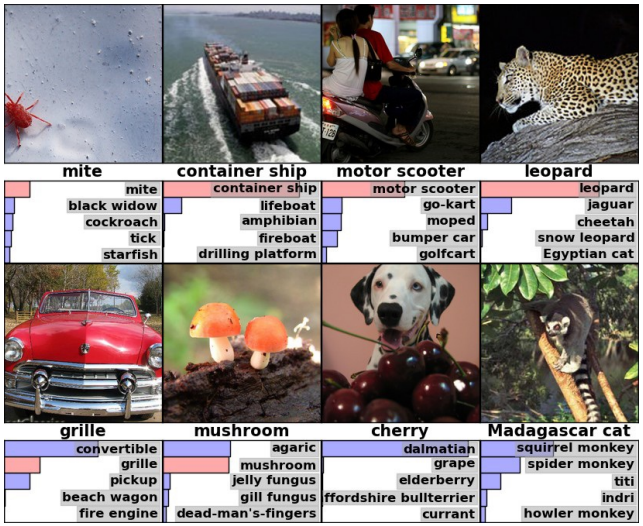
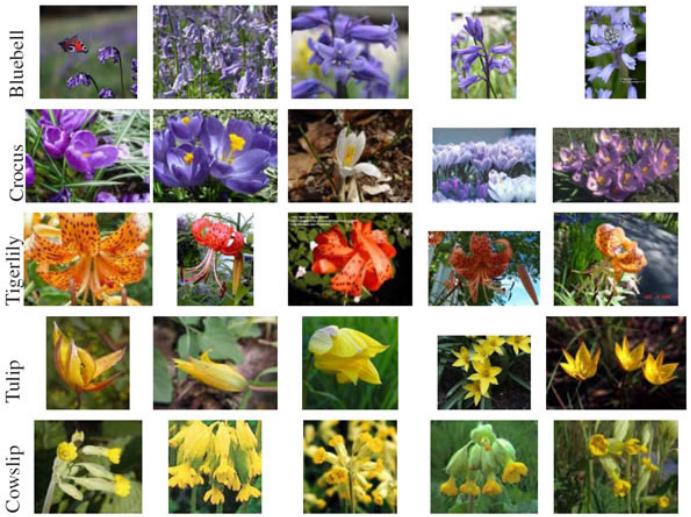
Data Sets for Deep Learning





Dataset	Classes	Train Samples
AG's News	4	120,000
Sogou News	5	450,000
DBPedia	14	560,000
Yelp Review Polarity	2	560,000
Yelp Review Full	5	650,000
Yahoo! Answers	10	1,400,000
Amazon Review Full	5	3,000,000
Amazon Review Polarity	2	3,600,000

Data Science Resources — Jon

Secure | https://www.jonkrohn.com/resources/

Jon Krohn, Cajoler of Datums

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Open Data Sources

To train a powerful model, the larger the data set, the better -- if it's well-organised and open, that's ideal. The following repositories are standouts that meet all these criteria:

- Data.gov (home of >150k US government-related datasets),
- Govcode, a collection of government open source projects,
- the Open Data Stack Exchange, and
- this curated list of 'awesome' public datasets
- this well-annotated list of data sets for natural language processing
- for biomedical and health data specifically, check out:
    - this University of Minnesota resource
    - this Medical Data for Machine Learning GitHub repo

For machine learning models that require *a lot* of *labelled* data, check out:

- UC Irvine's repository
- Yahoo's massive 13TB data set comprised of 100 billion user interactions with news items
- Google's image and video data sets
- Luke de Oliveira's *Greatest Public Datasets for AI* blog post
- CrowdFlower's Data for Everyone

Finally, here are extensive pages on importing data from the Web into R, provided by CRAN and MRAN.

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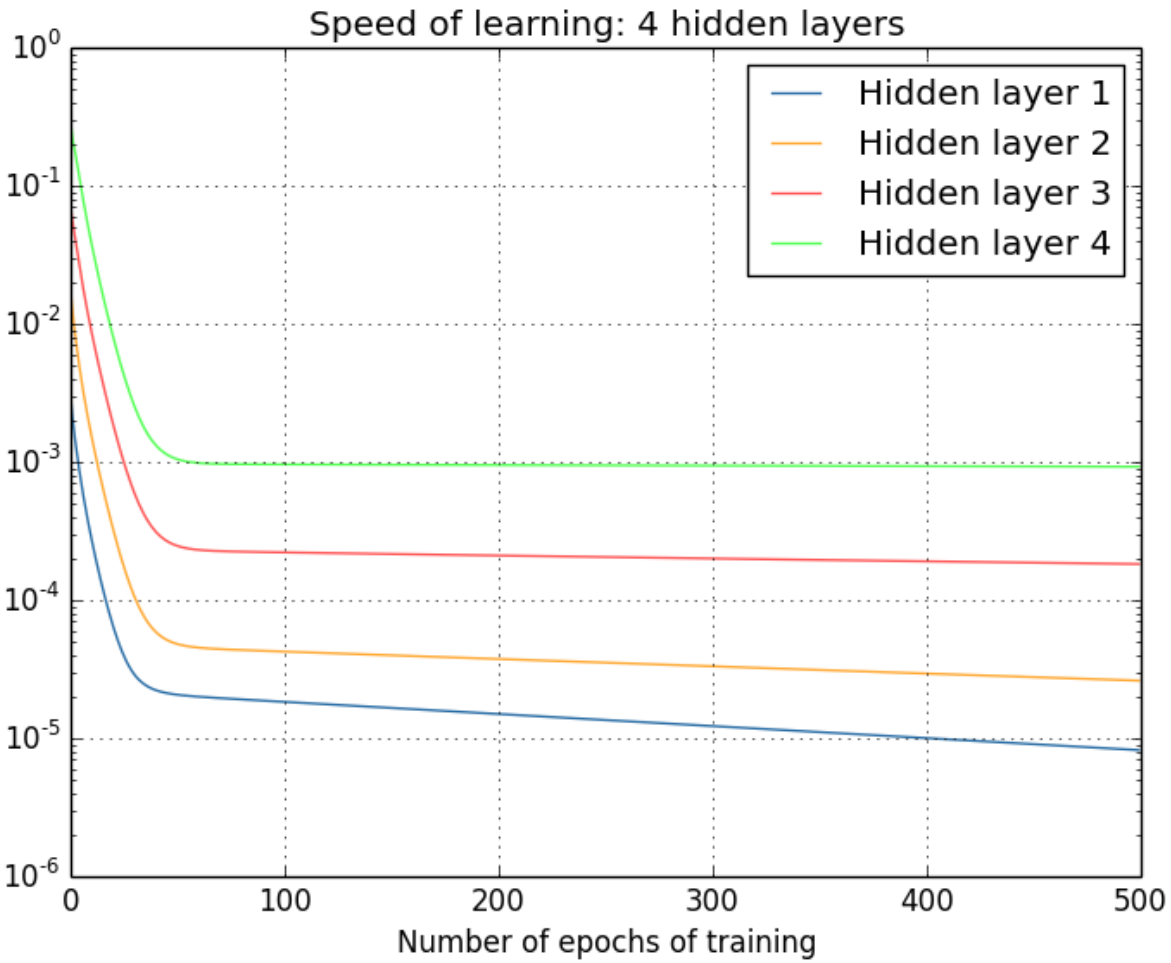
Essential Theory III

Weight Initialization and Mini-Batches

[neurons notebook]

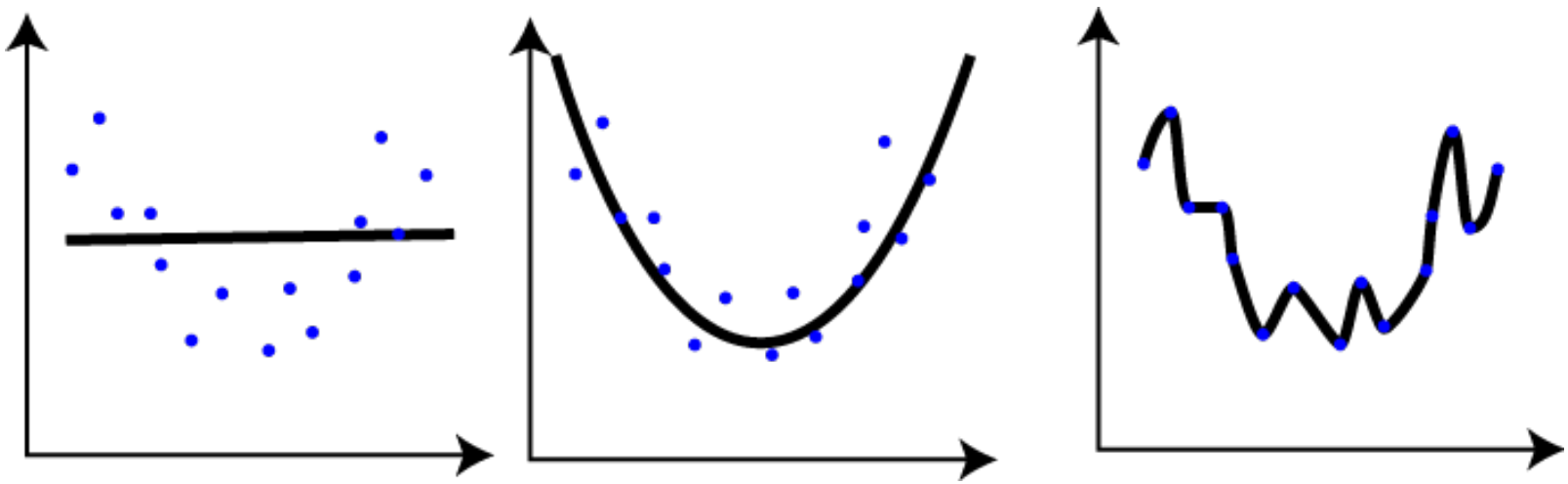
Essential Theory IV

Unstable Gradients and Avoiding Overfitting



Essential Theory IV

Unstable Gradients and Avoiding Overfitting

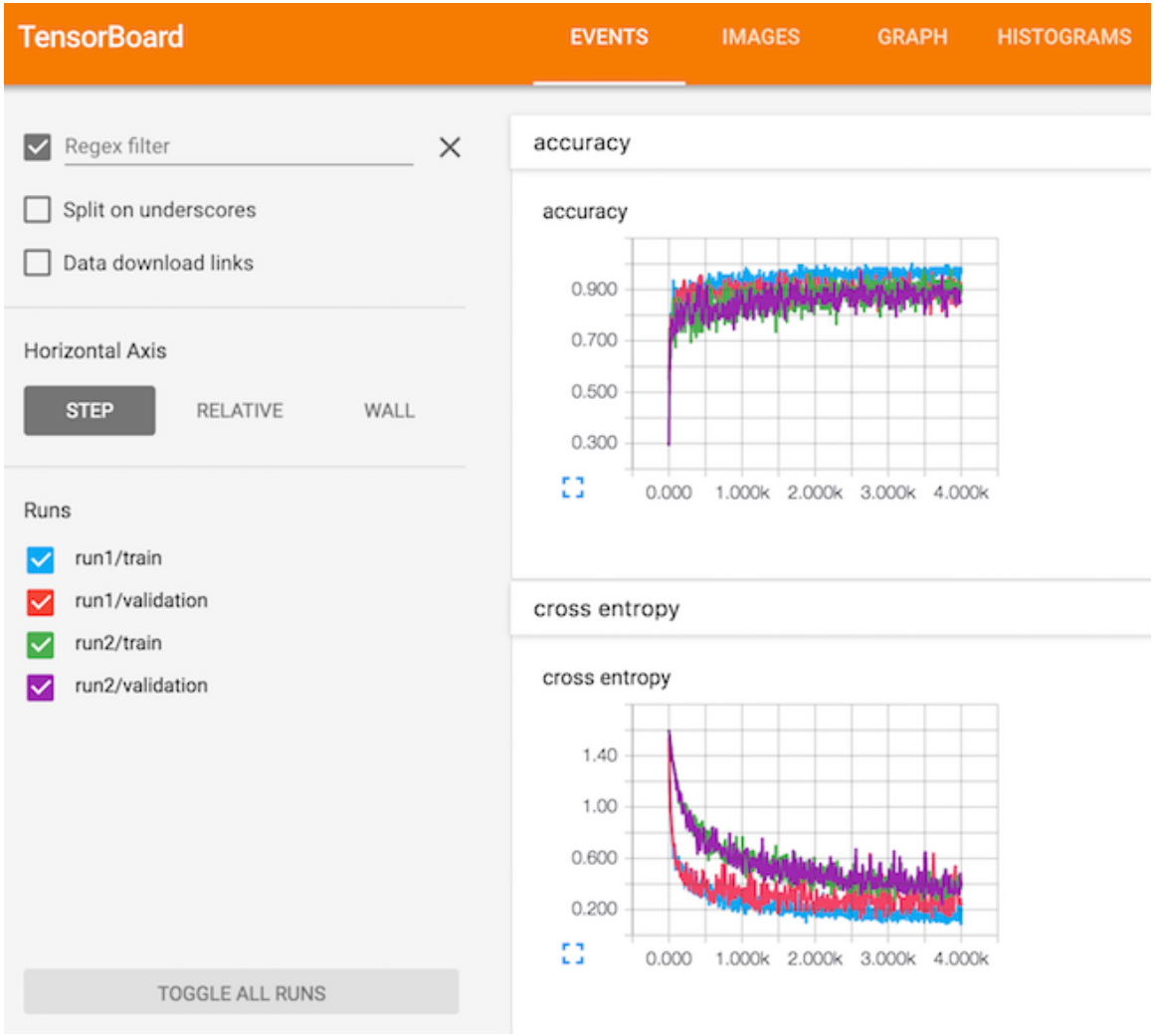


A Deep Neural Network

[deep notebook]

TensorBoard

and the Interpretation of Model Outputs



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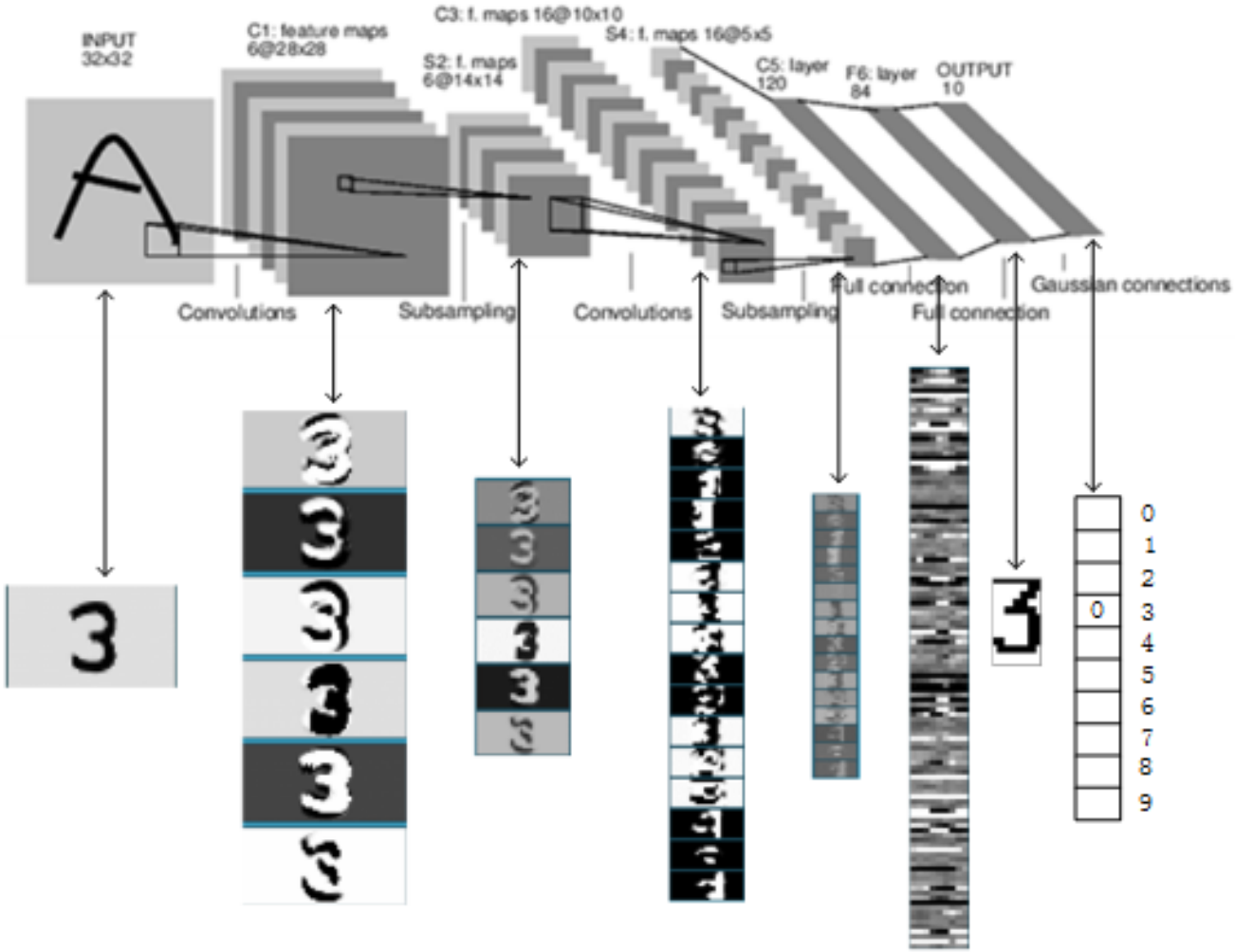
Intro to ConvNets

for Visual Recognition

[deepvis]

LeNet-5

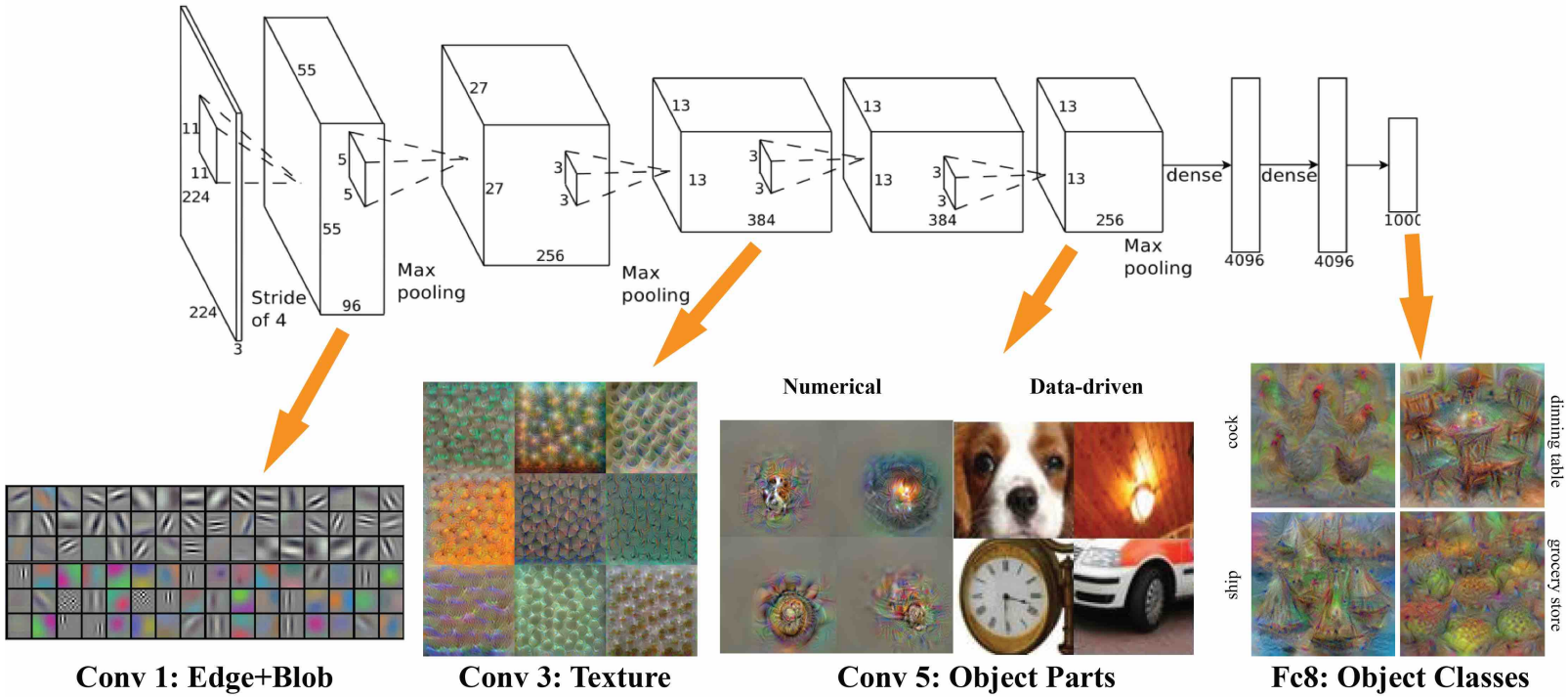
Classic ConvNet Architecture I



[notebook]

AlexNet

Classic ConvNet Architecture II



[notebook]

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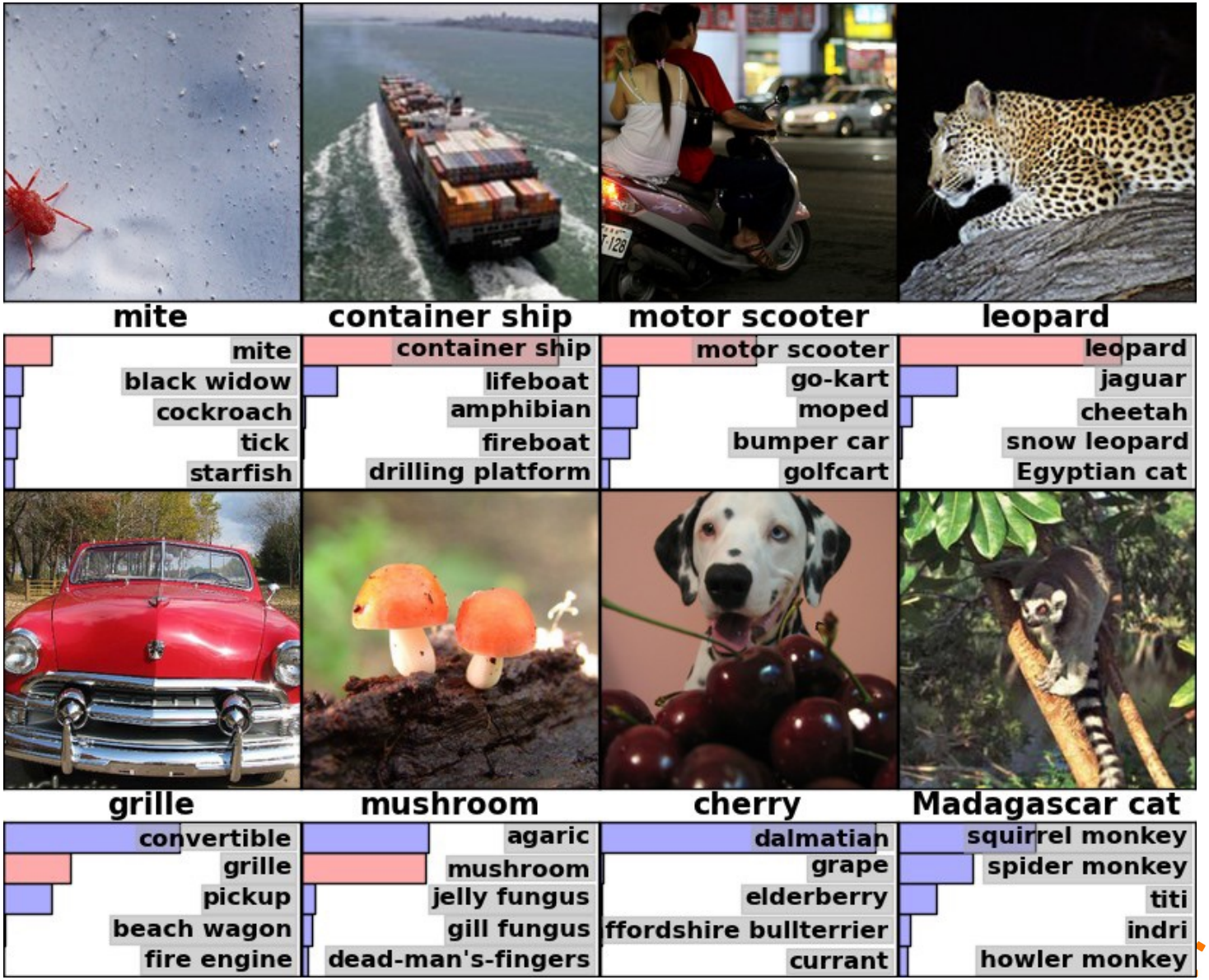
Transfer Learning



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Leading DL Libraries

A Comparison

	Caffe	**Torch**	**MXNet**	**TensorFlow**
language	Python, Matlab	Lua, C *PyTorch*	Python, R, C++ Julia, Matlab JavaScript, Go Scala, Perl	Python, R, C++ C, Java, Go
pre-trained models	Model Zoo	ModelZoo	Lasagne	Inception, others
parallel GPUs: data	Yes	Yes	Yes	Yes
parallel GPUs: model		Yes		Yes
source code	Readable	Readable		
for RNNs			Good	Best
high-level APIs			Keras	Keras, TFLearn

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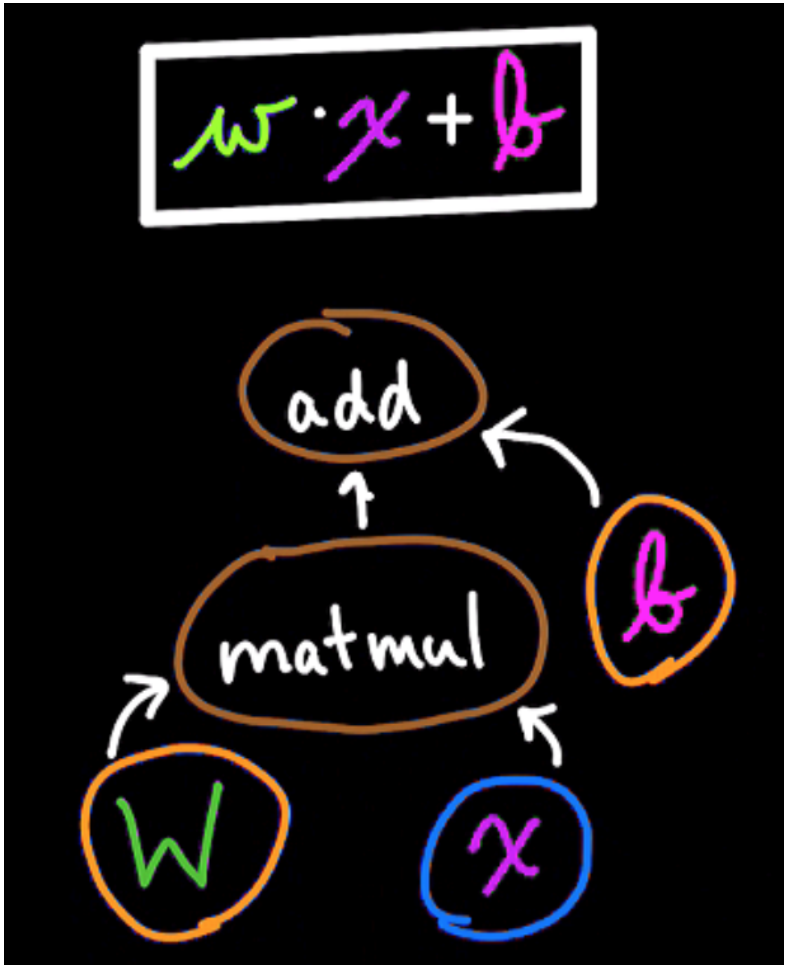
TensorFlow Graphs



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[LeNet-5 in TF]

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Improving Model Performance

1. Xavier Glorot initialization
2. problem simplification
3. layer architecture
4. cost function
5. avoid overfitting
6. variable learning rate η
7. epochs
8. regularization parameters, e.g., λ
9. mini-batch size
10. grid-search automation

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Tuning Hyperparameters

...in `lenet_in_keras.ipynb`:

```
model = Sequential()
model.add(Conv2D(32, kernel_size=(3, 3), activation='relu', input_shape=(28, 28, 1)))
model.add(Conv2D(64, kernel_size=(3, 3), activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))
model.add(Dropout(0.25))
model.add(Flatten())
model.add(Dense(128, activation='relu'))
model.add(Dropout(0.5))
model.add(Dense(n_classes, activation='softmax'))
```

...in `lenet_in_tensorflow.ipynb`:

```
# max pooling layer:
pool_size = 2
mp_layer_dropout = 0.25

# dense layer:
n_dense = 128
dense_layer_dropout = 0.5
```

```
# convolutional and max-pooling layers:
conv_1 = conv2d(square_x, weights['W_c1'], biases['b_c1'])
conv_2 = conv2d(conv_1, weights['W_c2'], biases['b_c2'])
pool_1 = maxpooling2d(conv_2, mp_psize)
pool_1 = tf.nn.dropout(pool_1, 1-mp_dropout)

# dense layer:
flat = tf.reshape(pool_1, [-1, weights['W_d1'].get_shape().as_list()[0]])
dense_1 = dense(flat, weights['W_d1'], biases['b_d1'])
dense_1 = tf.nn.dropout(dense_1, 1-dense_dropout)
```

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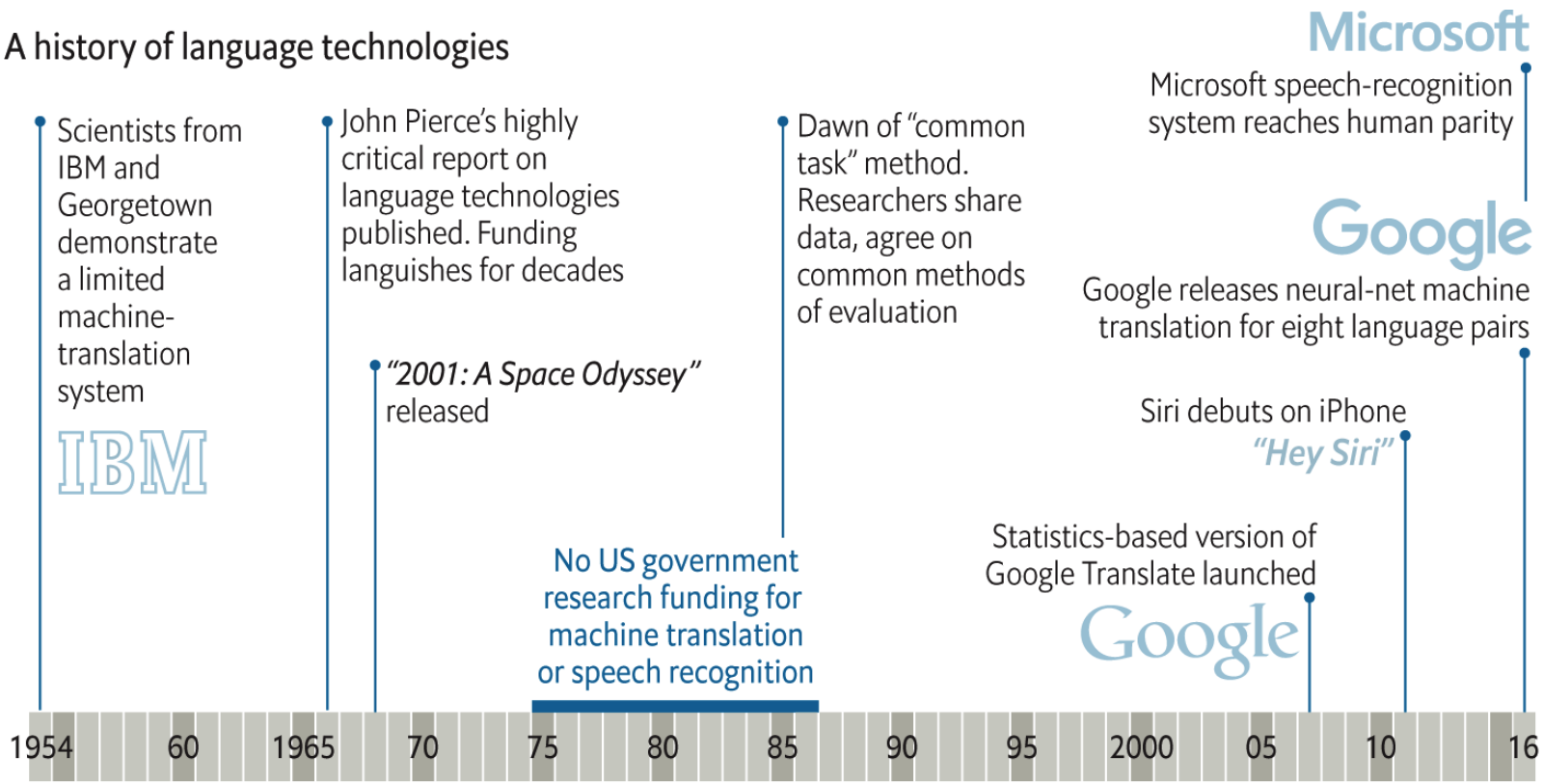
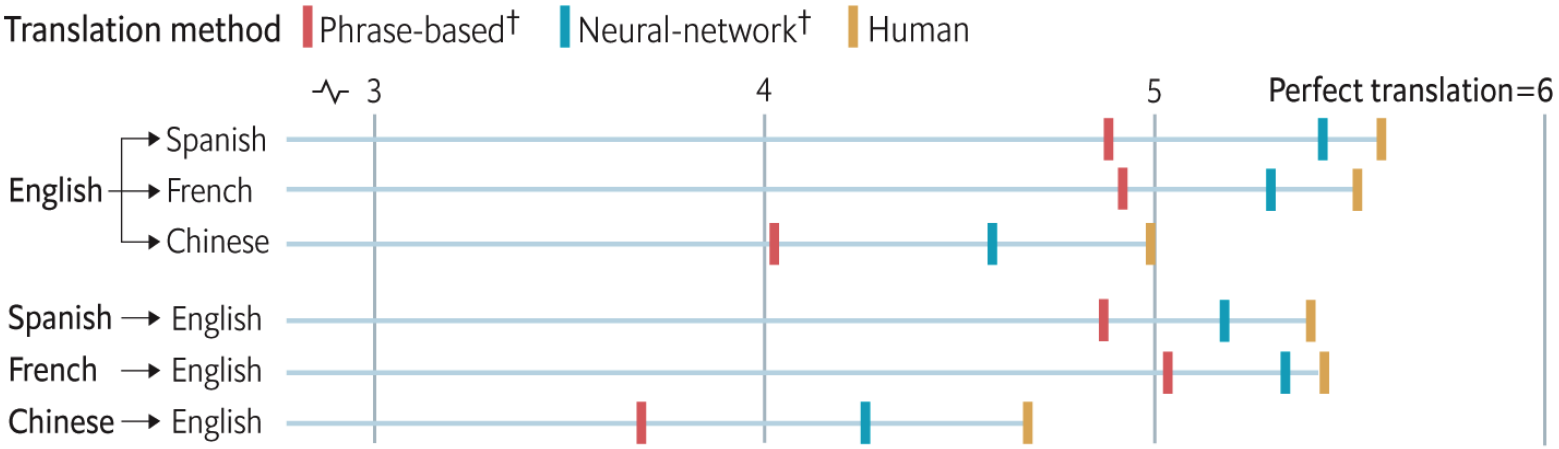

A history of language technologies
Scientists from IBM and Georgetown demonstrate a limited machine-translation system
IBM
John Pierce's highly critical report on language technologies published. Funding languishes for decades
"2001: A Space Odyssey" released
No US government research funding for machine translation or speech recognition
Dawn of "common task" method. Researchers share data, agree on common methods of evaluation
Statistics-based version of Google Translate launched
Google
Siri debuts on iPhone
"Hey Siri"
Google releases neural-net machine translation for eight language pairs
Google
Microsoft speech-recognition system reaches human parity
Microsoft
1954
60
1965
70
75
80
85
90
95
2000
05
10
16


Translation method
Phrase-based†
Neural-network†
Human
3
4
5
Perfect translation=6
English
Spanish
French
Chinese
Spanish → English
French → English
Chinese → English

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Sunspring

Sunspring

INT. SHIP

We see H pull a book from a shelf, flip through it while speaking, and then put it back.

H
In a future with mass unemployment, young people are forced to sell blood. That's the first thing I can do.

H2
You should see the boys and shut up. I was the one who was going to be a hundred years old.

H
I saw him again. The way you were sent to me... that was a big honest idea. I am not a bright light.

C
Well, I have to go to the skull. I don't know.

He picks up a light screen and fights the security force of the particles of a transmission on his face.

H
(continuing)
What do you mean?

C
(smiles)
I don't know anything about any of this.

H
(to Hauk, taking his eyes from his mouth)
Then what?

H2
There's no answer.

C
(frowning)
We're going to see the money.

H
(reading)
"All right, you can't tell me that."

Steps back. Coffey is still going through.

C
I was coming to that thing because you were so pretty.

H
I don't know. I don't know what you're talking about.

C
That's right.

H
So what are you doing?

H2
I don't want to be honest with you.

He looks at him for a moment, then smiles at him.

H
You don't have to be a doctor.

H2
I am not sure. I don't know what you're talking about.

H
I want to see you too.

H2
What do you mean?

He starts to shake.

H
I'm sorry, but I'm sure you wouldn't even touch me.

H2
I don't know what you're talking about.

H
The principle is completely constructed for the same time.

H2
(smiling)
It was all about you to be true.

H
You didn't even see the movie with the rest of the base.

H2
I don't know.

H
I don't care.

H2
I know that it's a consequence. Whatever you want to know about the presence of the story, I'm a little bit of a boy on the floor.

H
I don't know. I just have to ask you to explain to me what you say.

H2
What do you mean?

H
Because I don't know what you're talking about.

H2
That was all the time.

H
I know that.

H2
I don't know.

H
(angry)
It would be a good time. I think I could have been my life.

H (CONT'D)
It may never be forgiven, but that is just too bad. I have to leave, but I'm not free of the world.

C
Yes. Perhaps I should take it from here. I'm not going to do something.

H
You can't afford to take this anywhere. It's not a dream. But I've got a good time to stay there.

C
Well, I think you can still be back on the table.

H
Mmm. It's a damn thing scared to say. Nothing is going to be a thing but I was the one that got on this rock with a child and then I left the other two.

He is standing in the stars and sitting on the floor. He takes a seat on the counter and pulls the camera over to his back. He stares at it. He is on the phone. He cuts the shotgun from the edge of the room and puts it in his mouth. He sees a black hole in the floor leading to the man on the roof.

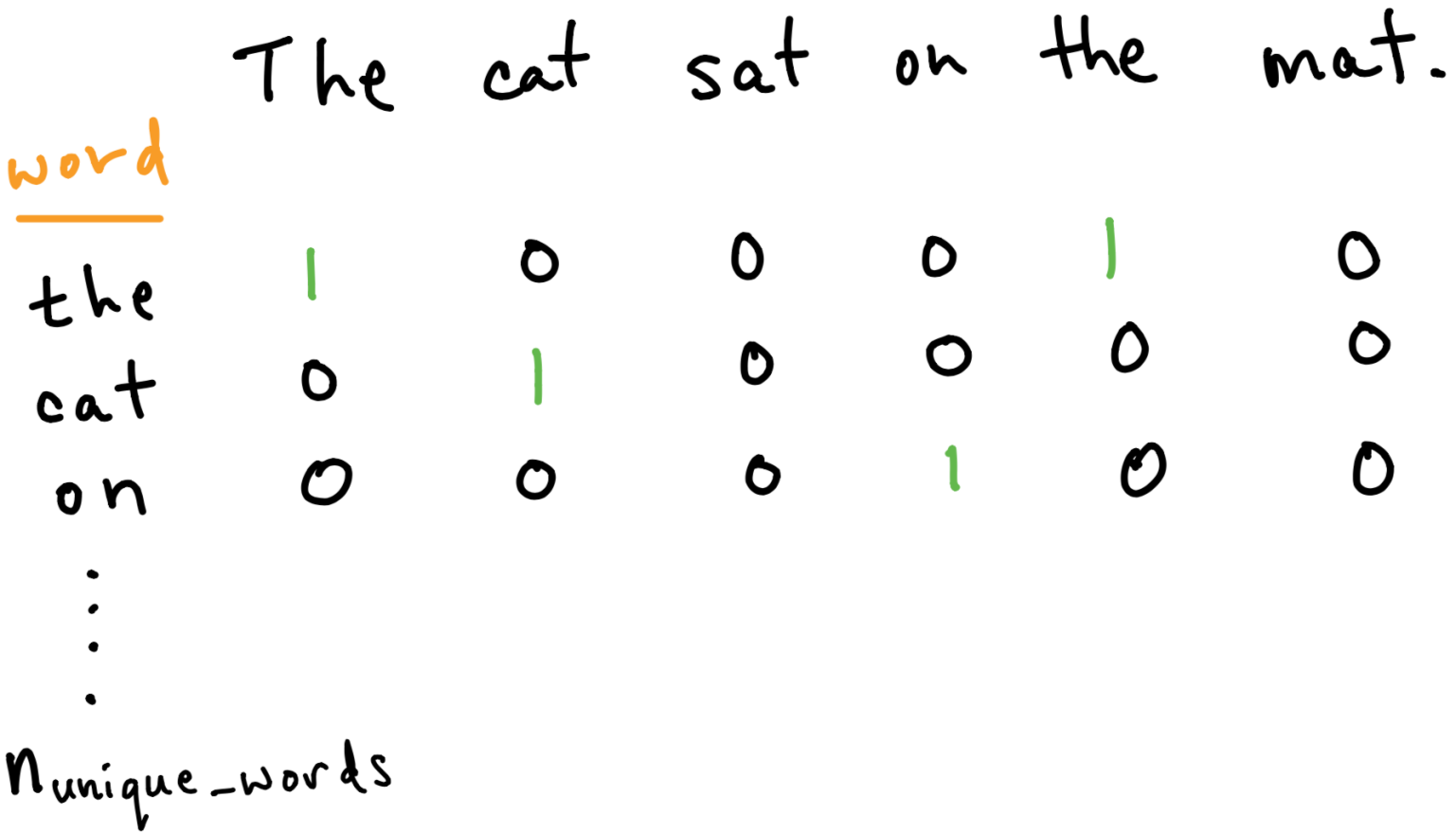
He comes up behind him to protect him. He is still standing next to him.

He looks through the door and the door closes. He looks at the bag from his backpack, and starts to cry.

T
Well, there's the situation with me and the light on the ship. The guy was trying to stop me. He was like a baby and he was gone. I was worried about him. But even if he would have done it all. He couldn't come any more. I didn't mean to be a virgin. I mean, he was weak. And I thought I'd change my mind. He was crazy to take it out. It was a long time ago. He was a little late. I was going to be a moment. I just wanted to tell you that I was much better than he did. I had to stop him and I couldn't even tell. I didn't want to hurt him. I'm sorry. I know I don't like him. I can go home and be so bad and I love him. So I can get him all the way over here and find the square and go to the game with him and she won't show up. Then I'll check it out. But I'm going to see him when he gets to me. He looks at me and he throws me out of his eyes. Then he said he'd go to bed with me.

Word Representations

One-Hot Word Representations



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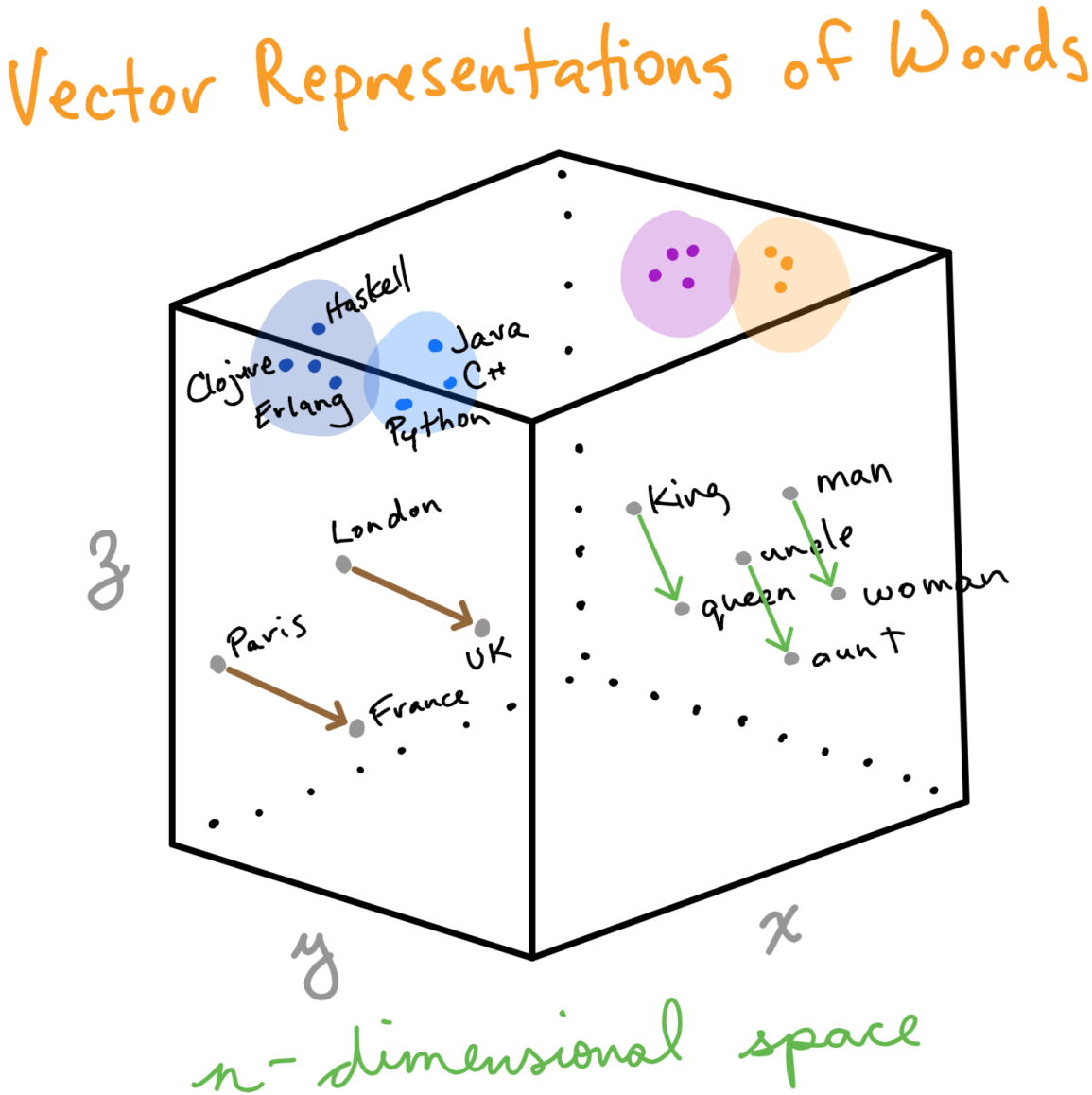


word2vec

[vse 2000]

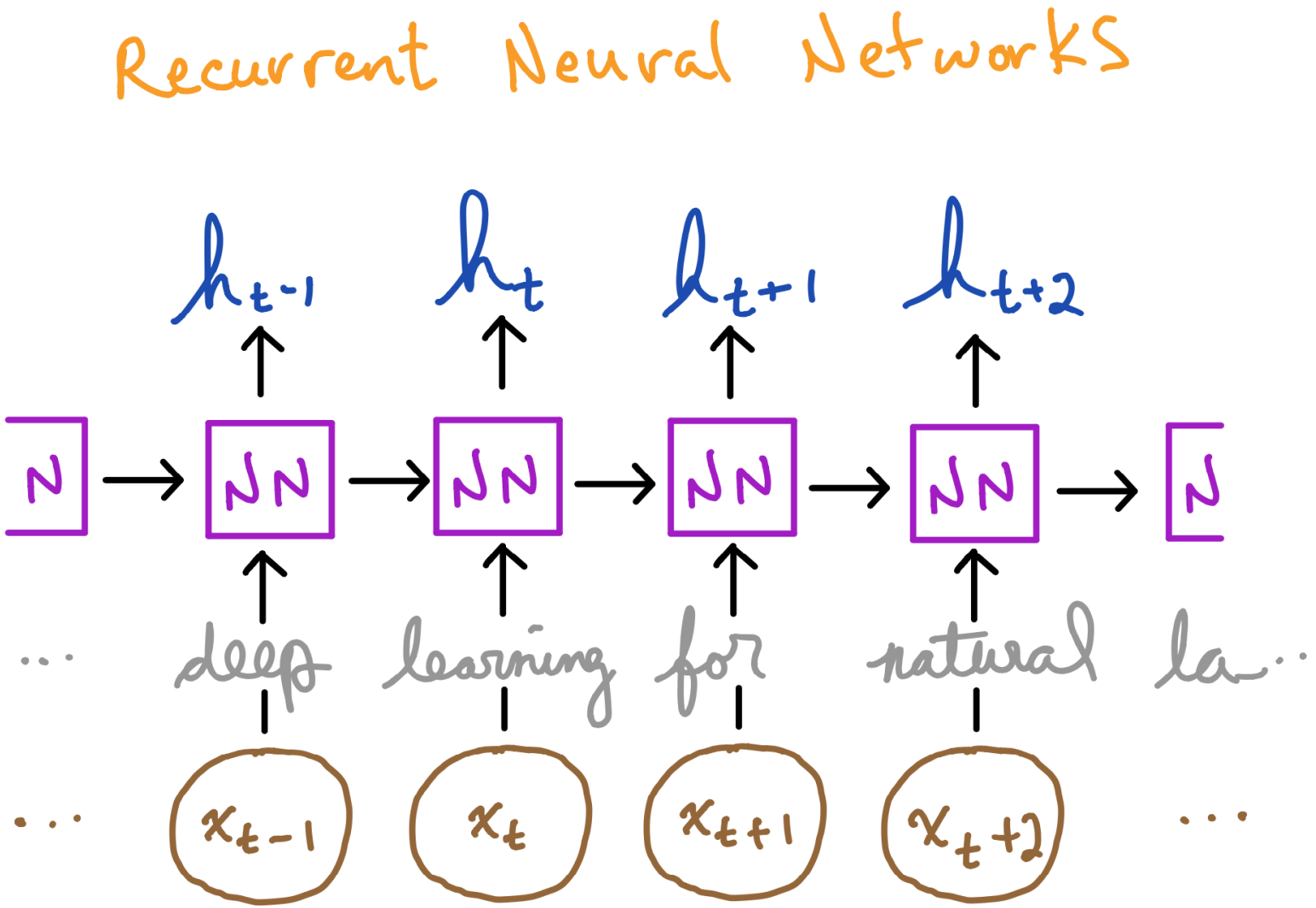
[word2viz]

NL Data Preprocessing

Best Practices

[NLP Best Practices notebook]

Recurrent Neural Networks



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Recurrent Neural Networks

[RNN notebook]

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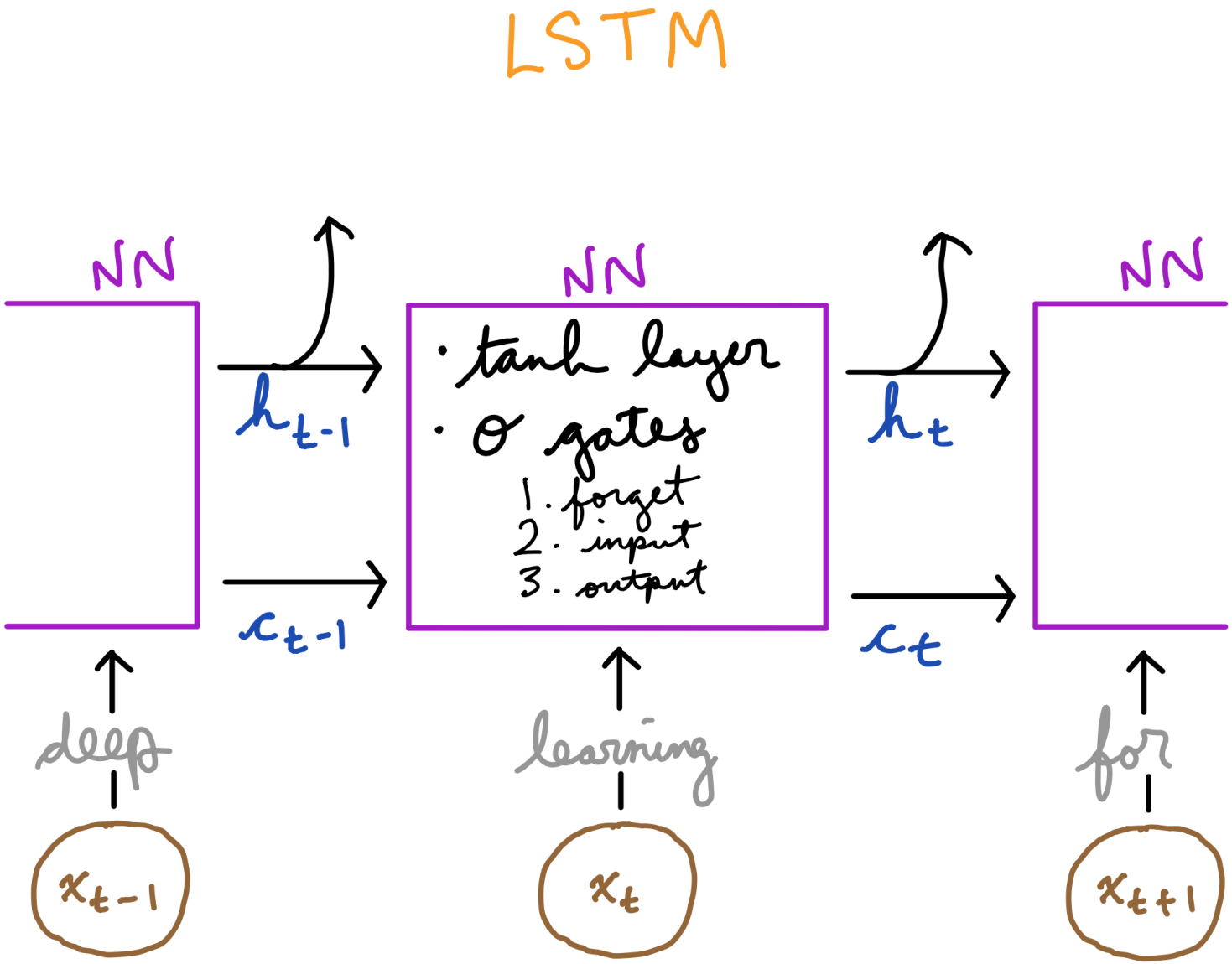
Bidirectional LSTMs



Bidirectional LSTMs

[BiLSTM notebook]

Parallel Network Architectures

[multi-ConvNet notebook]

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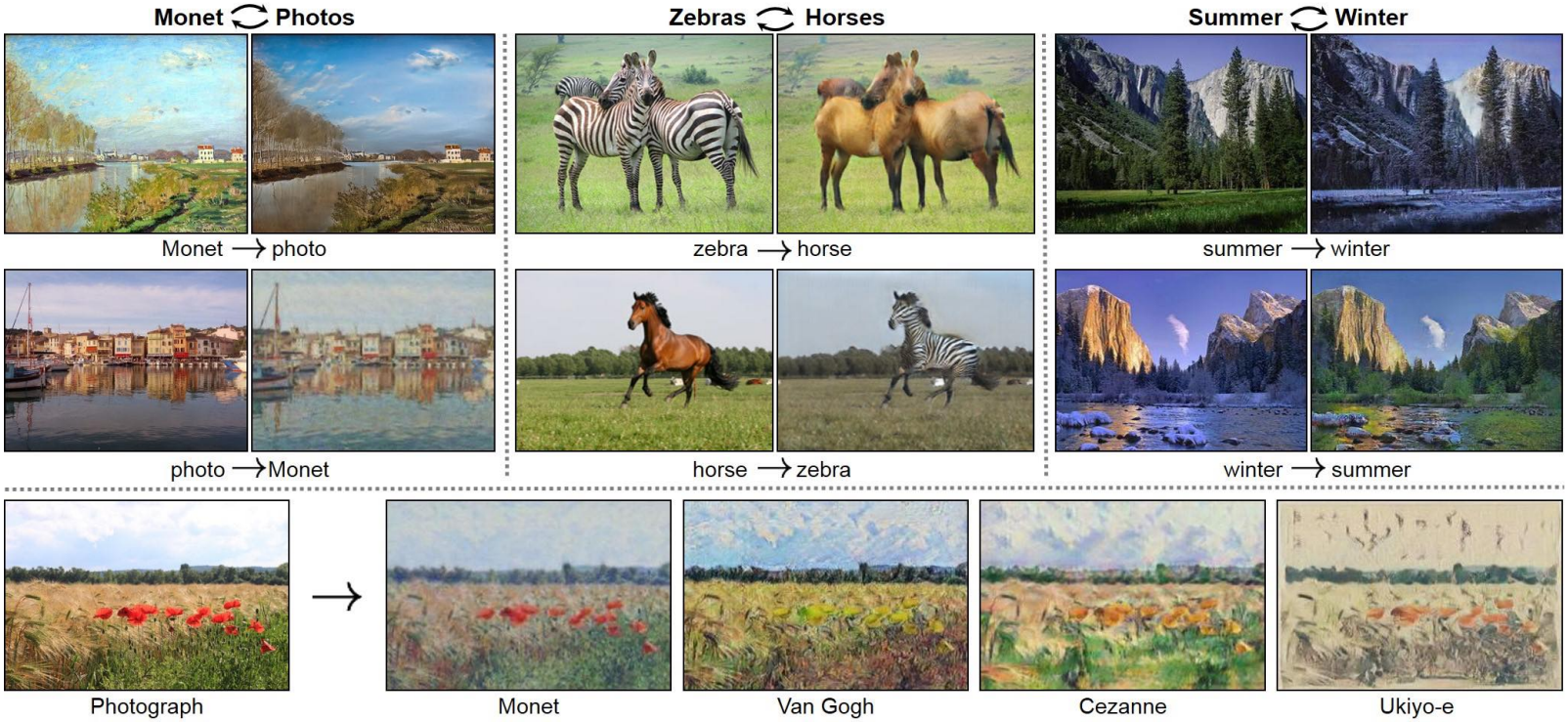
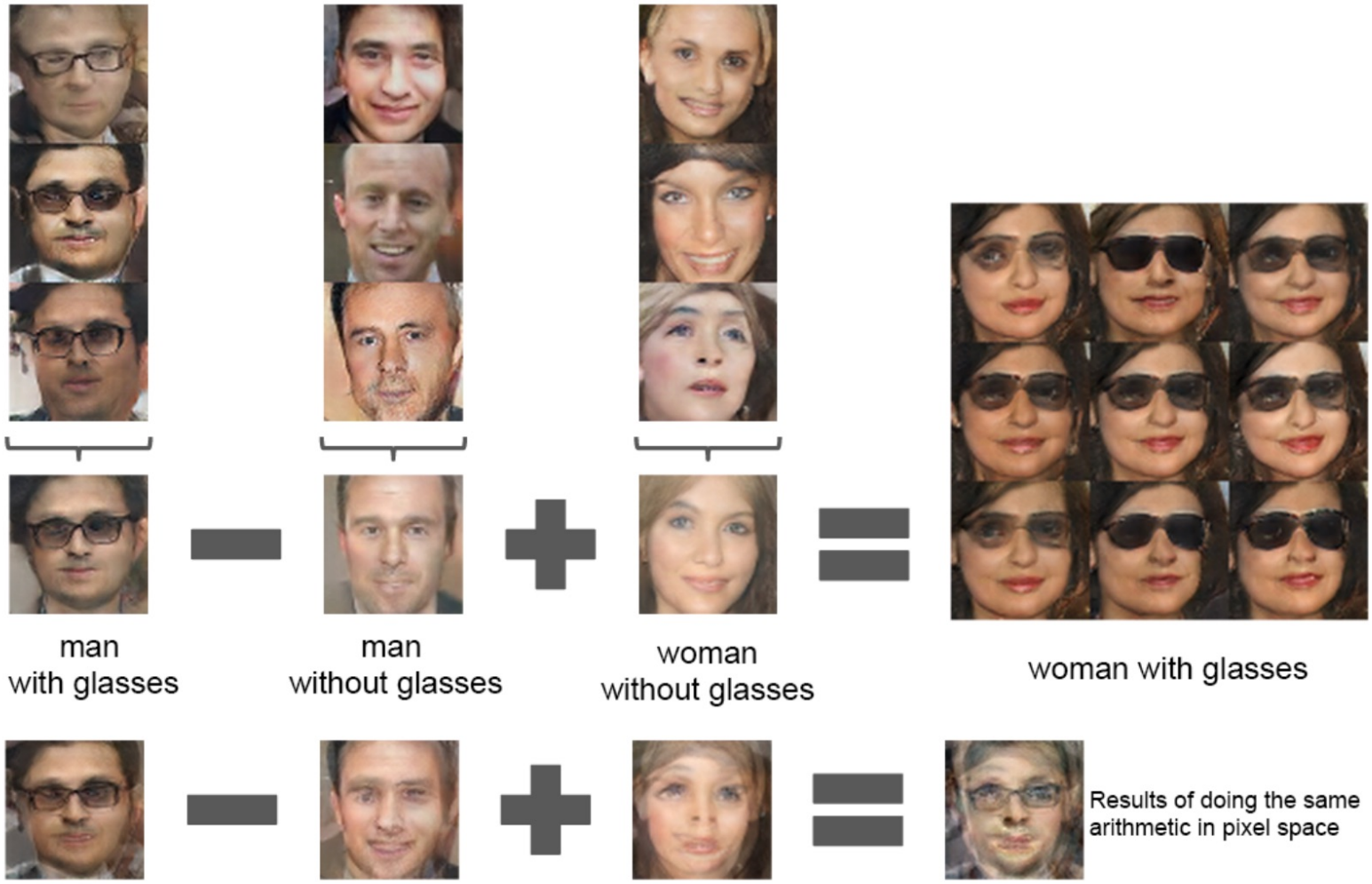

Monet ⇄ Photos
Zebras ⇄ Horses
Summer ⇄ Winter
Monet → photo
zebra → horse
summer → winter
photo → Monet
horse → zebra
winter → summer
Photograph
Monet
Van Gogh
Cezanne
Ukiyo-e

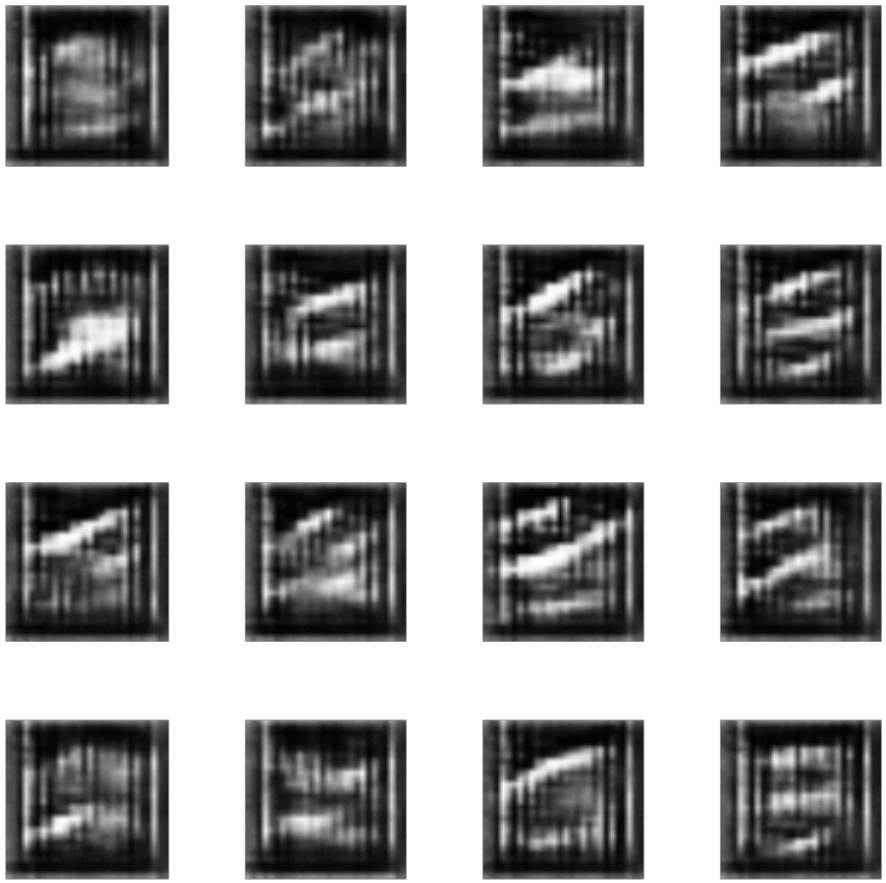

man
with glasses
man
without glasses
woman
without glasses
woman with glasses
Results of doing the same arithmetic in pixel space

Karras et al. at NVIDIA

ICLR 2018 submission

[CelebA-HQ Latent Space Interpolations]

[Quick, Draw!]



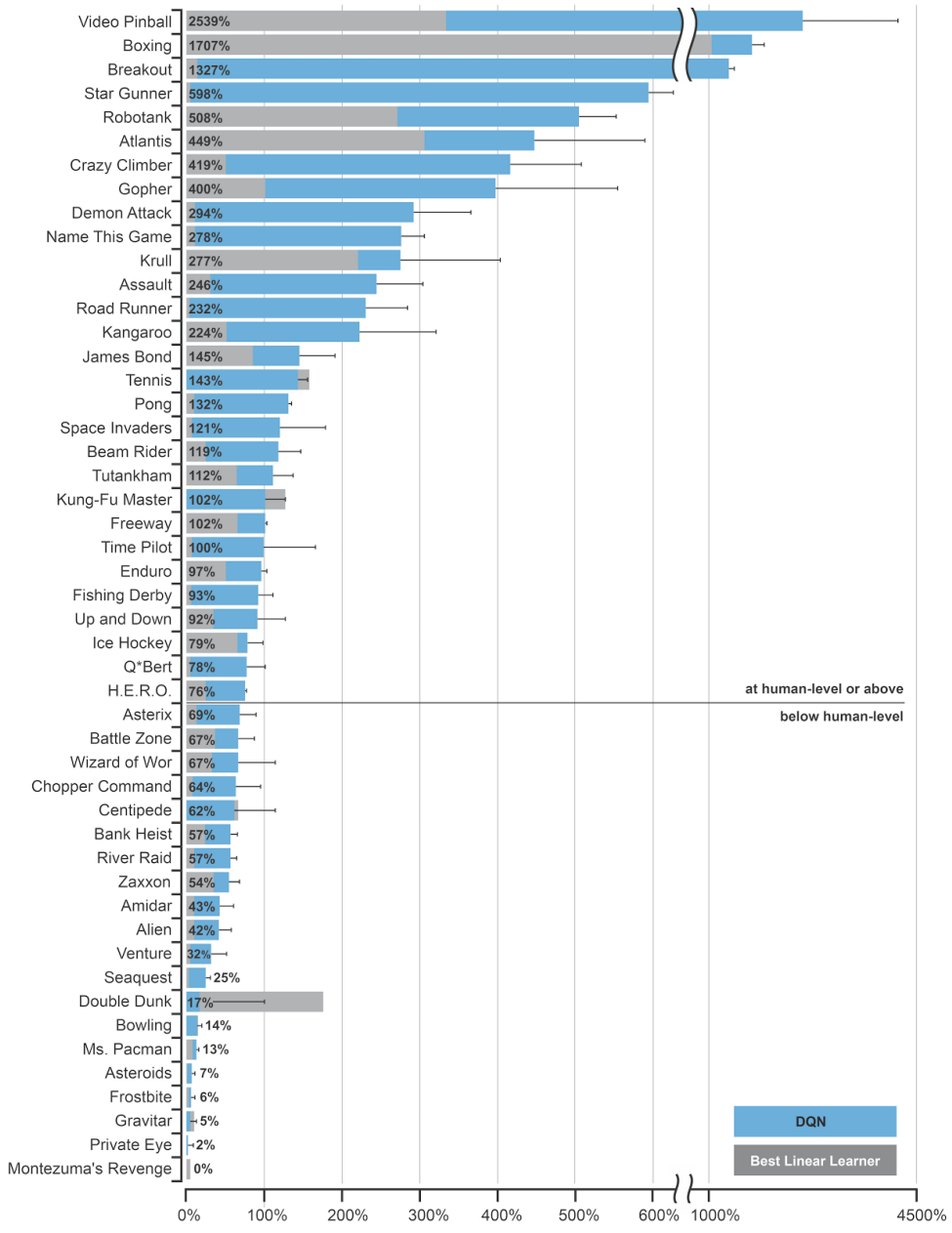
Introduction
Unreasonable Effectiveness of DL
Theory
How DL Works
Building Deep
Machine Vision
TensorFlow
TensorFlow Intro
DL with TensorFlow
Advanced
NLP
GANs
Deep RL
AI Revolution

Outline

1 Introduction
Unreasonable Effectiveness of Deep Learning
2 Theory
How Deep Learning Works
Building & Training a Deep Network
Machine Vision
3 TensorFlow
TensorFlow Intro
Deep Learning with TensorFlow
4 Advanced Topics
Natural Language Processing
Generative Adversarial Networks
10: Deep Reinforcement Learning
5 The AI Revolution

Deep Q-Learning

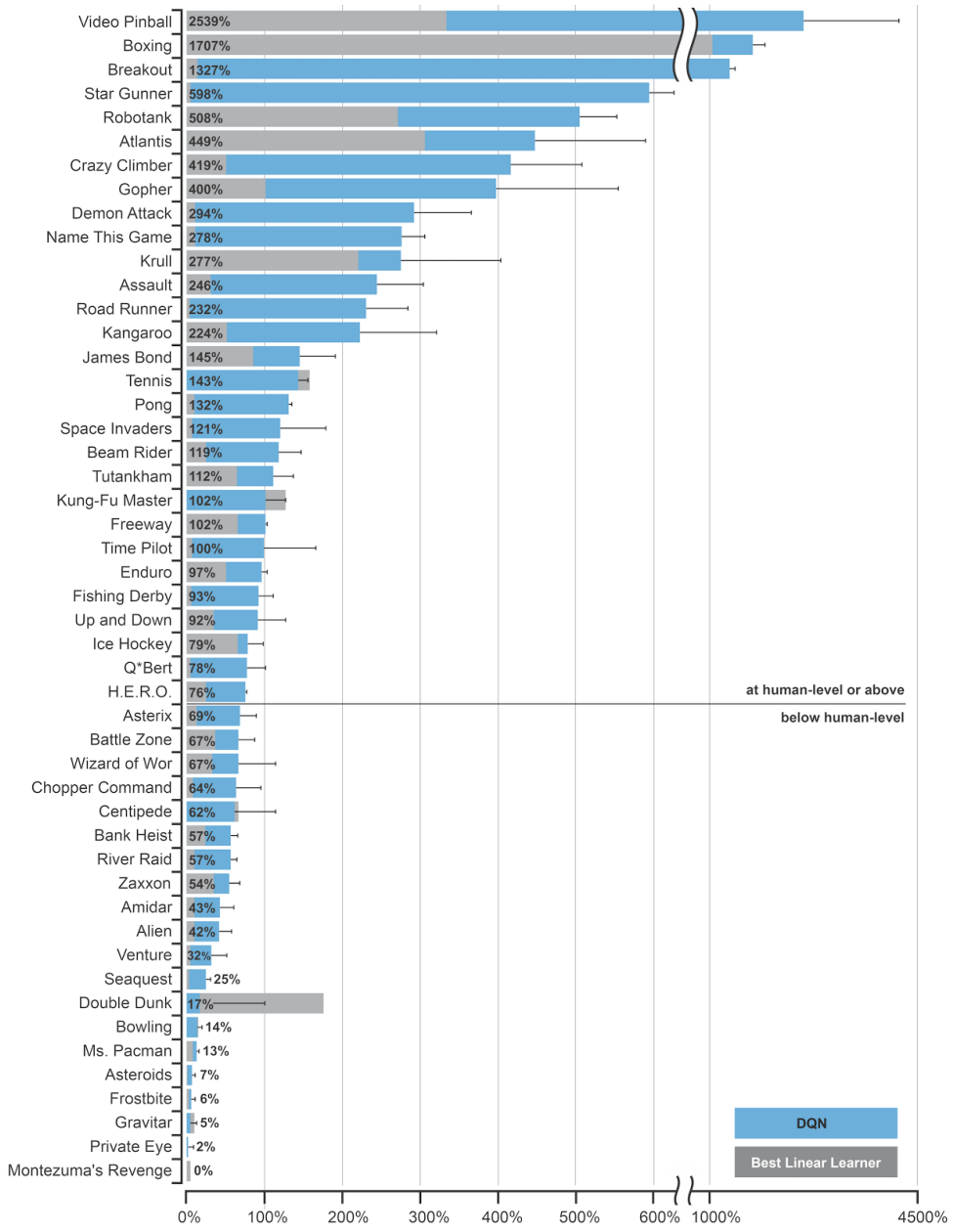
Mnih et al. (2015)



[Atari Games]

Deep Q-Learning

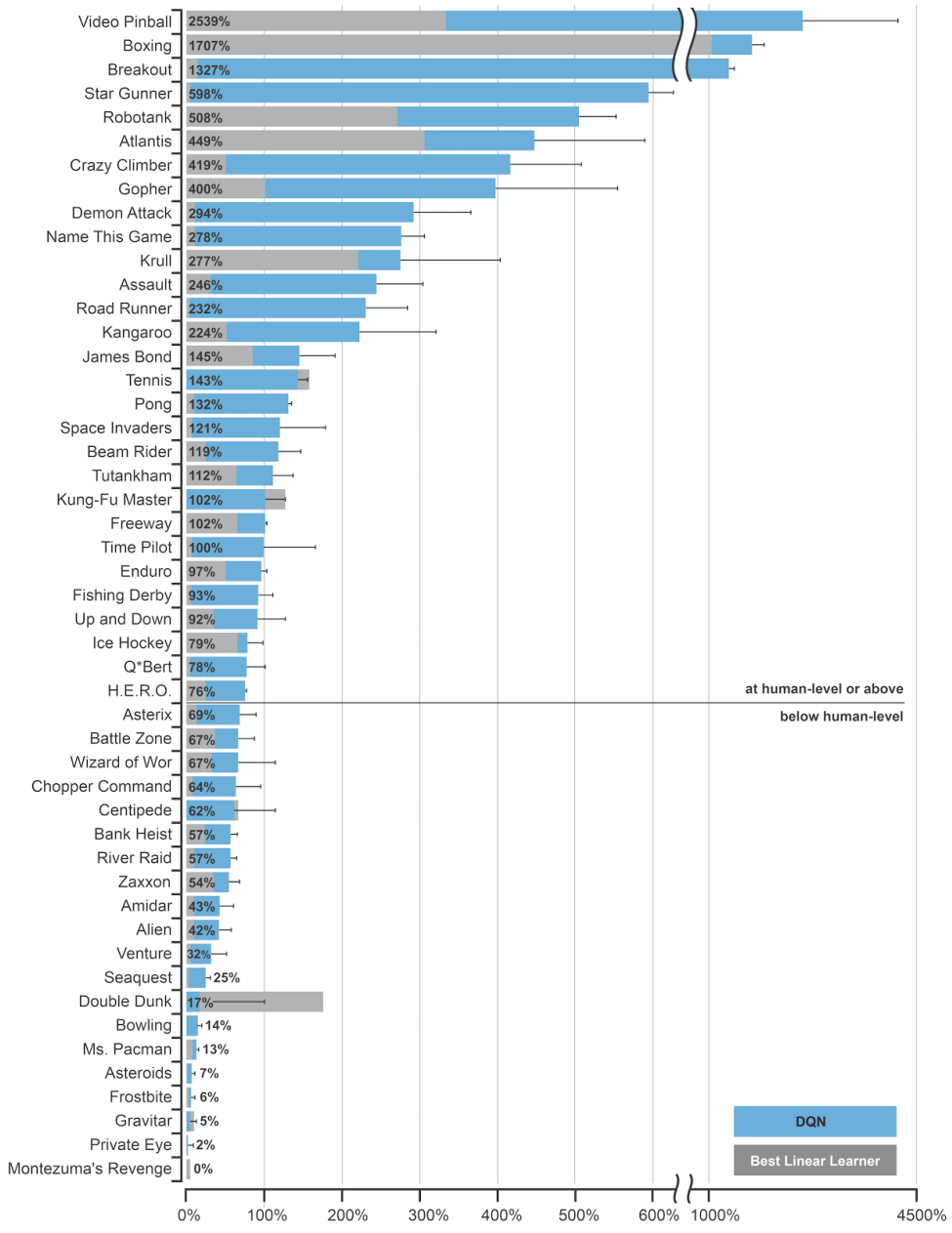
Mnih et al. (2015)



[Atari Games]

Deep Q-Learning

Mnih et al. (2015)



[Atari Games]

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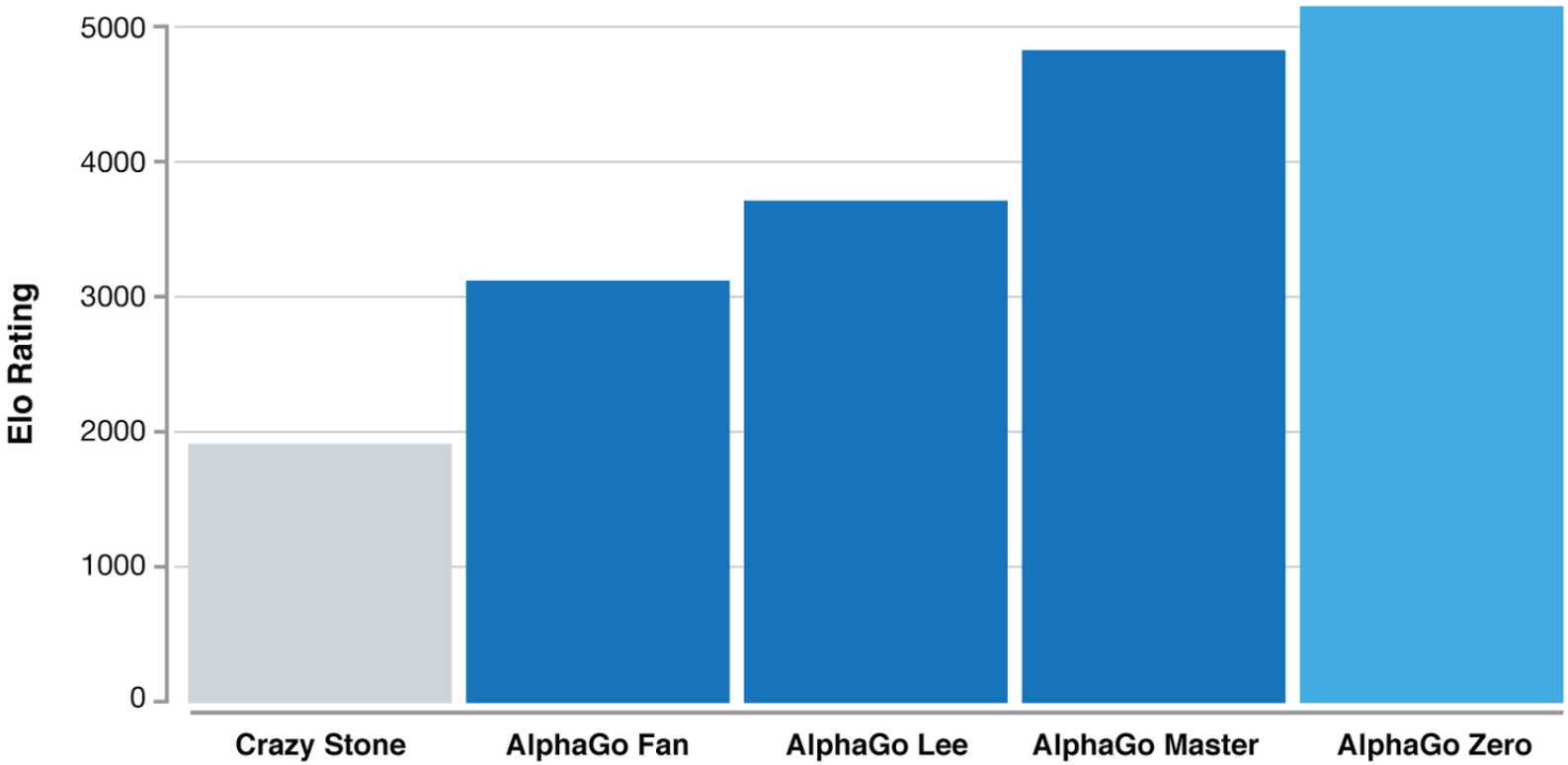
AlphaGo

Silver et al. (2016)

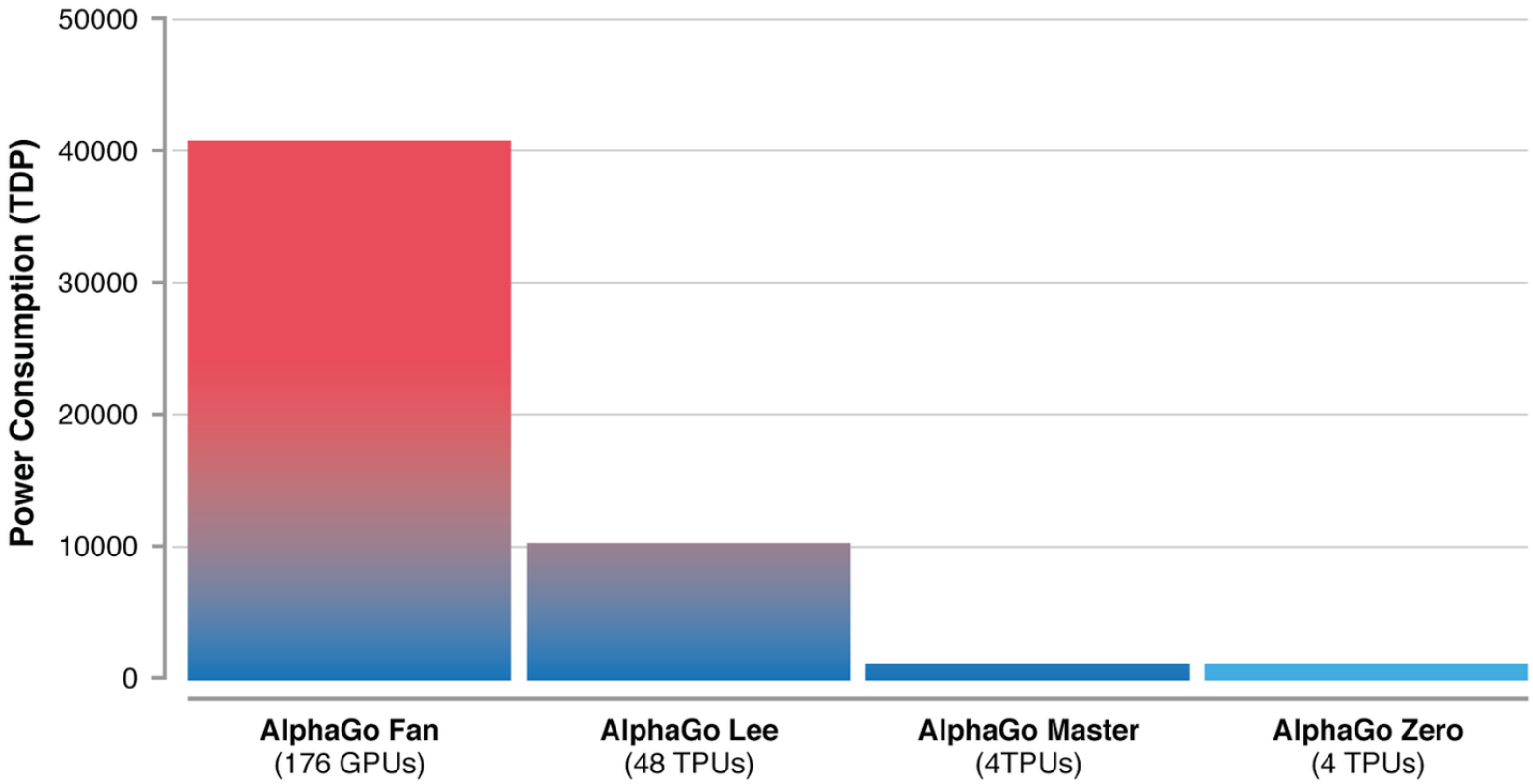
AlphaGo Zero

Silver et al. (2017)



AlphaGo Zero

Silver et al. (2017)

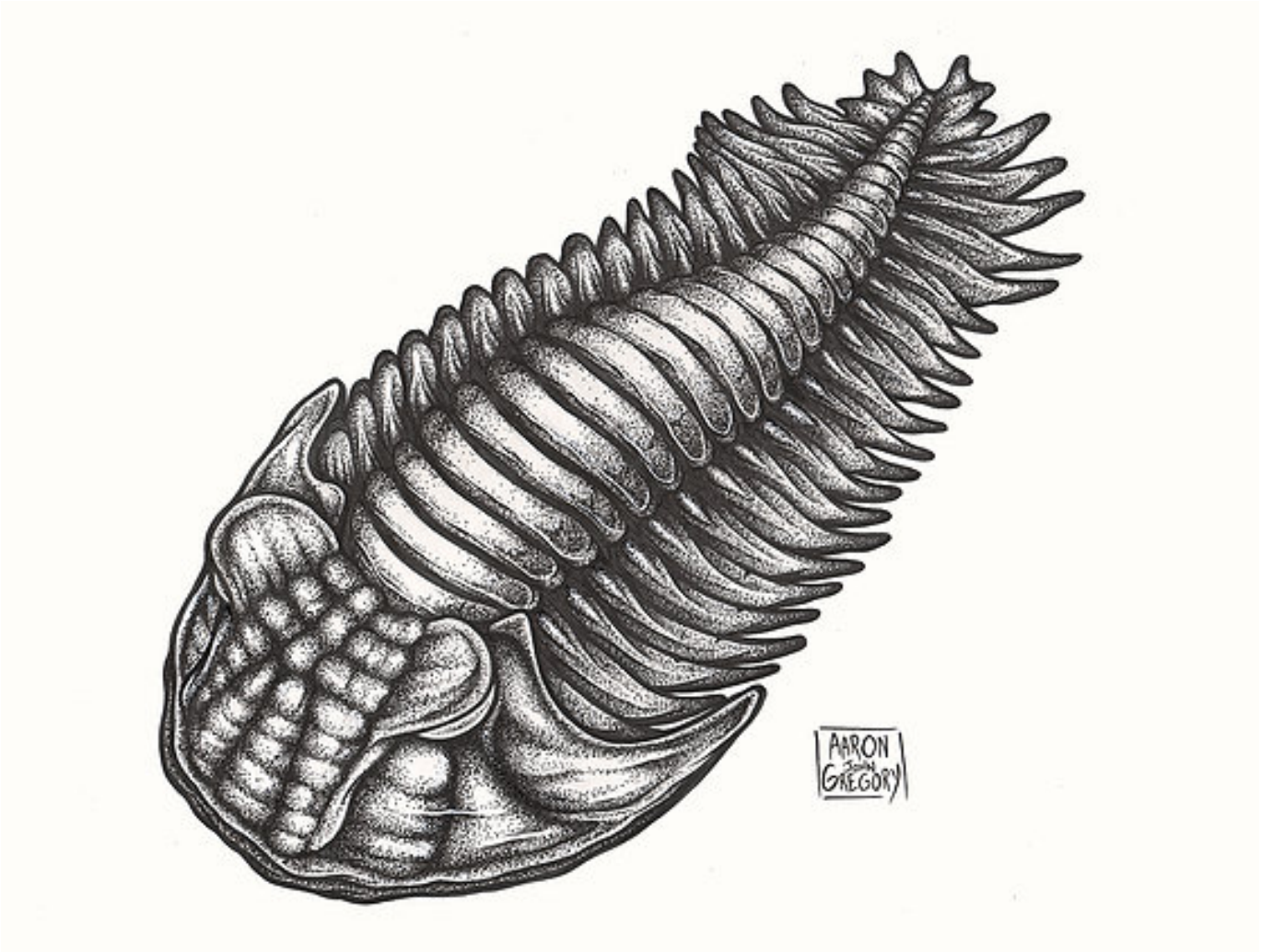


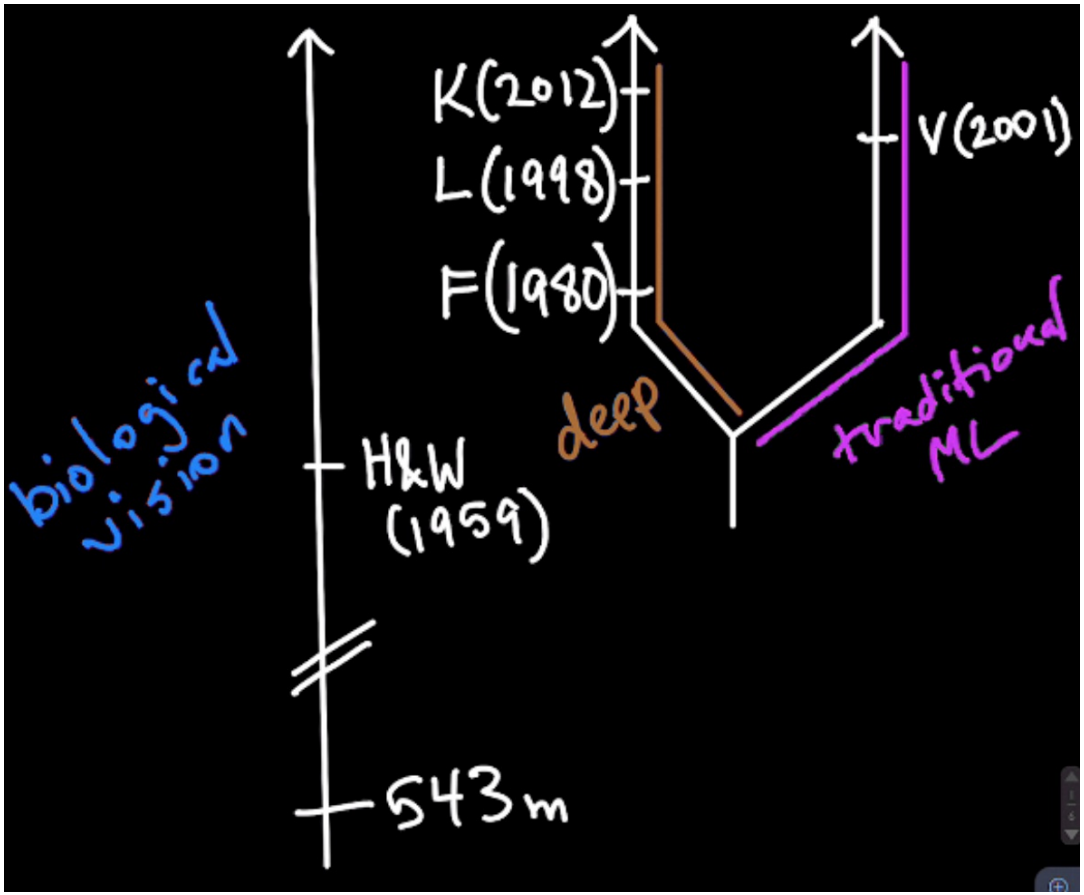
[OpenAI Universe]

[Google DeepMind Lab]

The AI Revolution

Hasn't Even Begun


AARON
GREGORY


K(2012)
L(1998)
F(1980)
V(2001)
biological vision
H&W (1959)
deep
traditional ML
543m

1. data doubling every 18 months
2. processing power cost halving every two years
3. cheap sensors appearing everywhere
4. Deep Learning techniques refined in academia and in industry

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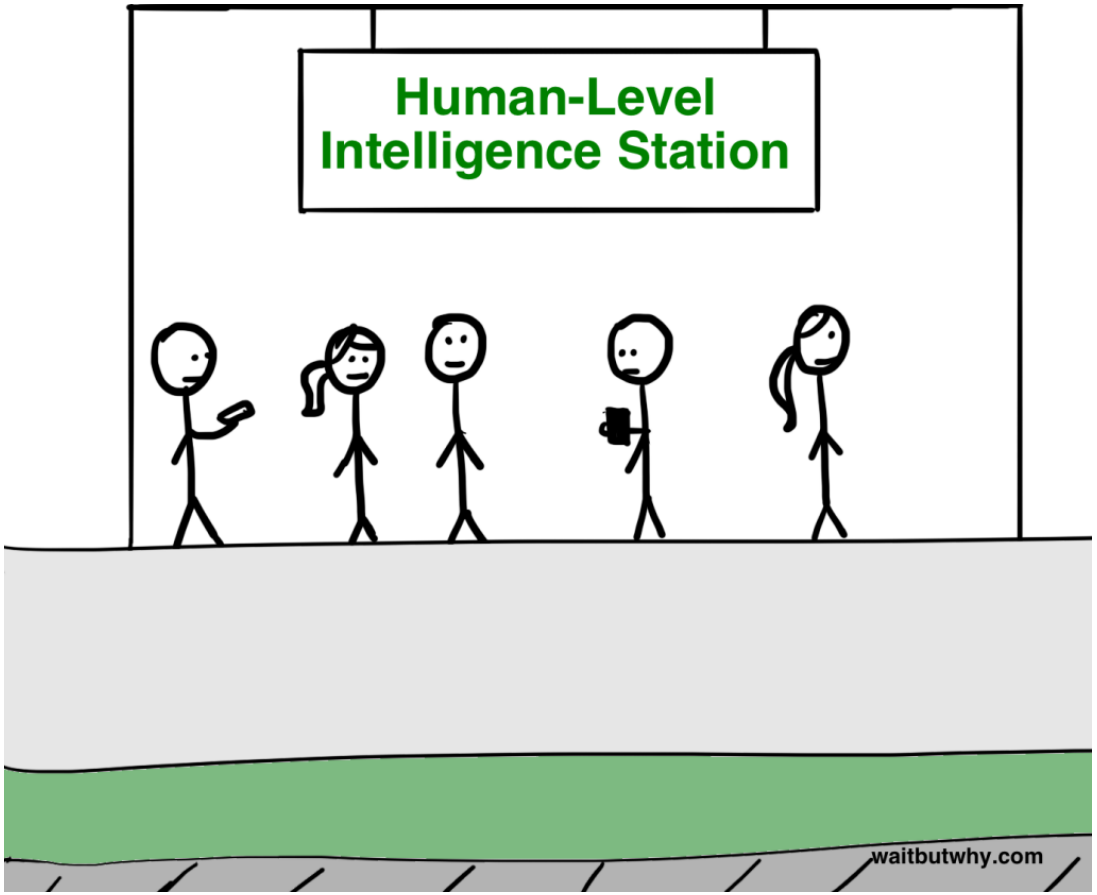
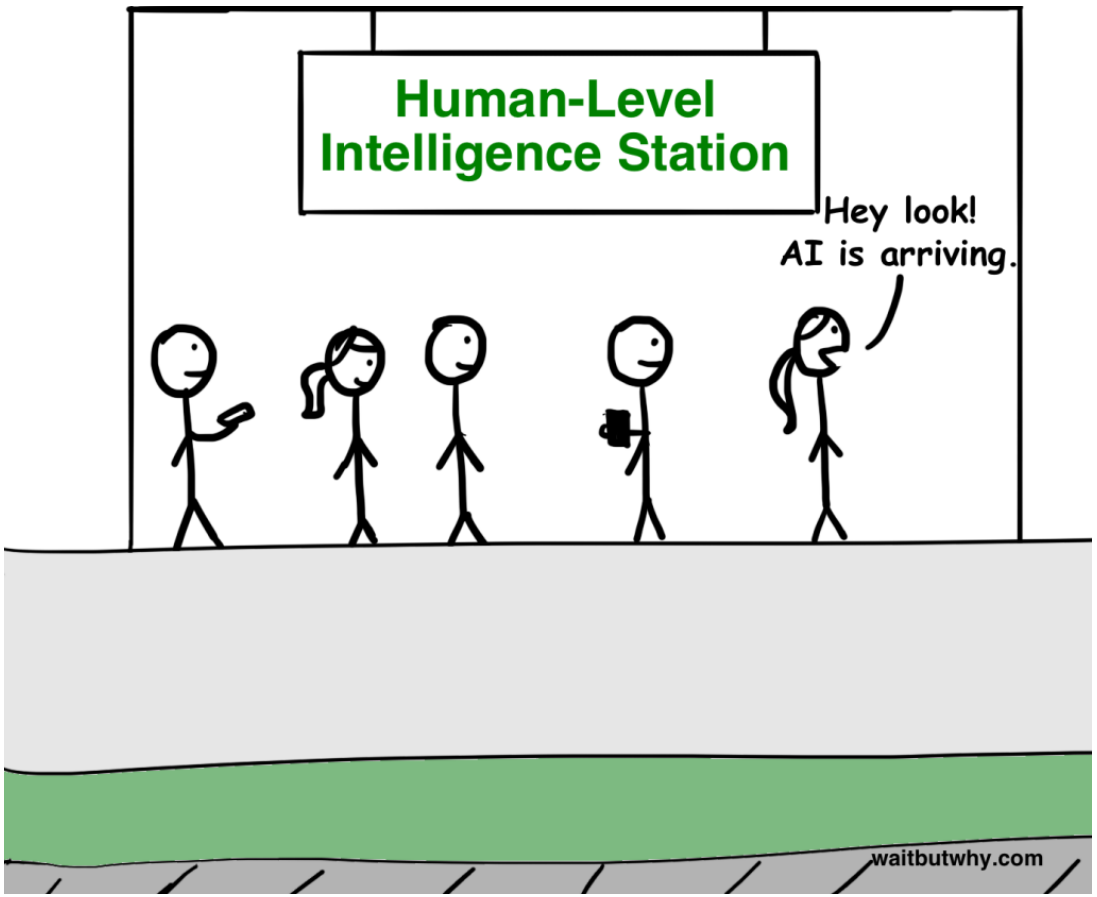
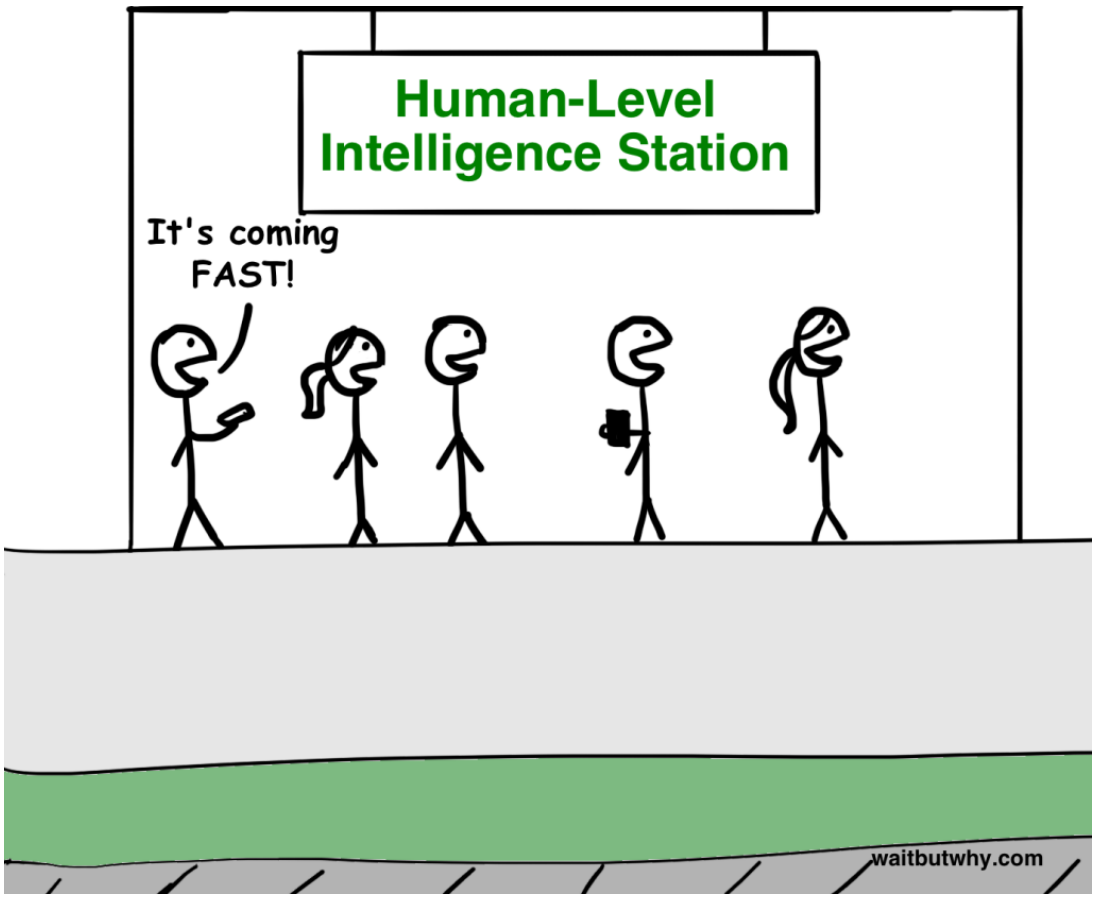
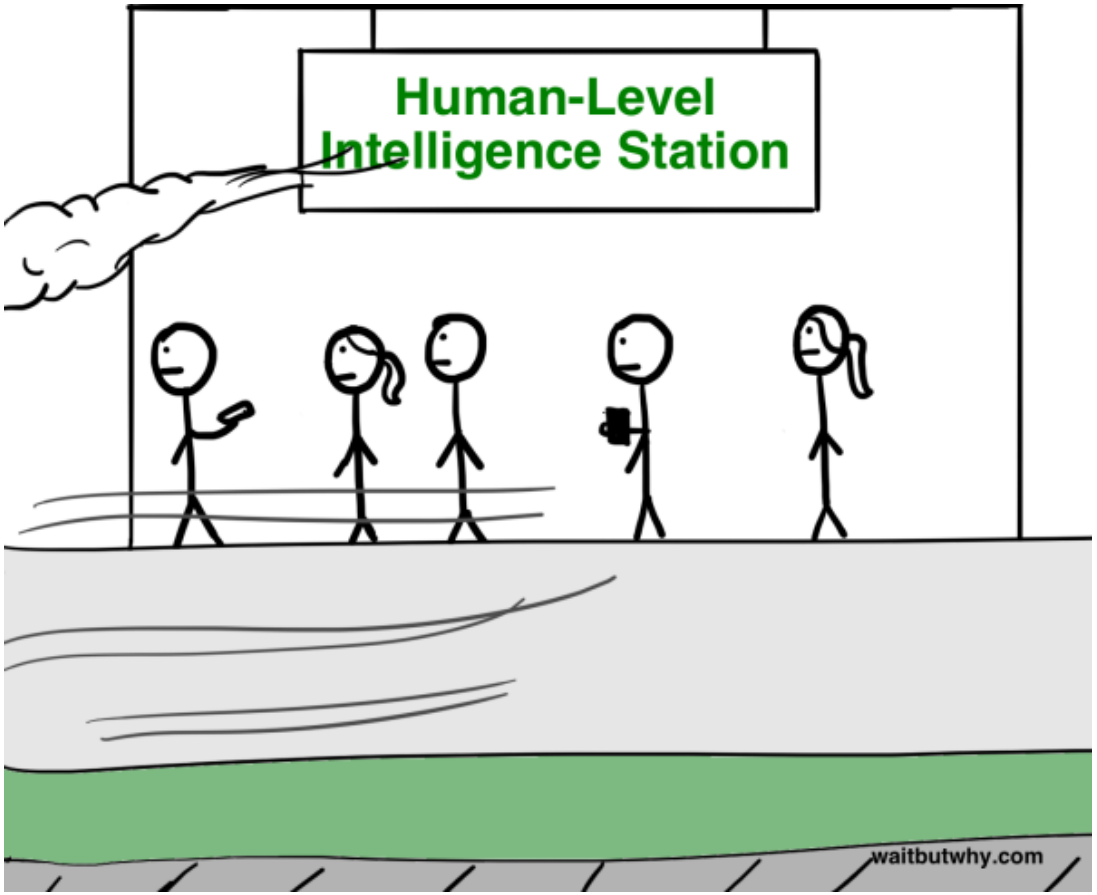
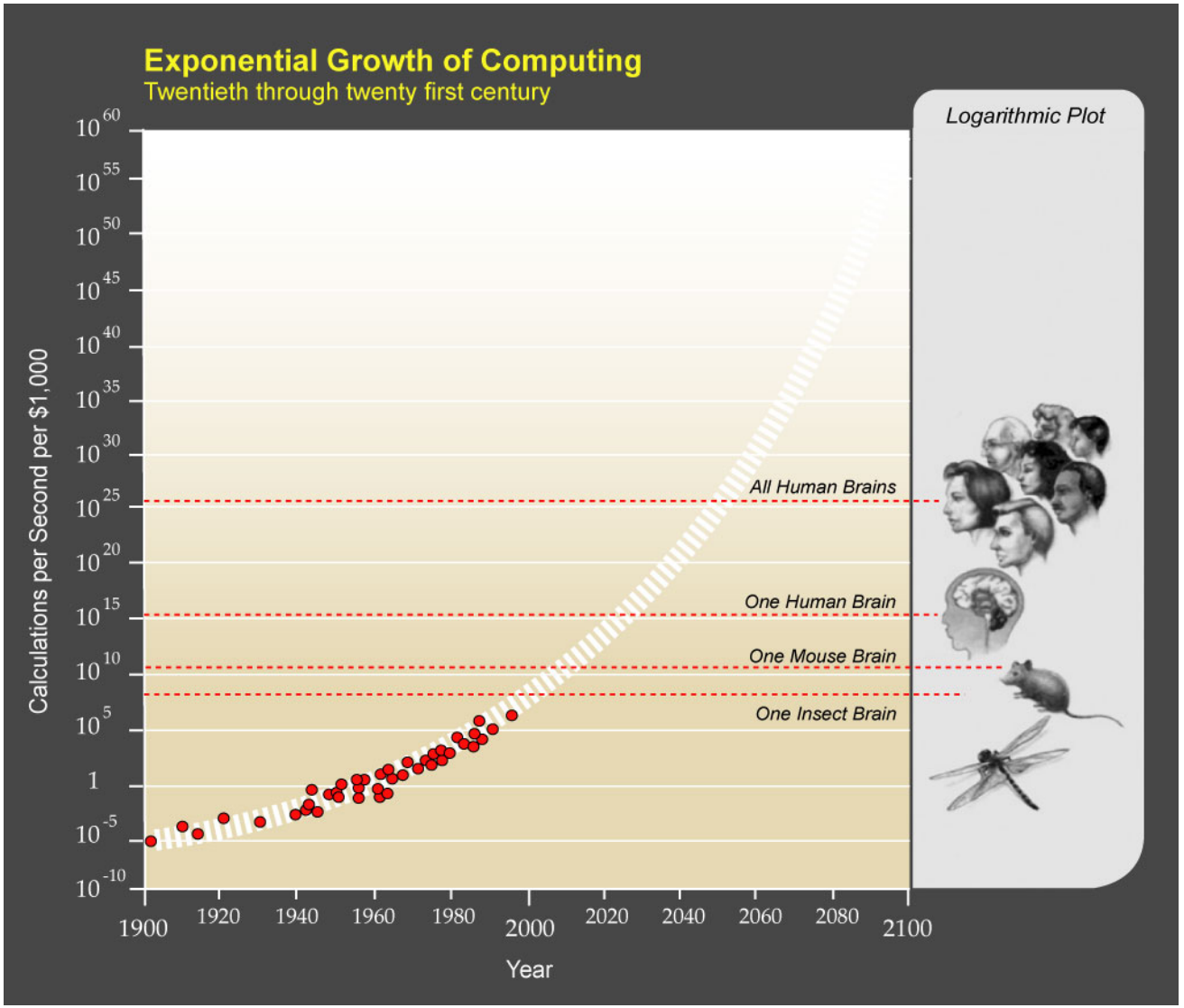
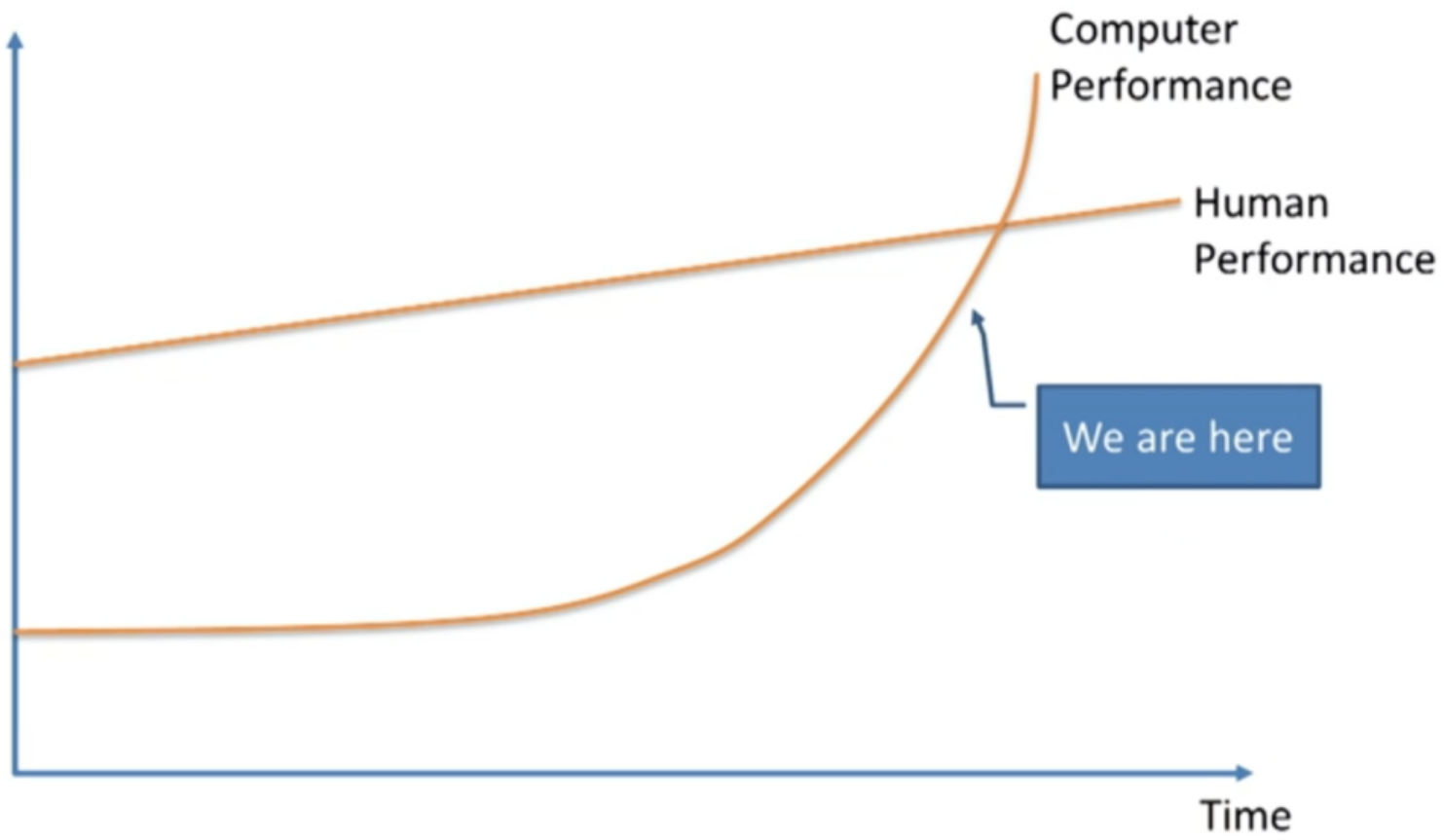

Human-Level
Intelligence Station
waitbutwhy.com

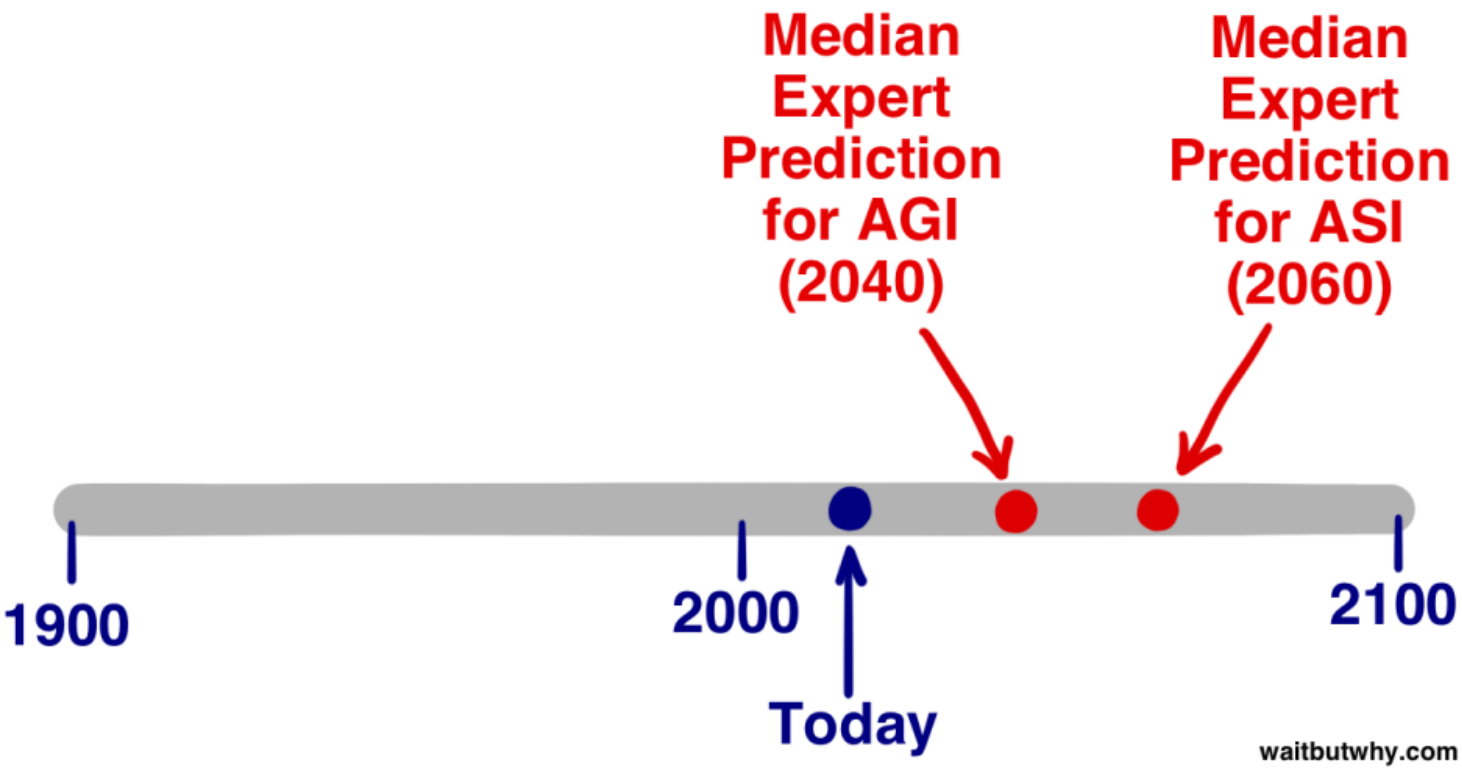

Human-Level Intelligence Station
Hey look!
AI is arriving.
waitbutwhy.com

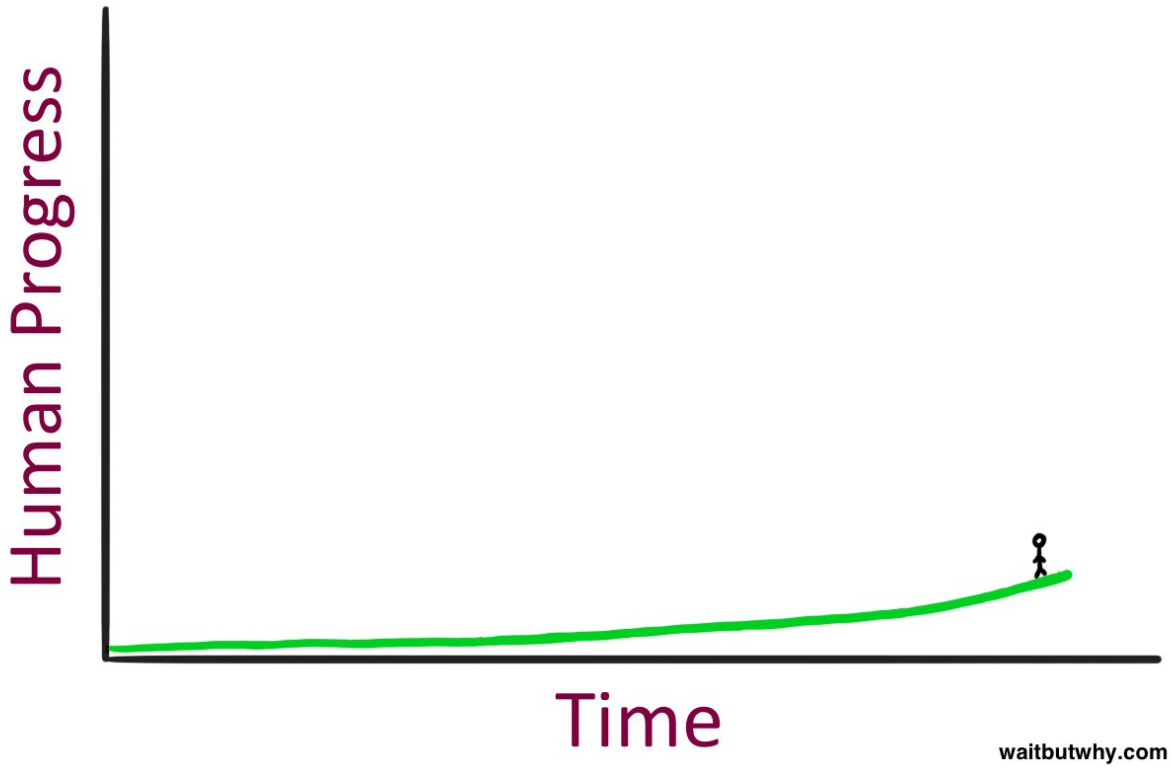

Human-Level Intelligence Station
It's coming FAST!
waitbutwhy.com

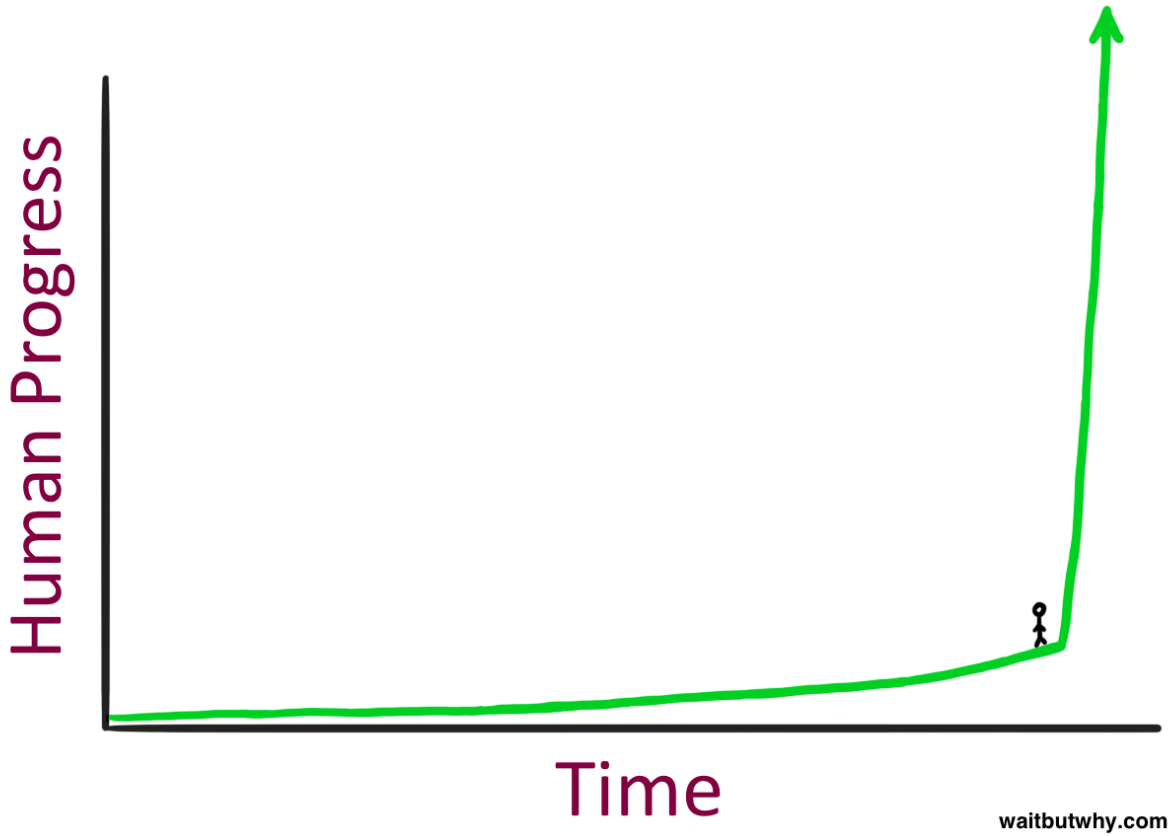

Human-Level
Intelligence Station
waitbutwhy.com


Exponential Growth of Computing
Twentieth through twenty first century
Logarithmic Plot
Calculations per Second per $1,000
10^{60}
10^{55}
10^{50}
10^{45}
10^{40}
10^{35}
10^{30}
10^{25}
10^{20}
10^{15}
10^{10}
10^{5}
1
10^{-5}
10^{-10}
All Human Brains
One Human Brain
One Mouse Brain
One Insect Brain
1900
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100
Year


Computer Performance
Human Performance
We are here
Time


Median Expert Prediction for AGI (2040)
Median Expert Prediction for ASI (2060)
1900
2000
Today
2100
waitbutwhy.com


Human Progress
Time
waitbutwhy.com


Human Progress
Time
waitbutwhy.com