



# *Deep Reinforcement Learning Live Training*

Superhuman Performance on  
Complex Problems with  
Deep Learning

# The Pomodoro Technique

-- Francesco Cirillo, 1980s

Today's Training Structure:

1. three **pomodoros** (25 minutes + 5 minute break)
2. bonus five-minute break
3. three further **pomodoros**

Questions typically handled at break end

# POLL

Where are you?

- The Americas
- Europe / Middle East / Africa
- Asia-Pacific
- Extra-Terrestrial Space

# POLL

What are you?

- Developer / Engineer
- Scientist / Analyst / Statistician / Mathematician
- Combination of the Above
- Other

untapt

# Deep Reinforcement Learning

1. The Foundations of Artificial Intelligence
2. Deep Q-Learning Networks
3. Advanced Deep Reinforcement Learning Agents

# Deep Reinforcement Learning

1.

## **The Foundations of Artificial Intelligence**

- The Contemporary State of A.I.
- Applications of Deep Reinforcement Learning
- Review of Prerequisite Deep Learning Theory

2.

## Deep Q-Learning Networks

3.

## Advanced Deep Reinforcement Learning Agents

# Dig Deeper (“reference RL LiveLessons”)

The screenshot shows a video player interface. On the left, there is a portrait of a man with a beard and short hair, wearing a dark blue button-down shirt. He is smiling and looking towards the camera. To his right, the title "Deep Reinforcement Learning and GANs LiveLessons" is displayed in white text. Below the title, there is a bullet point followed by a URL: "• [github.com/the-deep-learners/TensorFlow-LiveLessons](https://github.com/the-deep-learners/TensorFlow-LiveLessons)". At the bottom left of the video frame, the Pearson logo is visible, consisting of a blue circle with a white question mark icon and the word "Pearson". At the bottom right, the "livelessons" logo is shown with the text "©2018 Pearson, Inc." underneath.

Search “*Deep Reinforcement Learning and GANs*” or “*Jon Krohn*” in Safari

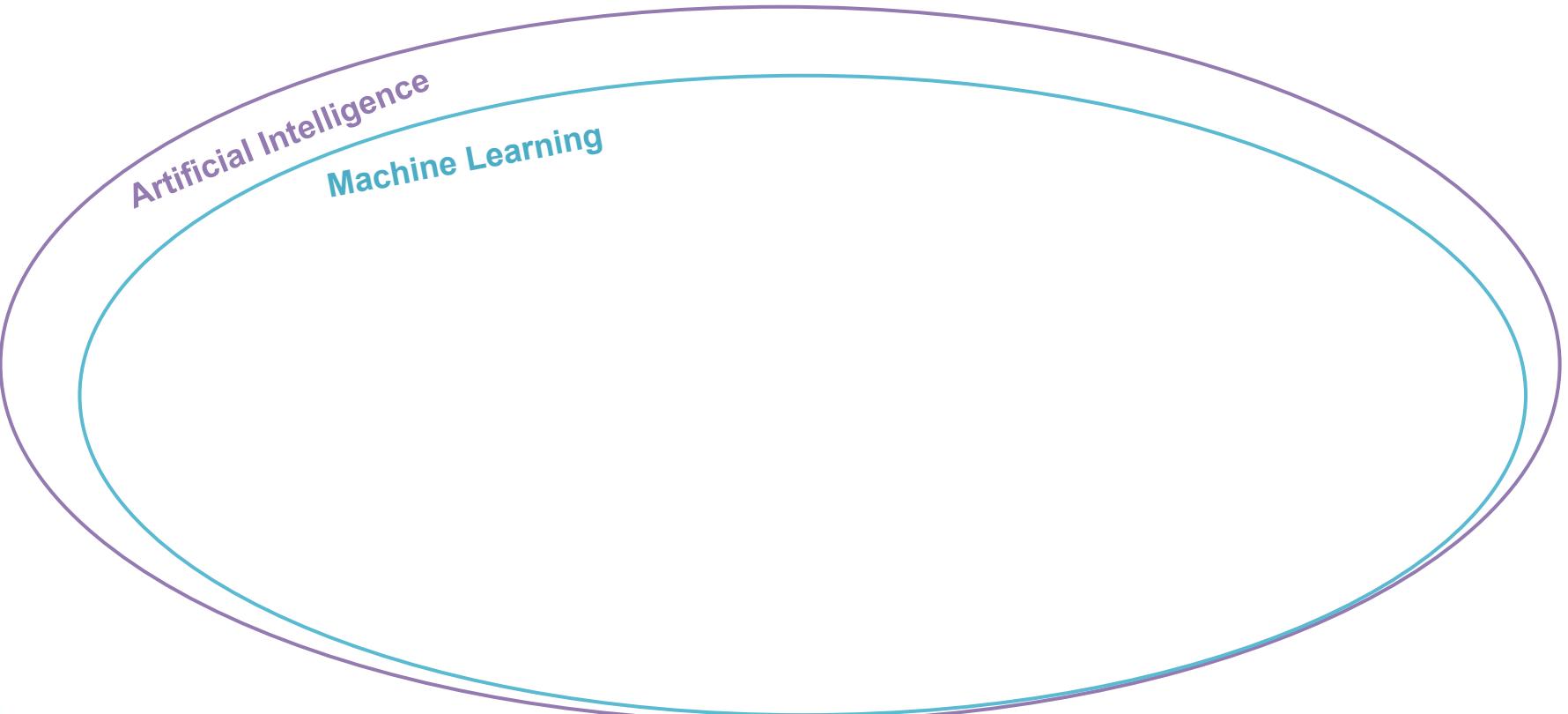
# Deep Learning for NLP

1. **The Foundations of Artificial Intelligence**
  - **The Contemporary State of A.I.** (*reference RL LiveLessons section 1.1*)
  - Applications of Deep Reinforcement Learning
  - Review of Prerequisite Deep Learning Theory
2. Deep Q-Learning Networks
3. Advanced Deep Reinforcement Learning Agents

# The Contemporary State of A.I.

Artificial Intelligence

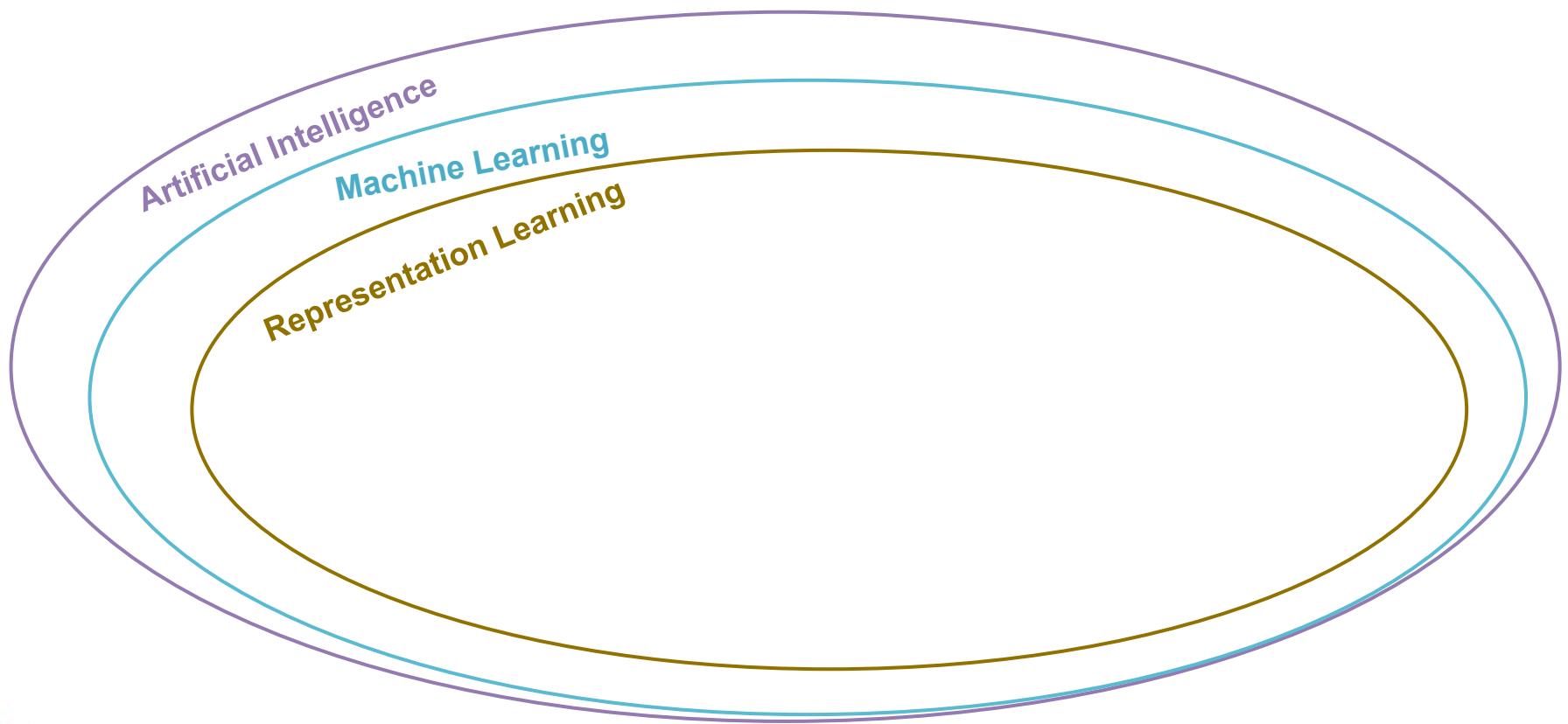
# The Contemporary State of A.I.



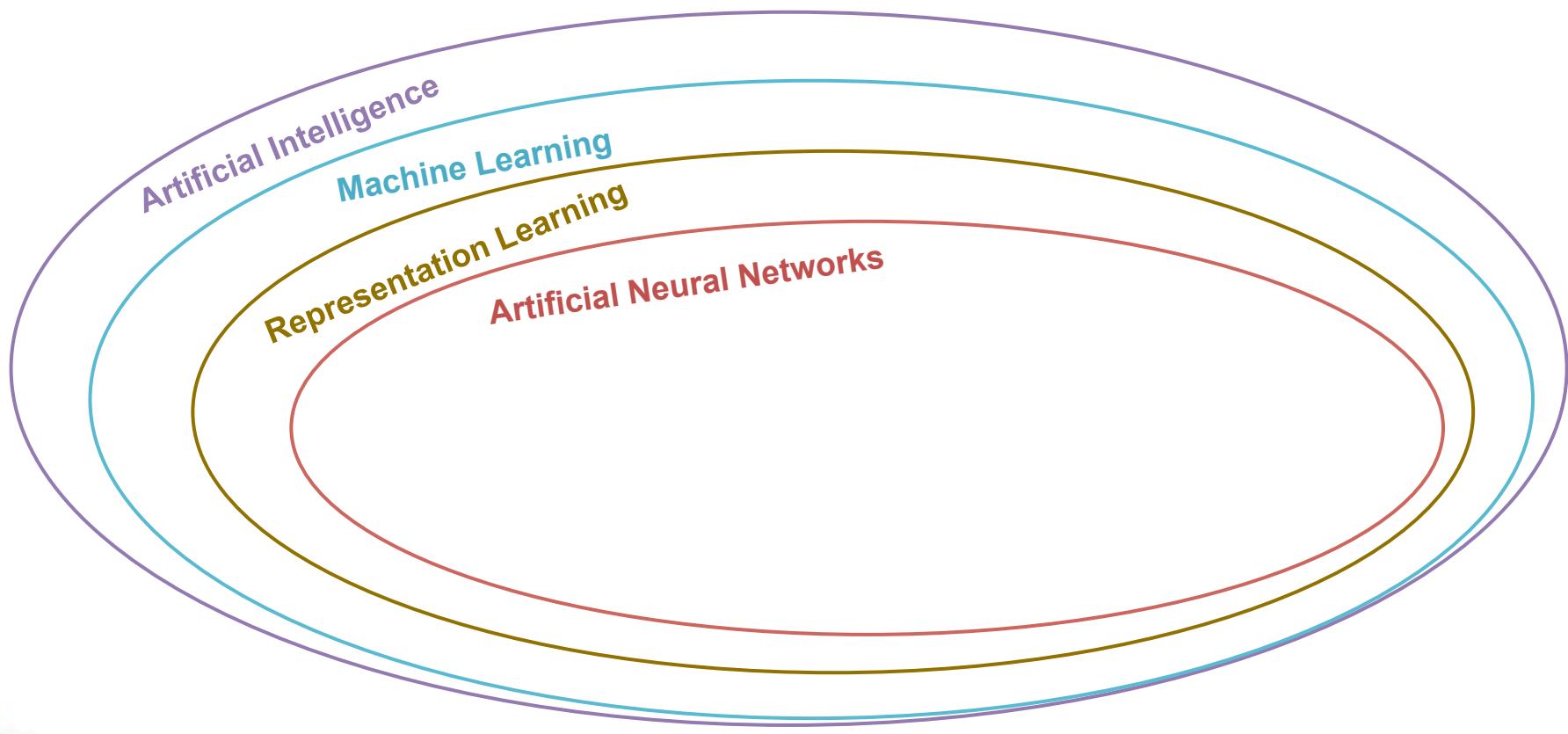
Artificial Intelligence

Machine Learning

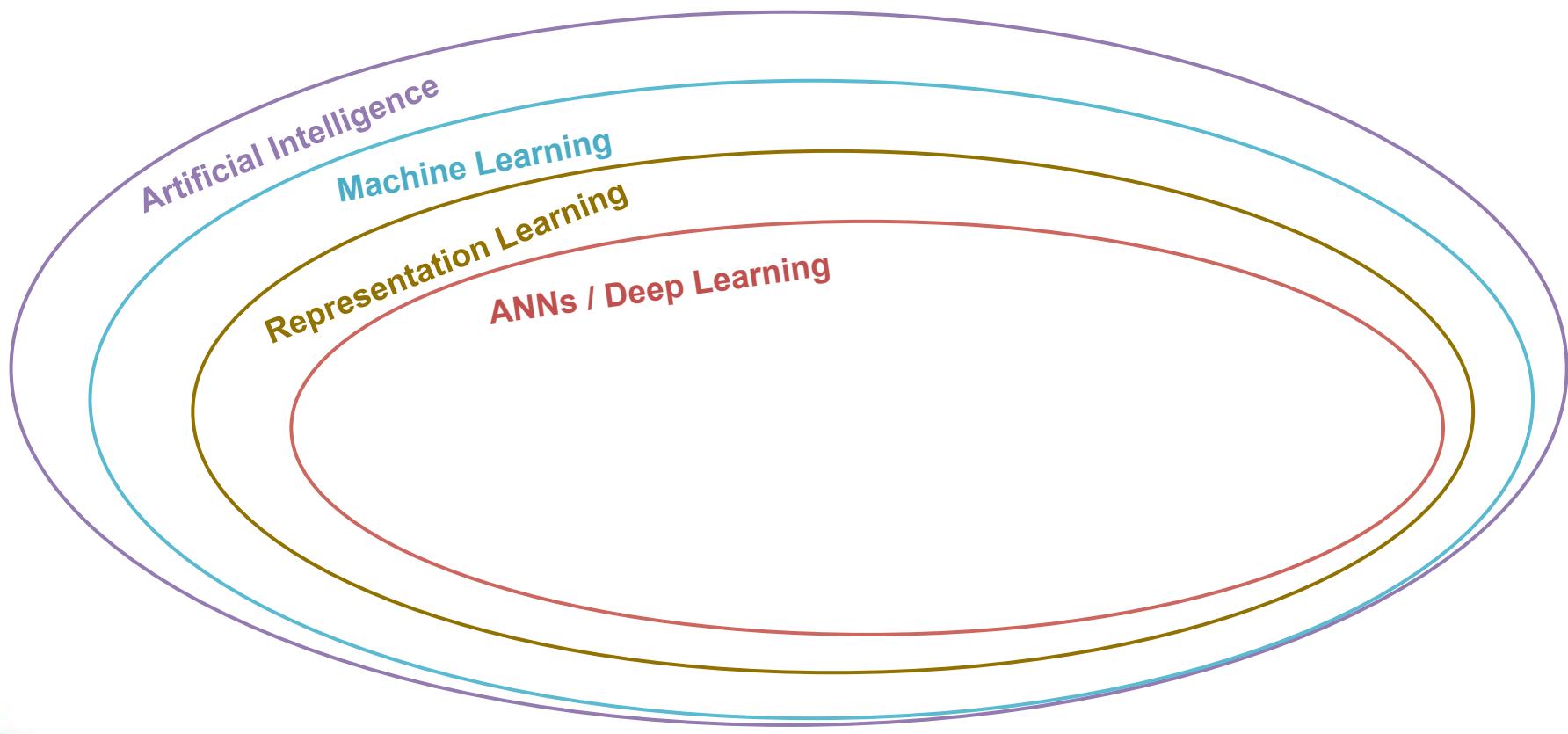
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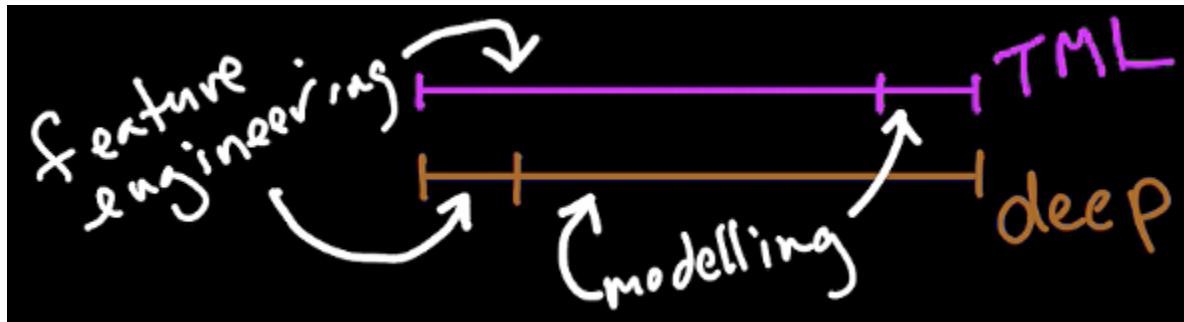
# The Contemporary State of A.I.



# The Contemporary State of A.I.



# Traditional ML vs Deep Learning



# Dense Networks



[unsplash.com/photos/ij5\\_qCBpIVY](https://unsplash.com/photos/ij5_qCBpIVY)

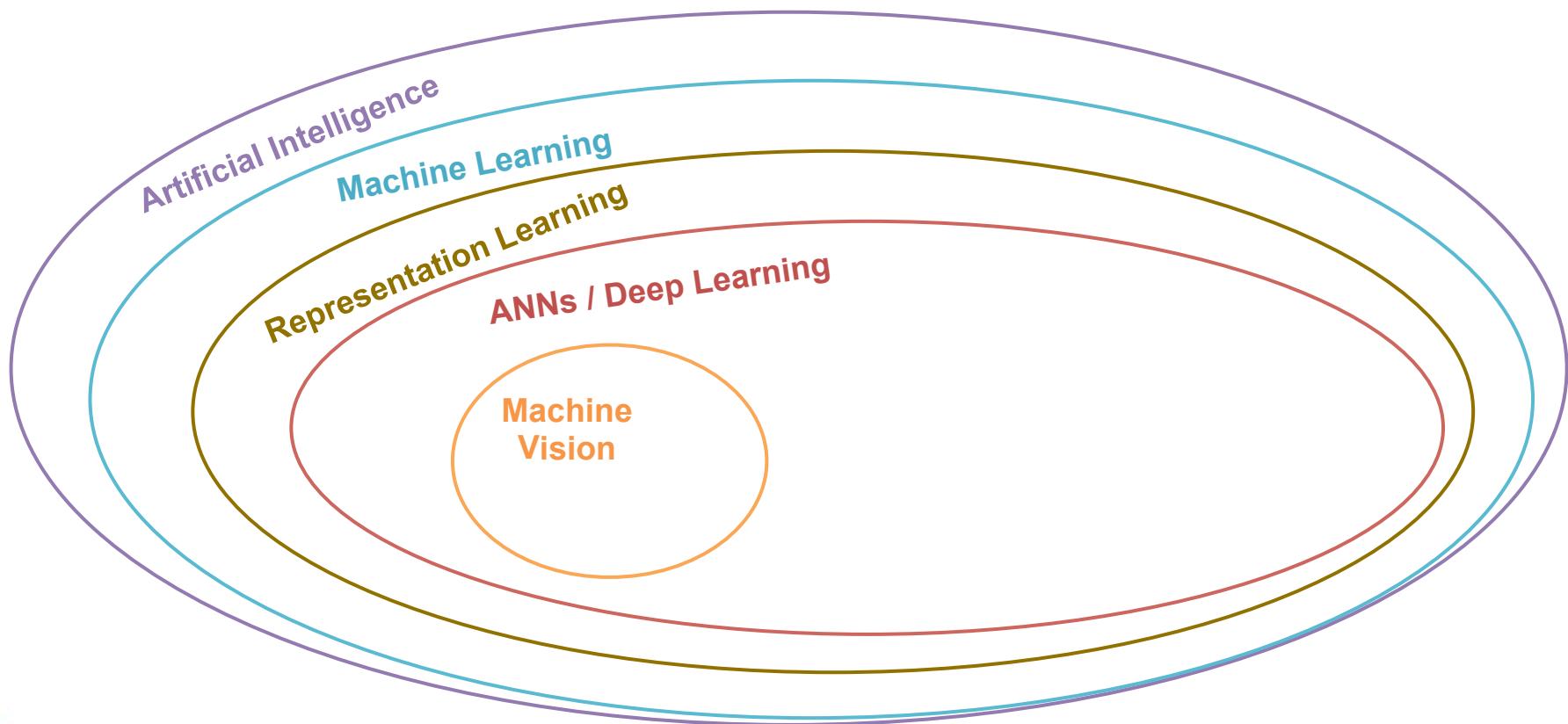


Deep Learning with TensorFlow:  
Applications of Deep Neural Networks  
to Machine Learning Tasks

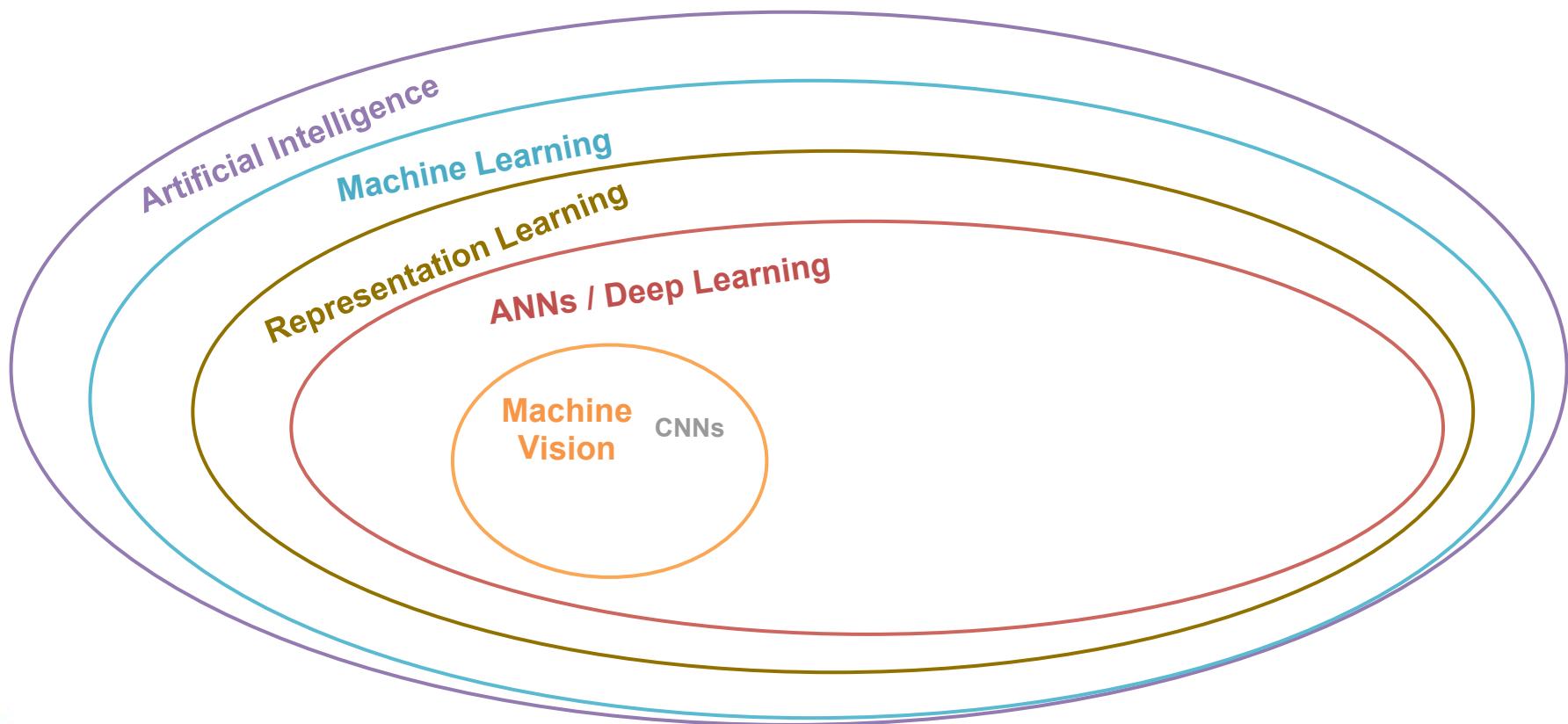
- [github.com/  
the-deep-learners/  
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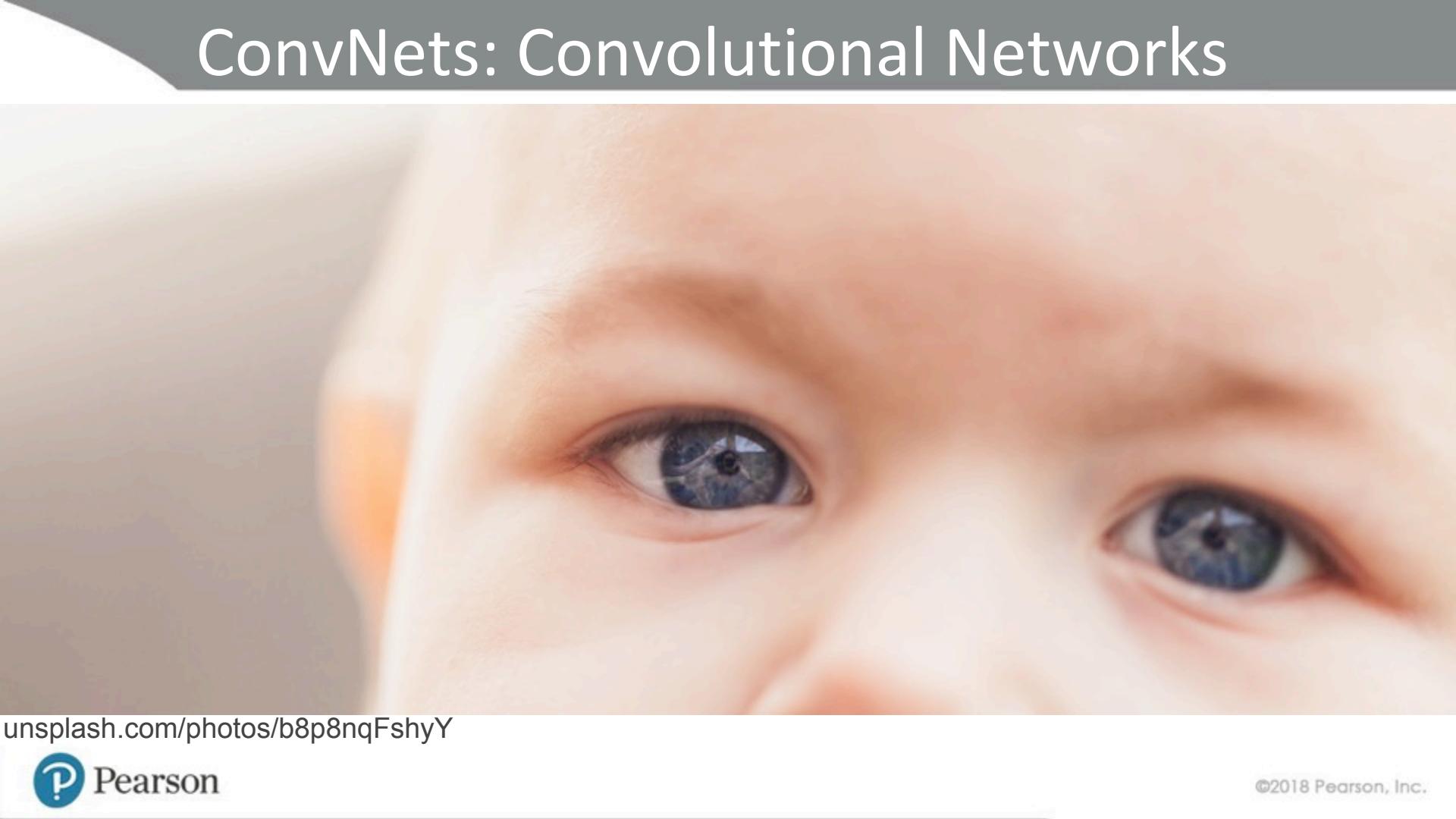
# The Contemporary State of A.I.



# The Contemporary State of A.I.



# ConvNets: Convolutional Networks

A close-up photograph of a young child's face, focusing on the eyes. The child has light-colored hair and blue eyes. The background is blurred, showing a soft, warm color palette.

[unsplash.com/photos/b8p8nqFshyY](https://unsplash.com/photos/b8p8nqFshyY)

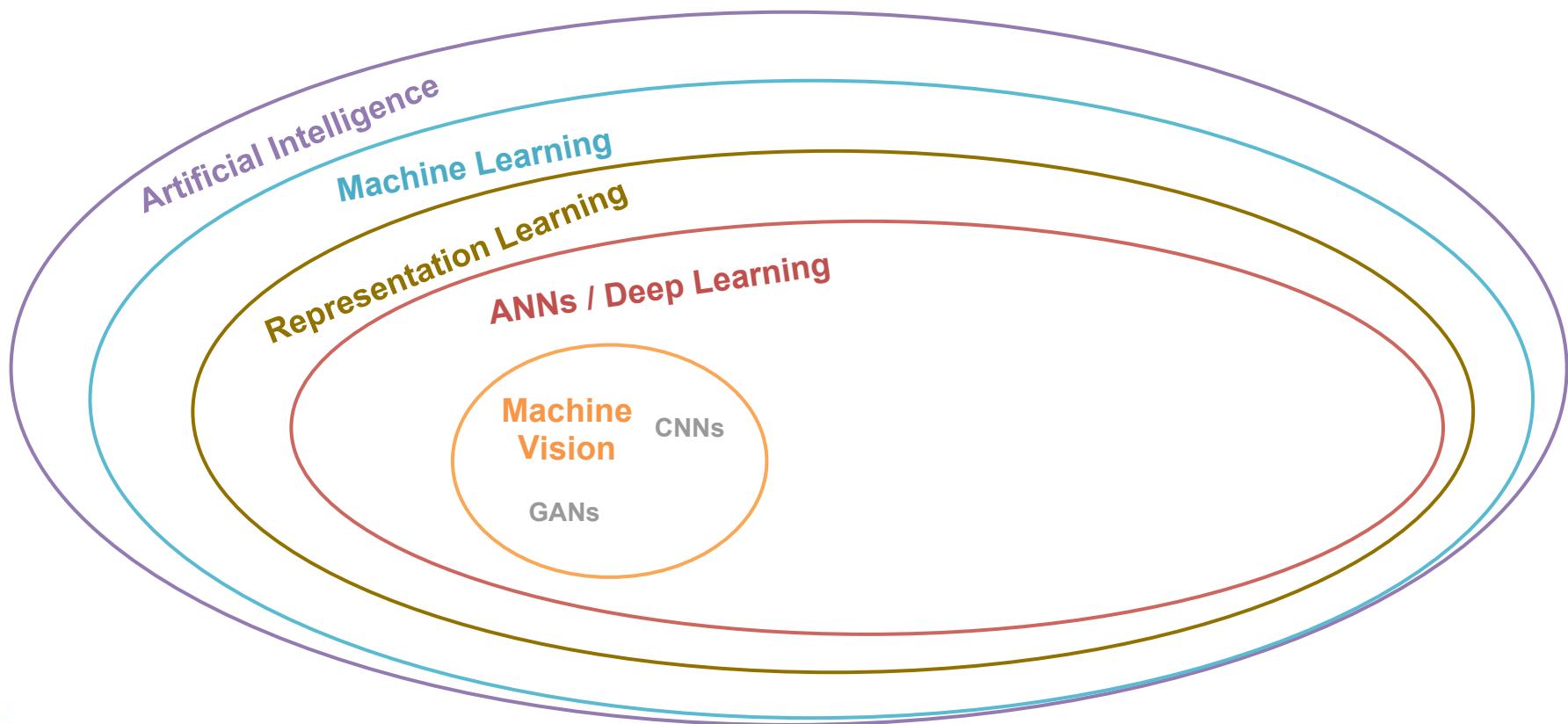


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# The Contemporary State of A.I.



# GANs: Generative Adversarial Networks



[unsplash.com/photos/FwF\\_fKj5tBo](https://unsplash.com/photos/FwF_fKj5tBo)

## Deep Reinforcement Learning and GANs LiveLessons

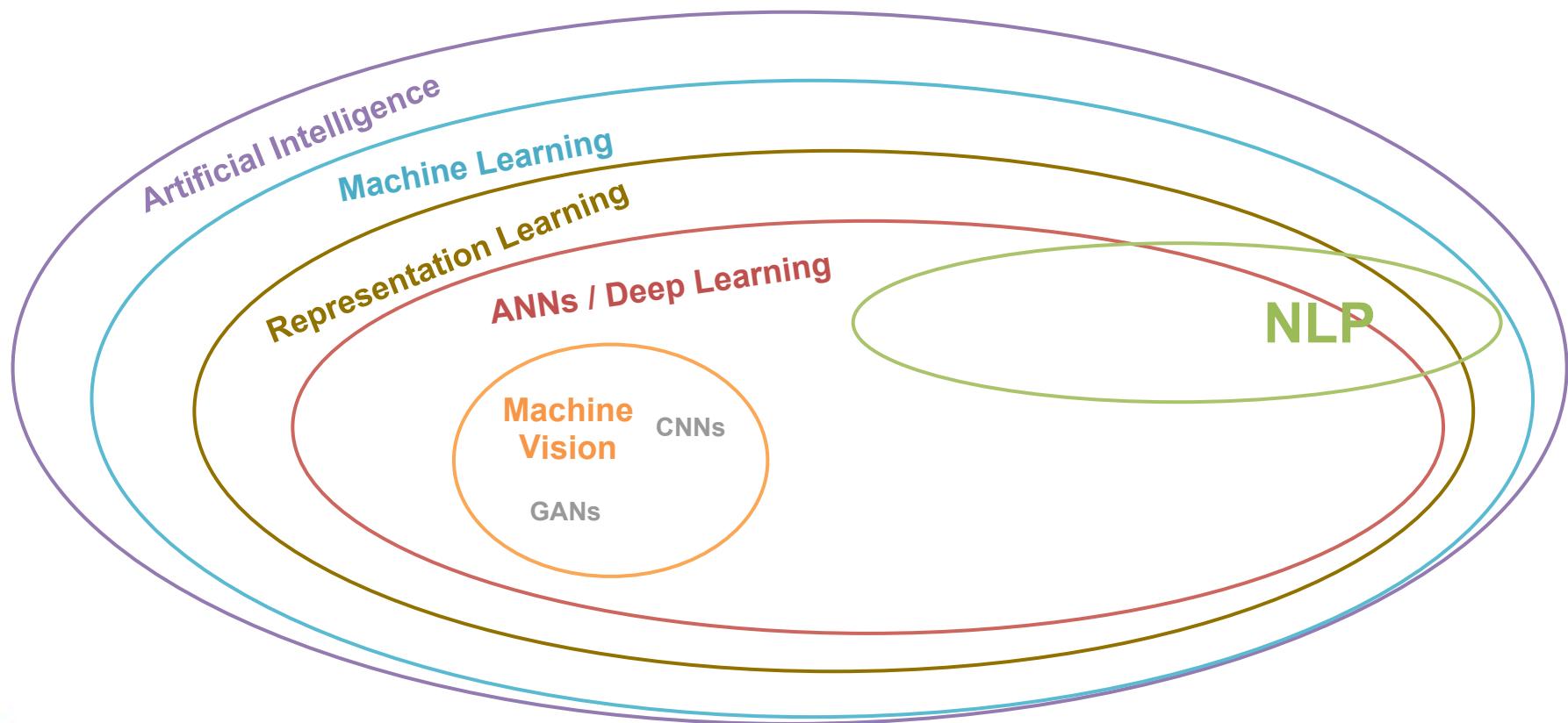
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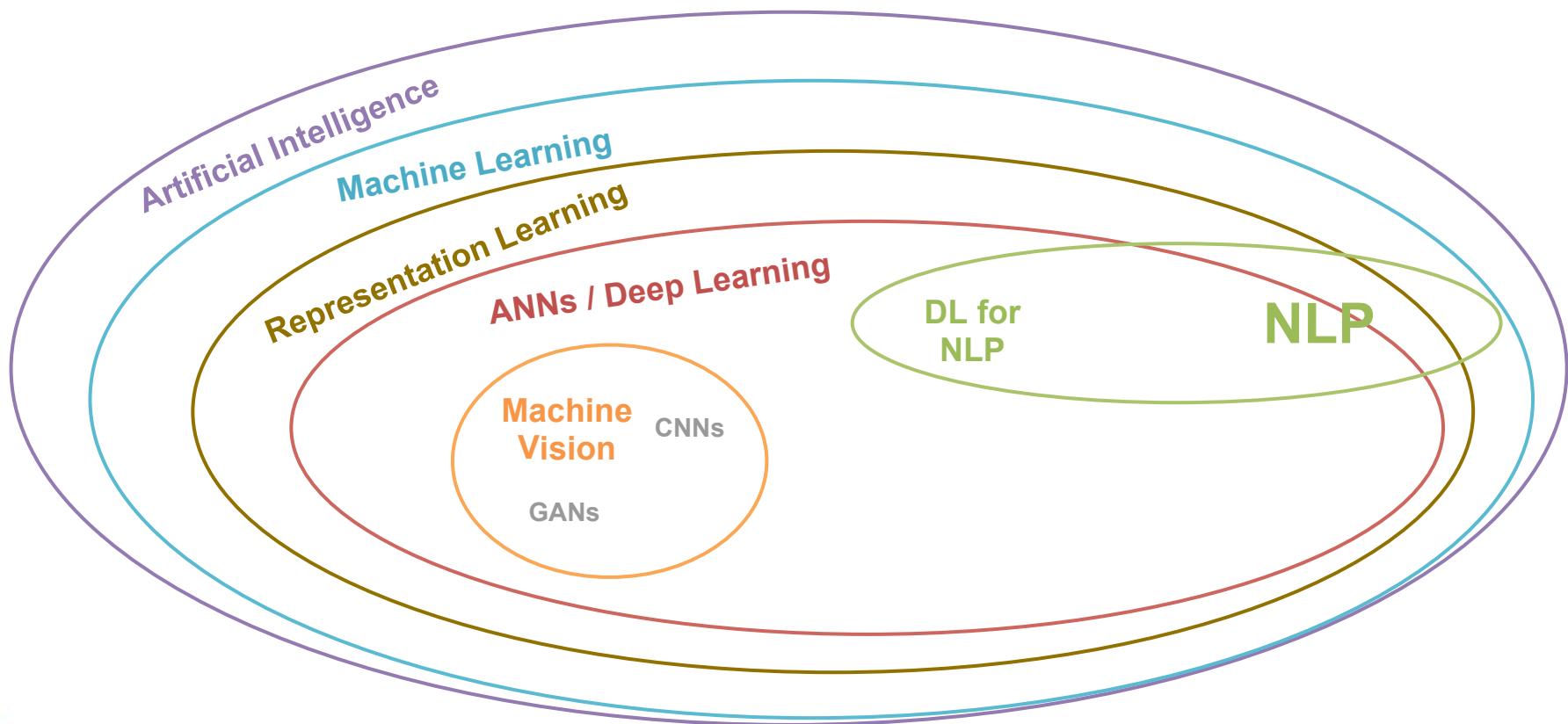
Pearson

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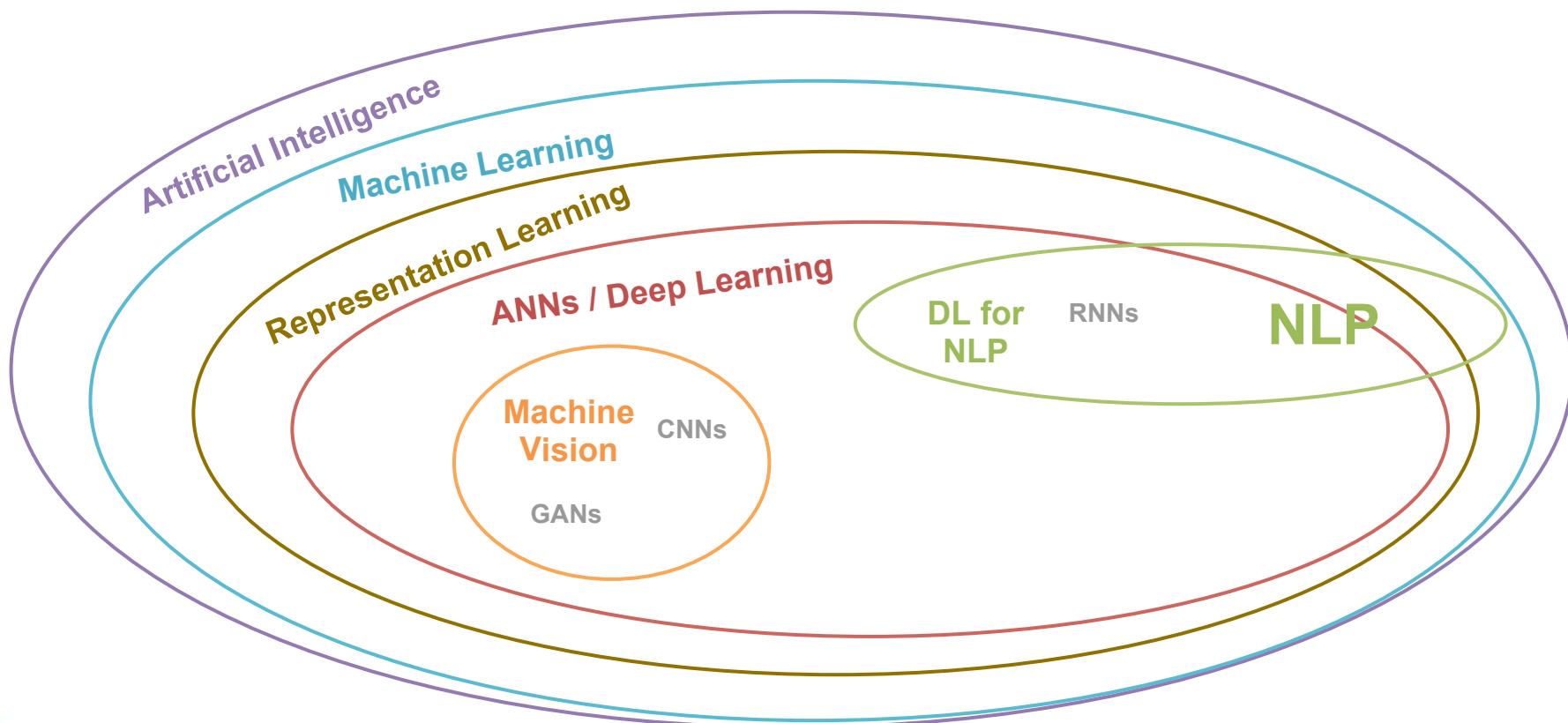
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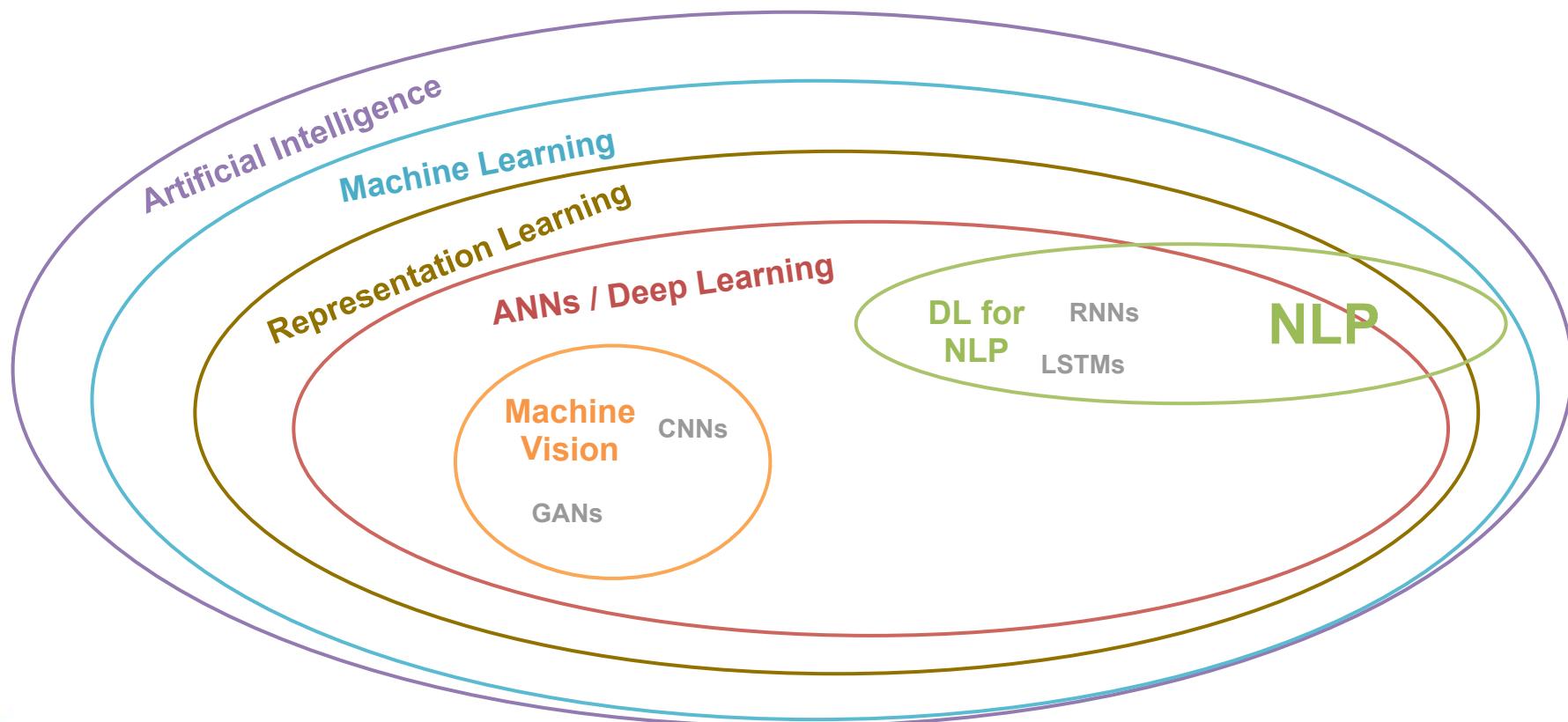
# The Contemporary State of A.I.



# The Contemporary State of A.I.



# The Contemporary State of A.I.



# RNNs: Recurrent Neural Networks



[unsplash.com/photos/cZhUxIQjILg](https://unsplash.com/photos/cZhUxIQjILg)

**livelessons**®  
video instruction from technology experts

## Deep Learning for Natural Language Processing



**Dr. Jon Krohn**  
Chief Data Scientist, untapt

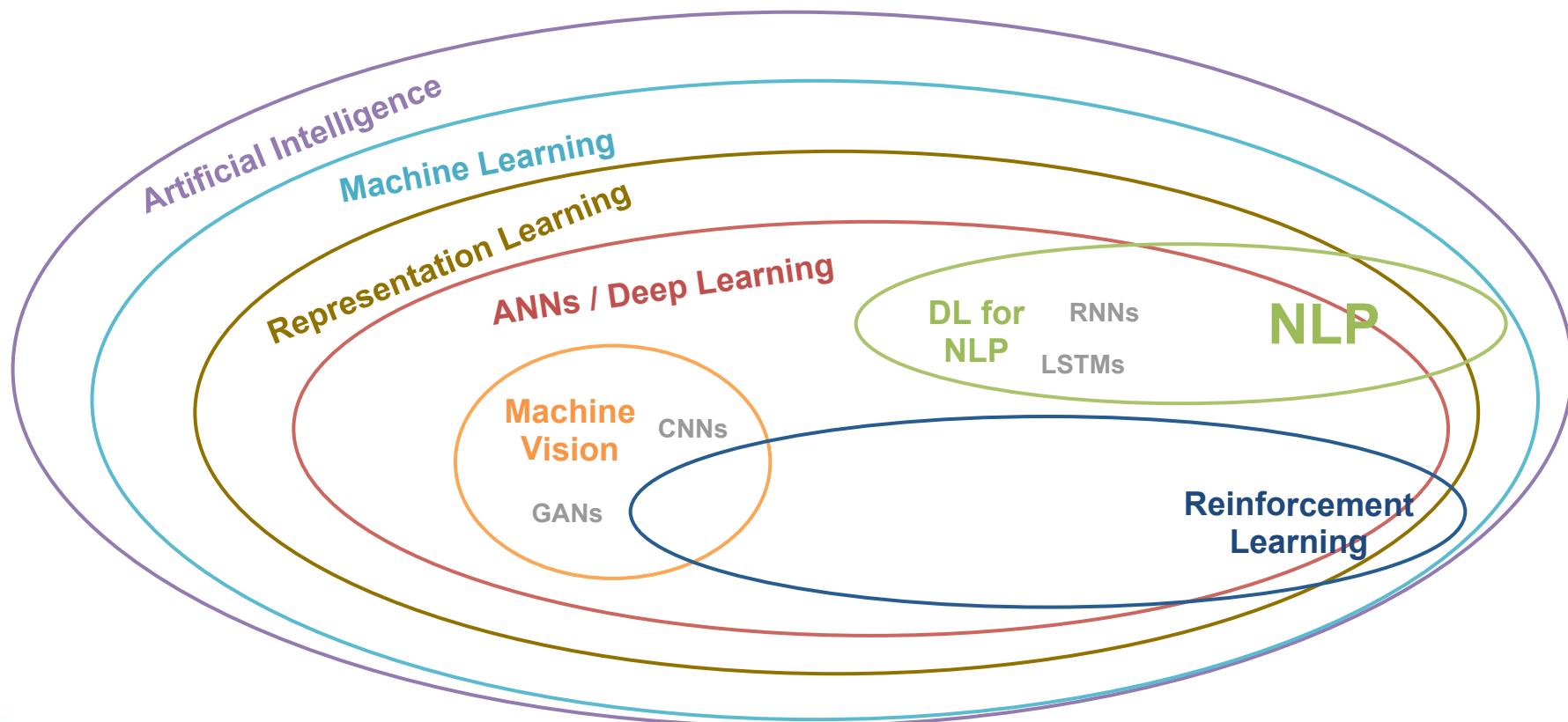


Pearson

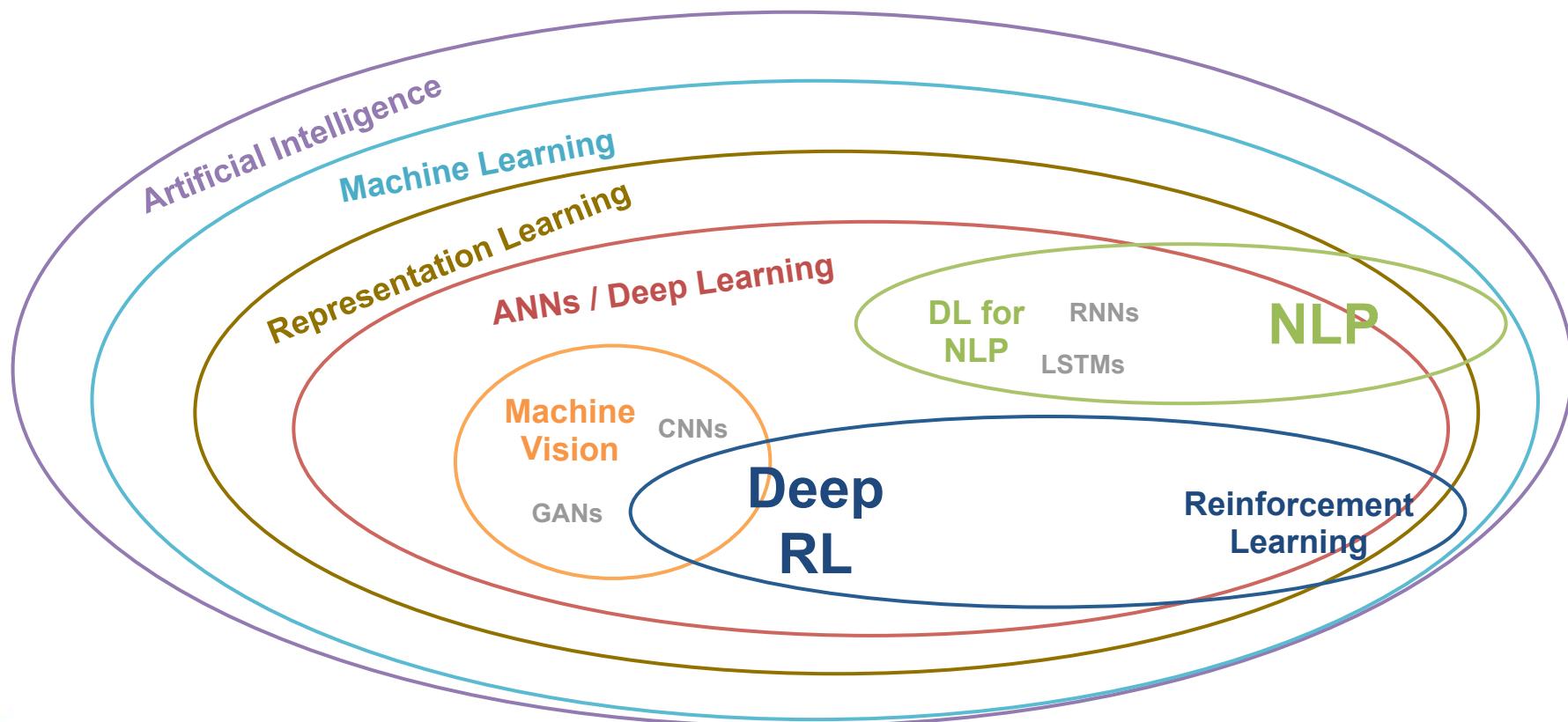
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Search “*Deep Learning for Natural Language Processing*” or “*Jon Krohn*” in Safari

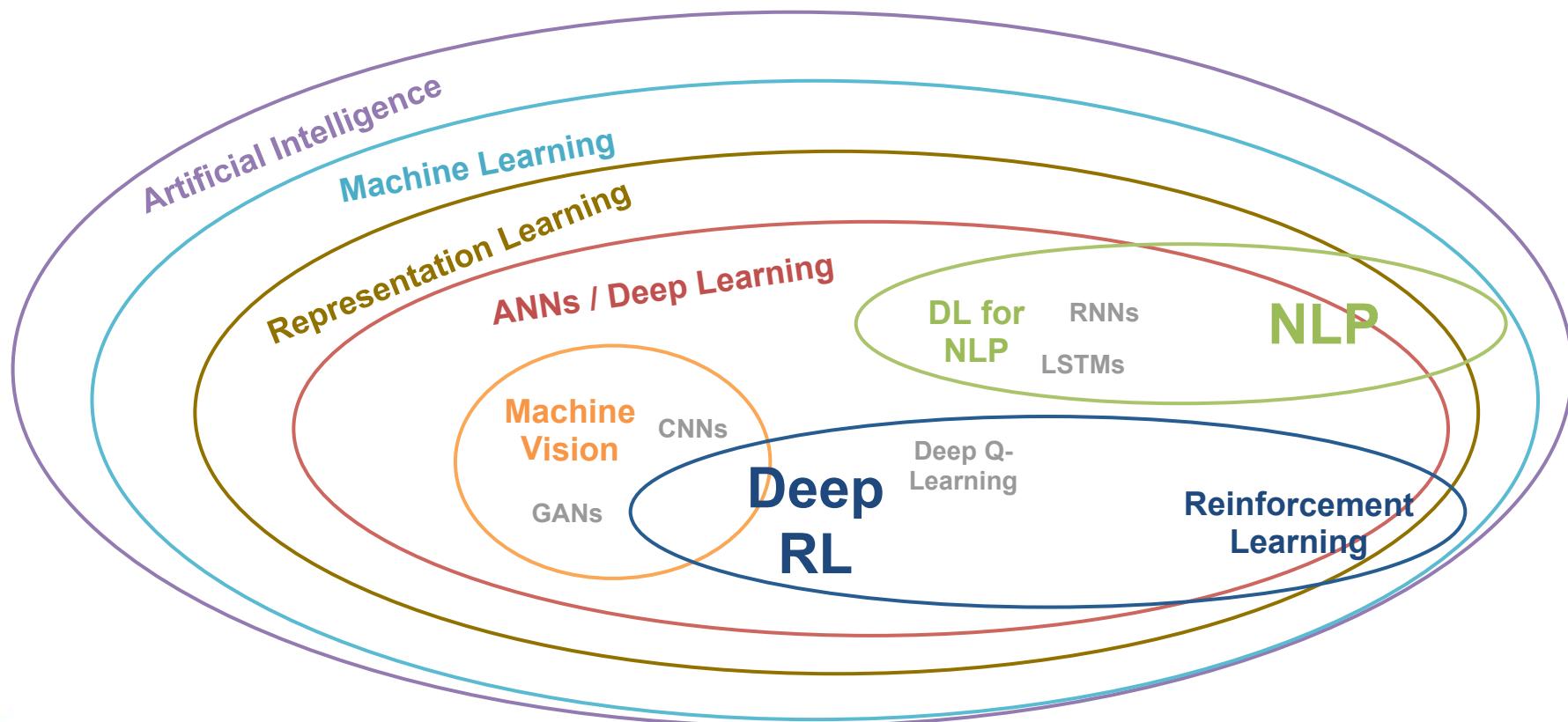
# The Contemporary State of A.I.



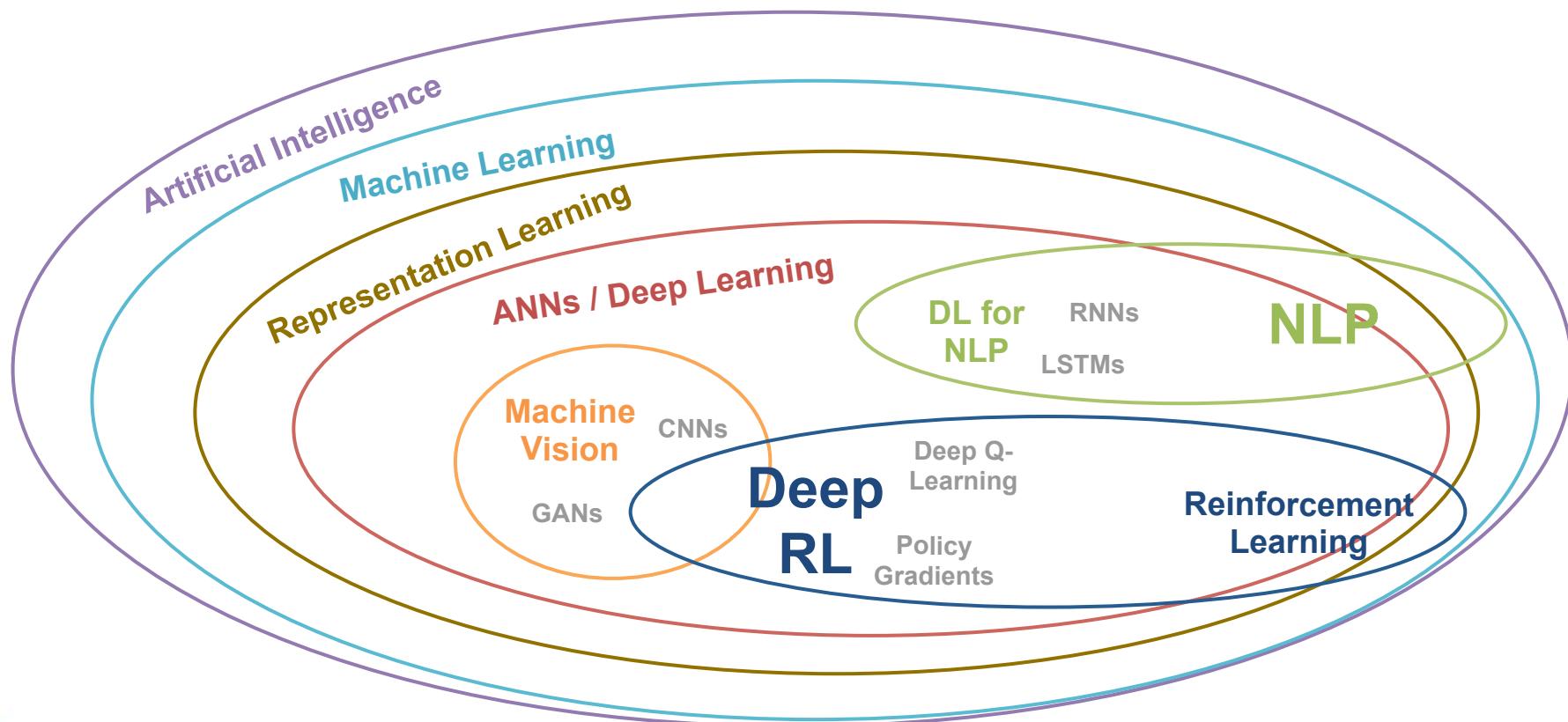
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# The Contemporary State of A.I.



# The Contemporary State of A.I.



# Deep Reinforcement Learning



[unsplash.com/photos/pxnDAT77rVg](https://unsplash.com/photos/pxnDAT77rVg)

# Categories of Artificial Intelligence

## 1. ANI: *Narrow*

# Categories of Artificial Intelligence

1. ANI: *Narrow*
2. AGI: *General*

# Categories of Artificial Intelligence

1. ANI: *Narrow*
2. AGI: *General*
3. ASI: *Super*

# Deep Reinforcement Learning

1.

## The Foundations of Artificial Intelligence

- The Contemporary State of A.I.
- **Applications of Deep Reinforcement Learning**  
*(reference RL LiveLessons section 1.3)*
- Review of Prerequisite Deep Learning Theory

2.

## Deep Q-Learning Networks

3.

## Advanced Deep Reinforcement Learning Agents

# Broad Categories of ML Problems

## 1. Supervised Learning

# Broad Categories of ML Problems

1. Supervised Learning
2. Unsupervised Learning

# Broad Categories of ML Problems

1. Supervised Learning
2. Unsupervised Learning
3. Reinforcement Learning

# Supervised Learning

- have  $x$  and  $y$

# Supervised Learning

- have  $x$  and  $y$
- goal: learn function that uses  $x$  to approximate  $y$

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- examples:
  - classification
    - MNIST digits
    - movie-review sentiment

# Supervised Learning

- have  $x$  and  $y$
- goal: learn function that uses  $x$  to approximate  $y$
- examples:
  - classification
    - MNIST digits
    - movie-review sentiment
  - regression
    - sales of a product
    - future value of an asset

# Unsupervised Learning

- have  $x$  only -- no  $y$  labels available

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# Unsupervised Learning

- have  $x$  only -- no  $y$  labels available
- goal: learn hidden, underlying structure of data  $x$
- examples:
  - word vectors
  - GANs

# Reinforcement Learning

- an *agent* takes *action* in an *environment*
- environment returns:
  - **reward** at timestep  $t$
  - **state** at timestep  $t+1$
- repeat!



# *Deep Reinforcement Learning*

An RL algo that incorporates (Deep) ANN layers:

- *Deep NN* can process complex sensory input
  - visual
  - sound
- *RL* can select action from complex possibilities

# “Playing Atari with Deep RL”

- Mnih et al. (2013)
  - NIPS and arXiv paper
  - DeepMind (acquired by Google in 2014)

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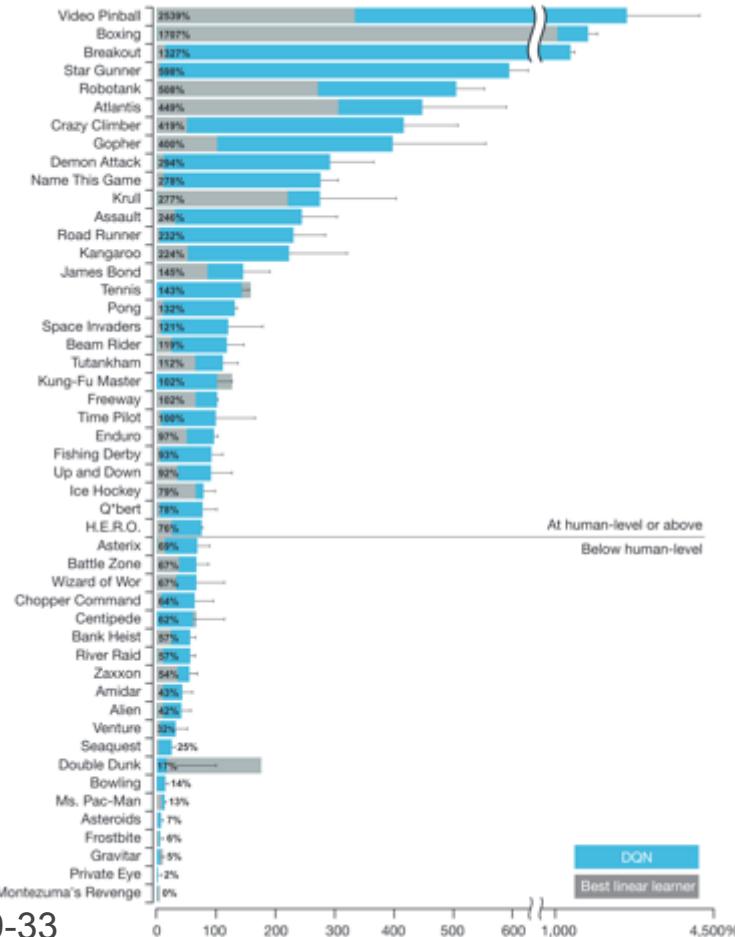
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- “Deep Q-Learning” algorithm
  - played seven Atari 2600 games
  - beat previous ML approaches on six
  - beat human expert on three

# Mnih et al. (2015)

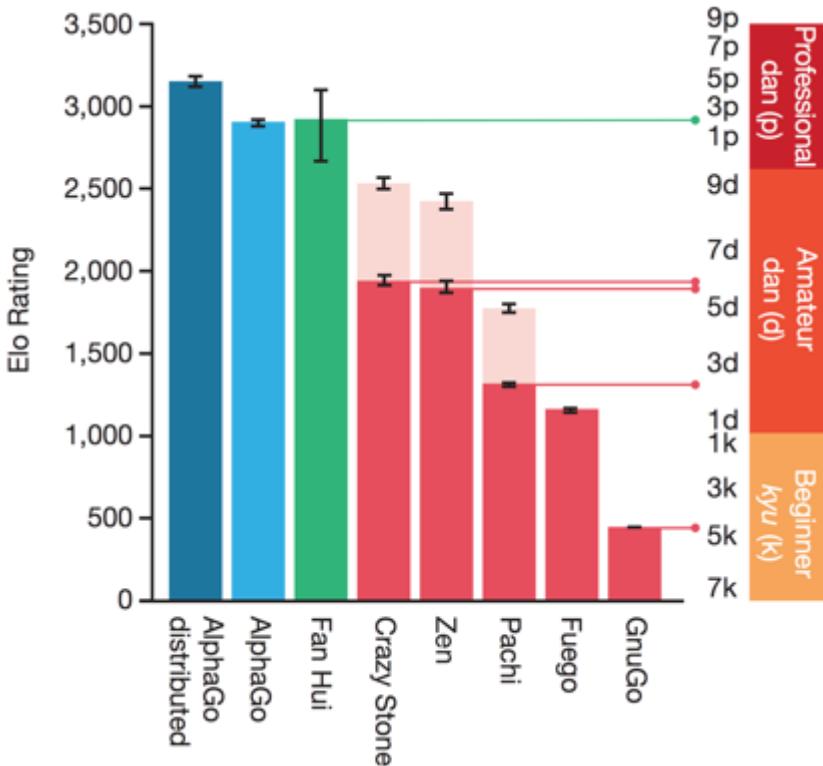


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Nature 518: 529-33

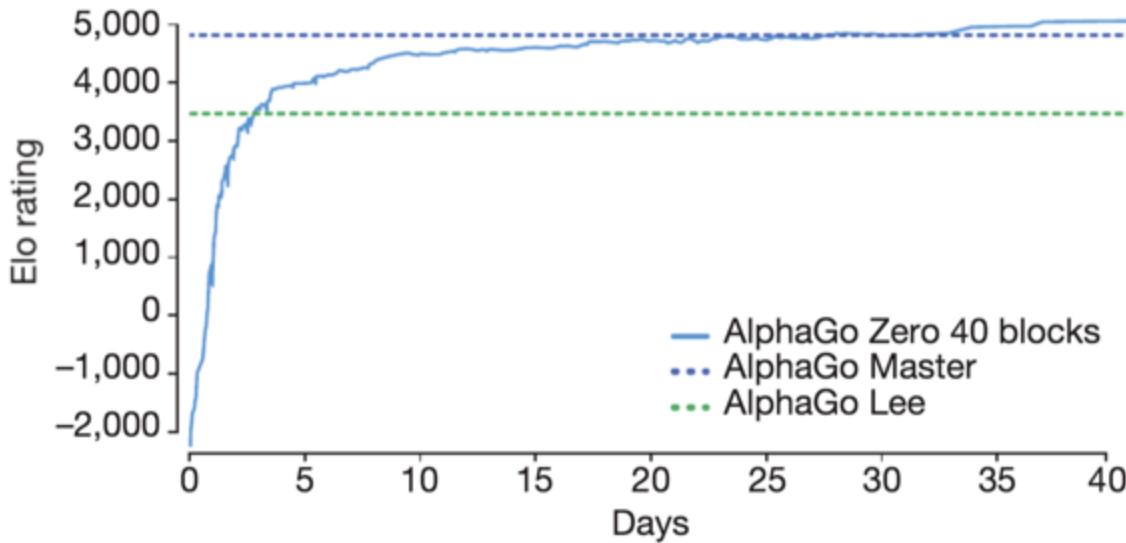
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# AlphaGo (Silver et al., 2016)

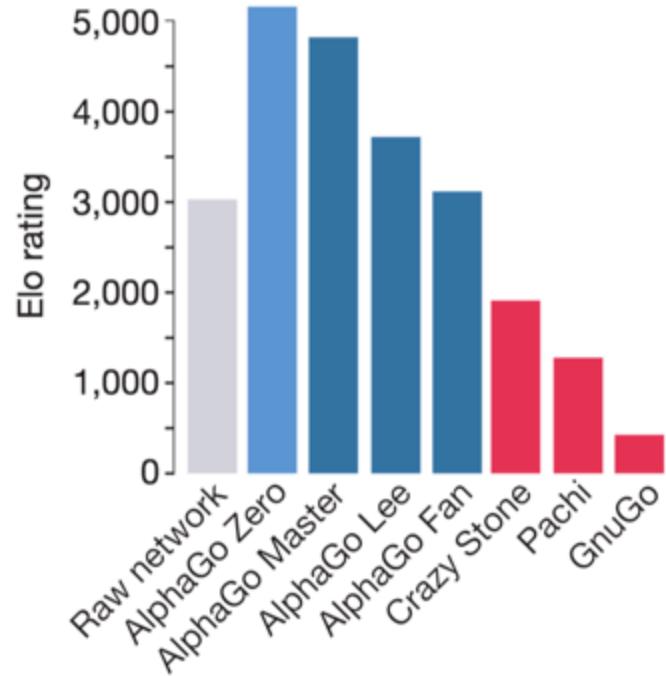


Nature 529: 484-9

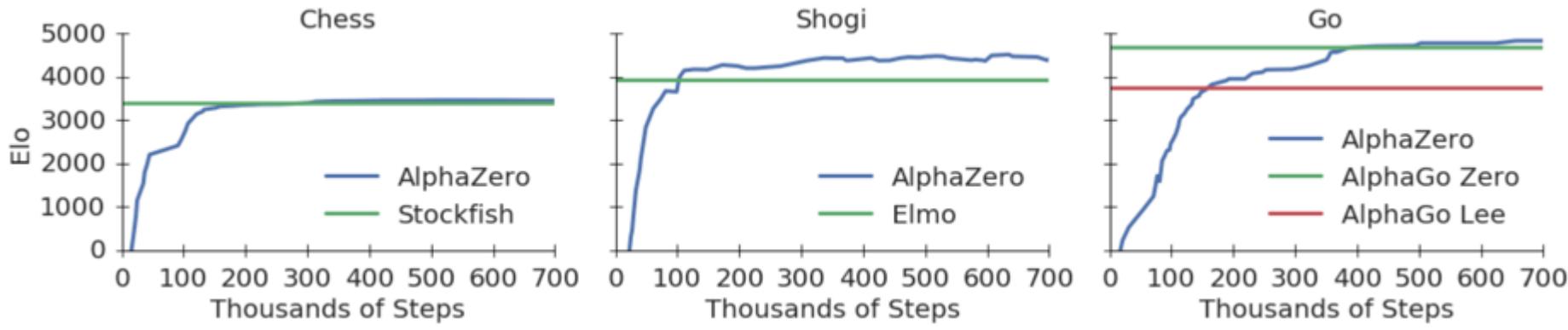
# AlphaGo Zero (Silver et al., 2017)



Nature 550: 354-9

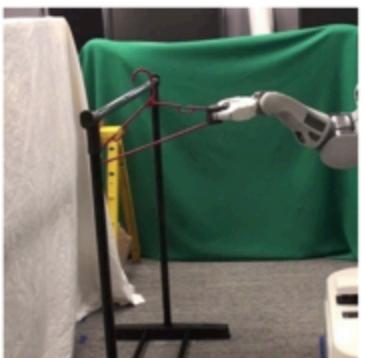
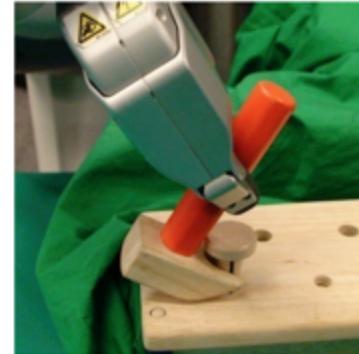
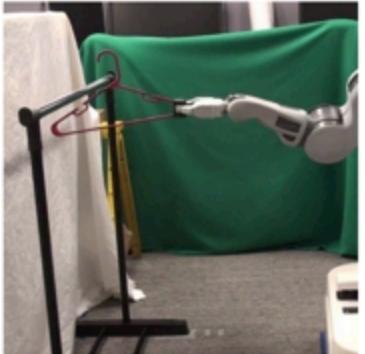


# AlphaZero (Silver et al., 2017)



arXiv: 1712.01815

# Levine et al. (2016)



(a) hanger

(b) cube

(c) hammer

(d) bottle

*Journal of Machine Learning Research 17: 1-40*

# Popular Deep RL Environments

1. OpenAI Gym: [github.com/openai/gym](https://github.com/openai/gym)

# Popular Deep RL Environments

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2. **DeepMind Lab:** [github.com/deepmind/lab](https://github.com/deepmind/lab)

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2. **DeepMind Lab:** [github.com/deepmind/lab](https://github.com/deepmind/lab)
3. **Unity:** [github.com/Unity-Technologies/ml-agents](https://github.com/Unity-Technologies/ml-agents)

# The Cart(pole) Before the Horse

Interactive Jupyter(Hub) Demo:

`cartpole_dqn.ipynb`

# More Cart(pole) Before the Horse

Local Jupyter Demo:

`cartpole_dqn.ipynb`

1. run `jupyter notebook` outside of Docker container
2. uncomment `env.render()`

# Rendering OpenAI Gym

- not necessary... *but fun!*
- not easily done within Docker container
- may vary by machine; my process was:
  - a. install as at [github.com/openai/gym](https://github.com/openai/gym)
  - b. install as at [anaconda.com](https://anaconda.com)
  - c. (pip install gym[atari])
  - d. pip uninstall pyglet
  - e. pip install pyglet==1.2.4
  - f. run jupyter notebook in TensorFlow-LiveLessons directory

# Deep Reinforcement Learning

1.

## The Foundations of Artificial Intelligence

- The Contemporary State of A.I.
- Applications of Deep Reinforcement Learning
- **Review of Prerequisite Deep Learning Theory**  
*(reference “Deep Learning with TensorFlow LiveLessons”)*

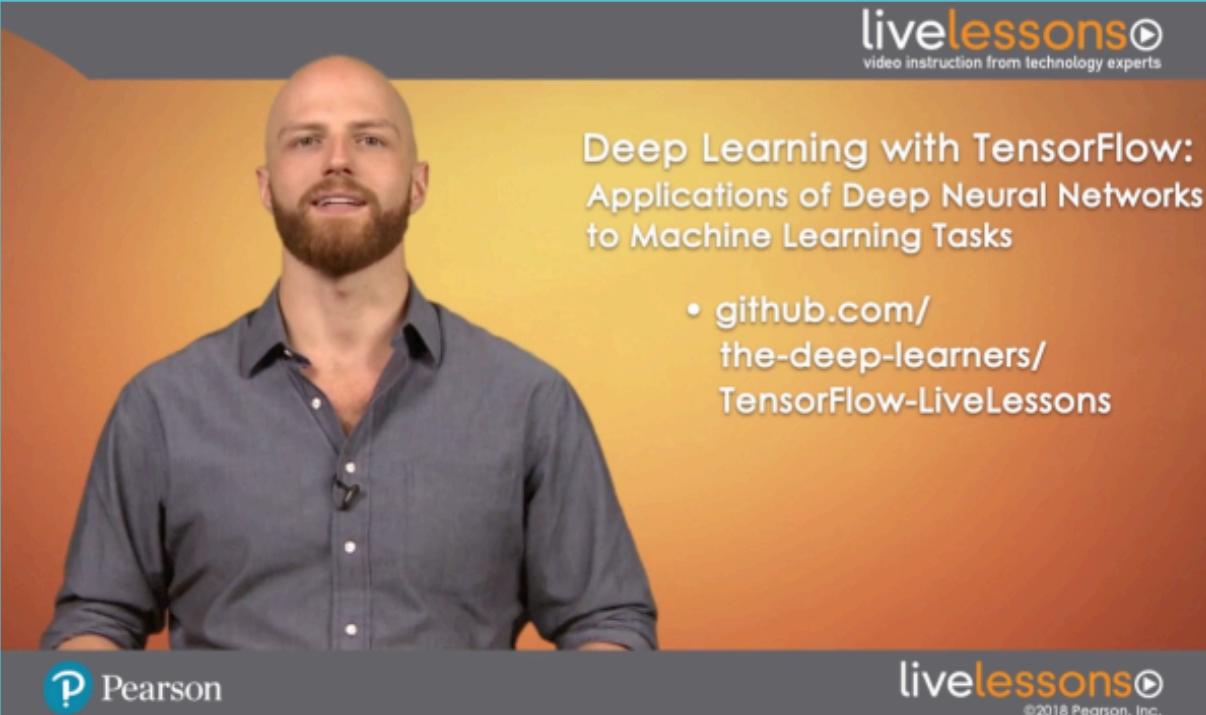
2.

## Deep Q-Learning Networks

3.

## Advanced Deep Reinforcement Learning Agents

# Deep Learning Fundamentals (assumed)



The image shows a screenshot of a video player for a liveLessons video. On the left, there is a video frame showing a man with a beard and short hair, wearing a dark grey button-down shirt, speaking. On the right, there is promotional text and logos. At the top right is the "livelessons" logo with the tagline "video instruction from technology experts". Below the logo is the title "Deep Learning with TensorFlow: Applications of Deep Neural Networks to Machine Learning Tasks". Underneath the title is a bullet point list: • [github.com/  
the-deep-learners/  
TensorFlow-LiveLessons](https://github.com/the-deep-learners/TensorFlow-LiveLessons). At the bottom left is the Pearson logo, and at the bottom right is the livelessons logo with the copyright notice "©2018 Pearson, Inc."

livelessons  
video instruction from technology experts

Deep Learning with TensorFlow:  
Applications of Deep Neural Networks  
to Machine Learning Tasks

- [github.com/  
the-deep-learners/  
TensorFlow-LiveLessons](https://github.com/the-deep-learners/TensorFlow-LiveLessons)

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Search “*Deep Learning with TensorFlow*” or “*Jon Krohn*” in Safari

# Your Arsenal

## Neurons

- sigmoid
- tanh
- ReLU

# Your Arsenal

## Neurons

- sigmoid
- tanh
- ReLU

## Cost Functions

- quadratic cost

$$\sum_i (y_i - \hat{y}_i)^2$$

# Your Arsenal

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- tanh
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## Cost Functions

- quadratic cost
- *cross-entropy*

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## *Stochastic Gradient Descent*

- mini-batch size
- learning rate
- second-order, e.g., Adam

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## Backpropagation

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## Neurons

- sigmoid
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## Layers

- dense / fully-connected

## Cost Functions

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- learning rate
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## Backpropagation

# Your Arsenal

## Neurons

- sigmoid
- tanh
- ReLU

## Layers

- dense / fully-connected
- convolutional (*if we were detecting pixels from, e.g., Atari*)

## Cost Functions

- quadratic cost
- *cross-entropy*

## Stochastic Gradient Descent

- mini-batch size
- learning rate
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## Backpropagation

# Deep Reinforcement Learning

1. The Foundations of Artificial Intelligence
2. **Deep Q-Learning Networks**
  - The Cartpole Game
  - Essential Deep Reinforcement Learning Theory
  - Defining a DQN Agent
  - Interacting with an OpenAI Gym Environment
3. Advanced Deep Reinforcement Learning Agents

# Deep Reinforcement Learning

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  - **The Cartpole Game** (*reference RL LiveLessons section 3.1*)
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# The Cartpole Game



## Environment States:

1. Cart Position
2. Cart Velocity
3. Pole Angle
4. Pole Angular Velocity

## Actions:

1. Move Cart Left
2. Move Cart Right

# Deep Reinforcement Learning

1. The Foundations of Artificial Intelligence
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  - **Essential Deep Reinforcement Learning Theory**  
*(reference RL LiveLessons sections 3.2 and 3.3)*
  - Defining a DQN Agent
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# Essential Deep RL Theory

Reference:

deep\_RL\_theory.pdf

# Deep Reinforcement Learning

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# Defining a DQN Agent

Interactive Jupyter(Hub) Demo:

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# Deep Reinforcement Learning

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# Interacting with OpenAI Gym

*Return to Interactive Jupyter(Hub) Demo:*

`cartpole_dqn.ipynb`

# Deep Reinforcement Learning

1. The Foundations of Artificial Intelligence
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- 3. Advanced Deep Reinforcement Learning Agents**
  - OpenAI Lab for Agent Experimentation and Optimization
  - Policy Gradients: the REINFORCE and Actor-Critic Algorithms
  - Software 2.0
  - Approaching Artificial General Intelligence

# Deep Reinforcement Learning

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# OpenAI Lab

Interactive Demo of:

[github.com/kengz/openai\\_lab](https://github.com/kengz/openai_lab)

# Deep Reinforcement Learning

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  - Approaching Artificial General Intelligence

# Popular Deep RL Agents

## 1. Deep Q-Learning Network (DQN)

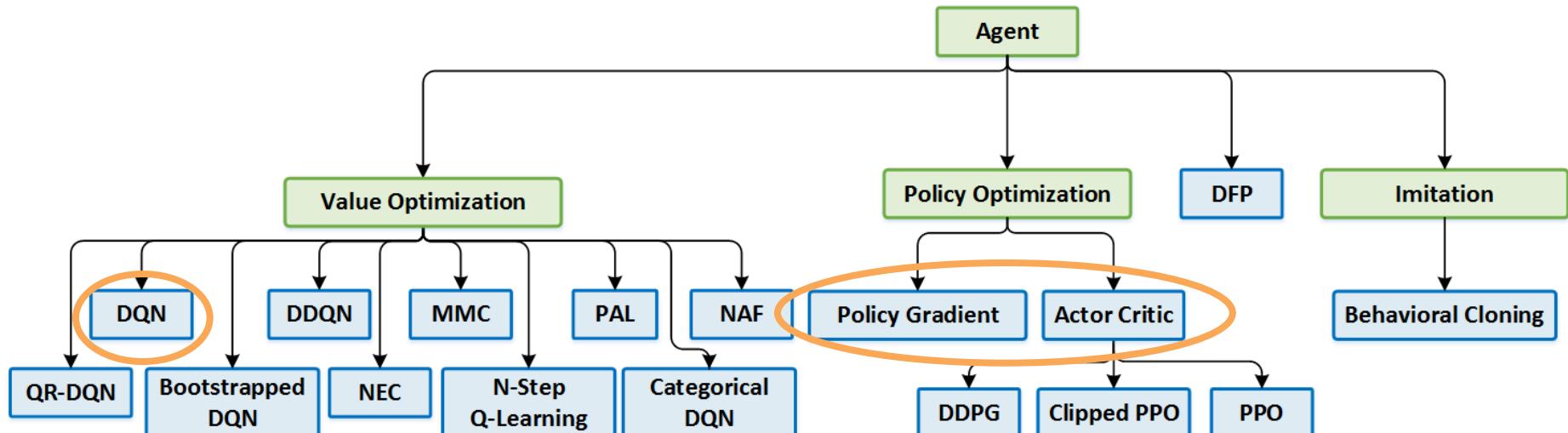
# Popular Deep RL Agents

1. Deep Q-Learning Network (DQN)
2. REINFORCE

# Popular Deep RL Agents

1. Deep Q-Learning Network (DQN)
2. REINFORCE
3. Actor-Critic

# Popular Deep RL Agents

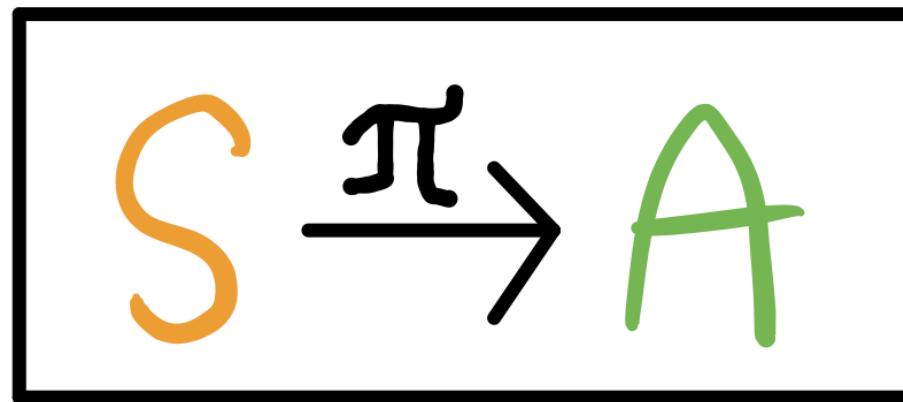


[github.com/NervanaSystems/coach](https://github.com/NervanaSystems/coach)

# Reinforcement Learning Resources

1. UC Berkeley CS294-112 *Deep Reinforcement Learning*
2. Sutton & Barto (2017) *Reinforcement Learning: An Introduction*

# Policy Gradients & REINFORCE



# Actor-Critic Algorithm

Actor - Critic  
↑                   ↑  
PG + Q-Learning

# Deep Reinforcement Learning

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  - Policy Gradients: the REINFORCE and Actor-Critic Algorithms
  - **Software 2.0** (*reference RL LiveLessons 5.3*)
  - Approaching Artificial General Intelligence

# Software 2.0

# Software 2.0 Pros

## 1. Computational Homogeneity

# Software 2.0 Pros

1. Computational Homogeneity
2. Constant Running Time

# Software 2.0 Pros

1. Computational Homogeneity
2. Constant Running Time
3. Constant Memory Use

# Software 2.0 Pros

1. Computational Homogeneity
2. Constant Running Time
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4. Portable Across Devices

# Software 2.0 Pros

1. Computational Homogeneity
2. Constant Running Time
3. Constant Memory Use
4. Portable Across Devices
5. Easy

# Software 2.0 Pros

1. Computational Homogeneity
2. Constant Running Time
3. Constant Memory Use
4. Portable Across Devices
5. Easy
6. Superior

# Deep Reinforcement Learning

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  - OpenAI Lab for Agent Experimentation and Optimization
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  - **Approaching Artificial General Intelligence**  
*(reference RL LiveLessons section 5.4)*

# Categories of Artificial Intelligence

1. ANI: *Narrow*
2. AGI: *General*
3. ASI: *Super*

# Factors Driving A.I.

Tim Urban's non-technical introduction:

[waitbutwhy.com/2015/01/](http://waitbutwhy.com/2015/01/artificial-intelligence-revolution-1.html)

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# Factors Driving A.I.

## 1. Data

# Factors Driving A.I.

1. Data
2. Computing Power

# Factors Driving A.I.

1. Data
2. Computing Power
3. Algorithms

# Factors Driving A.I.

1. Data
2. Computing Power
3. Algorithms
4. Infrastructure

# Deep Learning AGI Barriers

# Deep Learning AGI Barriers

1. Requires Training on Many, Many Samples

# Deep Learning AGI Barriers

1. Requires Training on Many, Many Samples
2. Black Box

# Deep Learning AGI Barriers

1. Requires Training on Many, Many Samples
2. Black Box
3. Doesn't Leverage Knowledge of the World

# Deep Learning AGI Barriers

1. Requires Training on Many, Many Samples
2. Black Box
3. Doesn't Leverage Knowledge of the World
4. Correlation = Causation

# Deep Learning AGI Barriers

1. Requires Training on Many, Many Samples
2. Black Box
3. Doesn't Leverage Knowledge of the World
4. Correlation = Causation
5. Unintuitive / Embarrassing / Adversarial Failures

# POLL

What other Deep Learning topic interests you most?

- Detail on Policy Gradients
- Natural Language Processing
- CNNs and Machine Vision
- Generative Adversarial Networks
- TensorBoard
- Something Else



Deep Learning with TensorFlow:  
Applications of Deep Neural Networks  
to Machine Learning Tasks

- [github.com/  
the-deep-learners/  
TensorFlow-LiveLessons](https://github.com/the-deep-learners/TensorFlow-LiveLessons)

Search “*Deep Learning with TensorFlow*” or “*Jon Krohn*” in Safari

## Deep Reinforcement Learning and GANs LiveLessons

- [github.com/the-deep-learners/TensorFlow-LiveLessons](https://github.com/the-deep-learners/TensorFlow-LiveLessons)



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## Deep Learning for Natural Language Processing



**Dr. Jon Krohn**  
Chief Data Scientist, untapt



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# Staying in Touch

[twitter.com/JonKrohnLearns](https://twitter.com/JonKrohnLearns)

[medium.com/@jonkrohn](https://medium.com/@jonkrohn)

[linkedin.com/in/jonkrohn](https://linkedin.com/in/jonkrohn)

*(with message mentioning today's Live Training)*

untapt

PLACEHOLDER  
FOR:

5-Minute Timer

PLACEHOLDER  
FOR:

10-Minute Timer