

Machine Learning for Astrophysics: Convolutional Neural Networks

John F Wu

STScI / JHU

jwuphysics.github.io







How would I teach my kid
to throw a baseball?



$$\frac{d}{dt} \frac{\partial L}{\partial \dot{q}_i} = \frac{\partial L}{\partial q_i}$$

Top-down



Bottom-up

versus

$$\frac{d}{dt} \frac{\partial L}{\partial \dot{q}_i} = \frac{\partial L}{\partial q_i}$$

Top-down

Implementing via code

Learning by iterating through successes and failures

Gaining big picture intuition

Bottom-up

Mathematical foundations

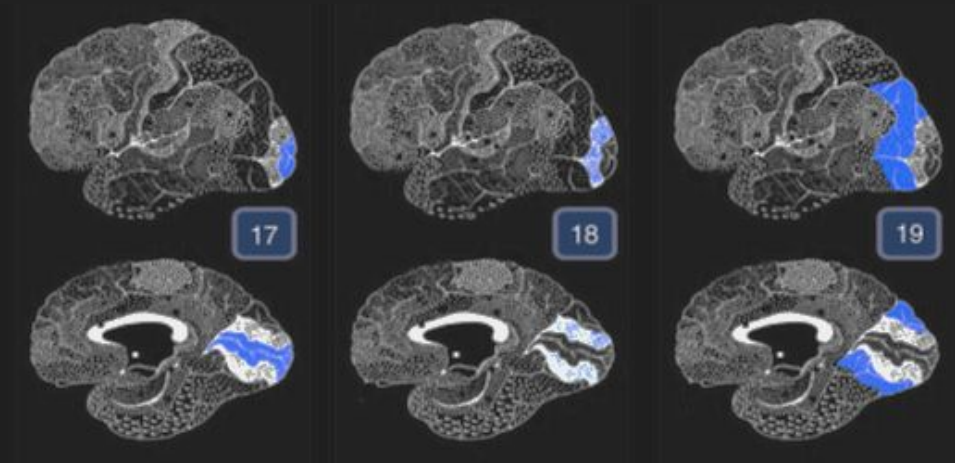
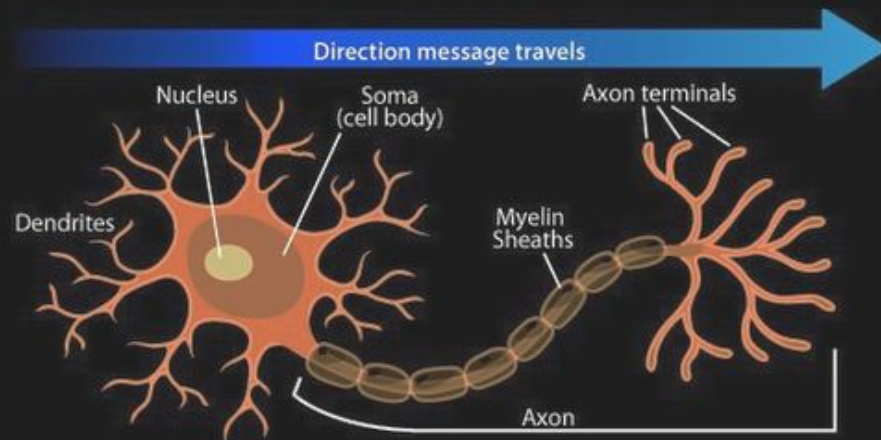
Learning through precise definitions and proofs

Understanding details and boundary cases

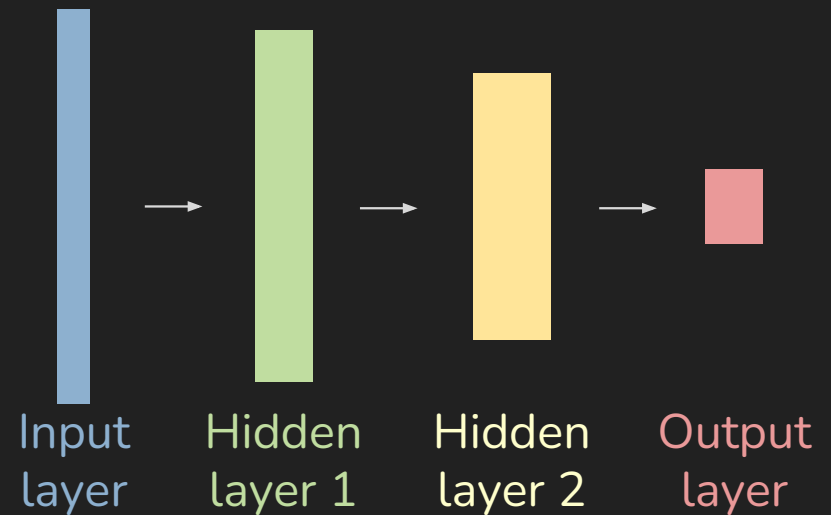
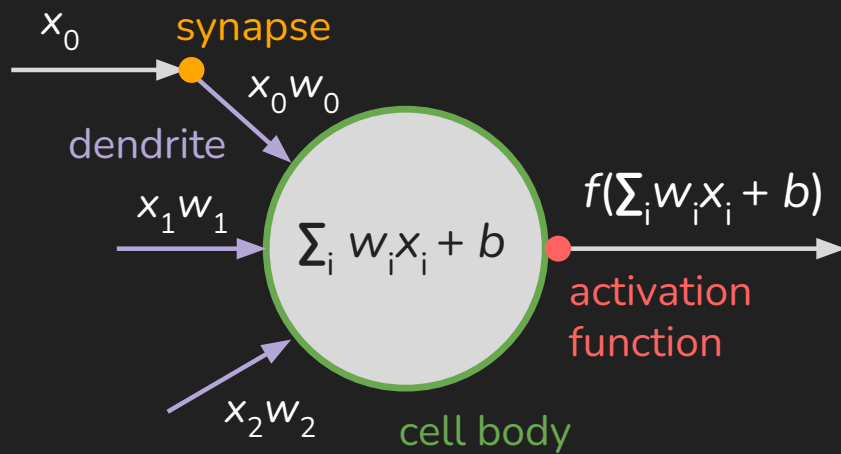
Neither style is *better*, but you should understand which learning style works best for you!

Convolutional Neural Networks (CNNs)

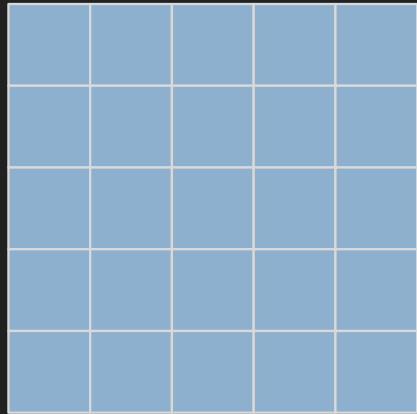
Biological neurons process and propagate signals



Artificial neurons process and propagate signals!



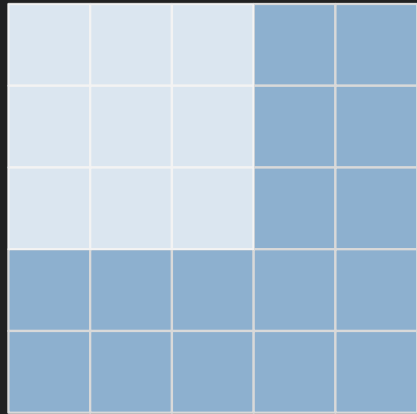
Convolutional layers are just morphological feature finders



Input image

$(x_0, x_1, \dots)$

Convolutional layers are just morphological feature finders

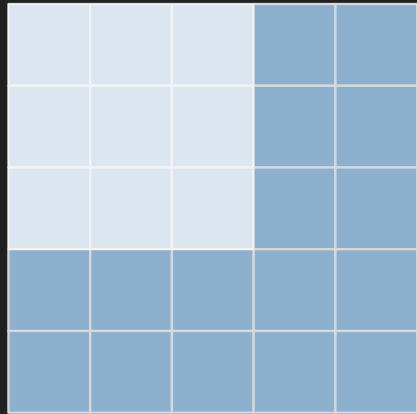


Input image $\otimes$ morphological feature

$(x_0, x_1, \dots)$

$(w_0, w_1, \dots)$

Convolutional layers are just morphological feature finders

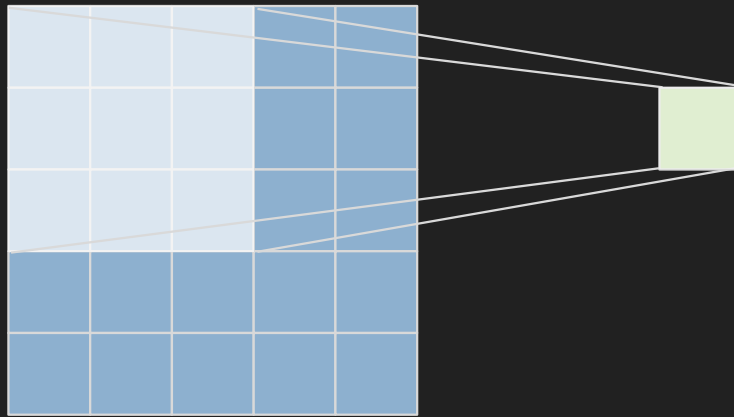


Input image $\otimes$ morphological feature

$(x_0, x_1, \dots)$

$(w_0, w_1, \dots)$

Convolutional layers are just morphological feature finders



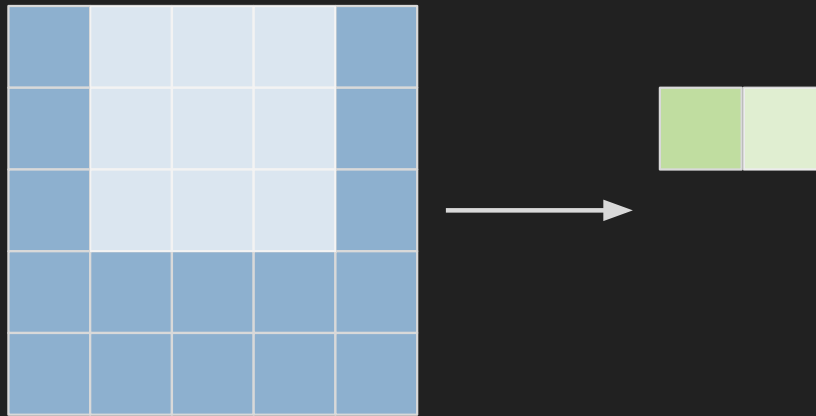
Input image $\otimes$ morphological feature $\rightarrow$ map of features

$$(x_0, x_1, \dots)$$

$$(w_0, w_1, \dots)$$

$$f(\sum_j w_{i-j} x_j + b)$$

Convolutional layers are just morphological feature finders



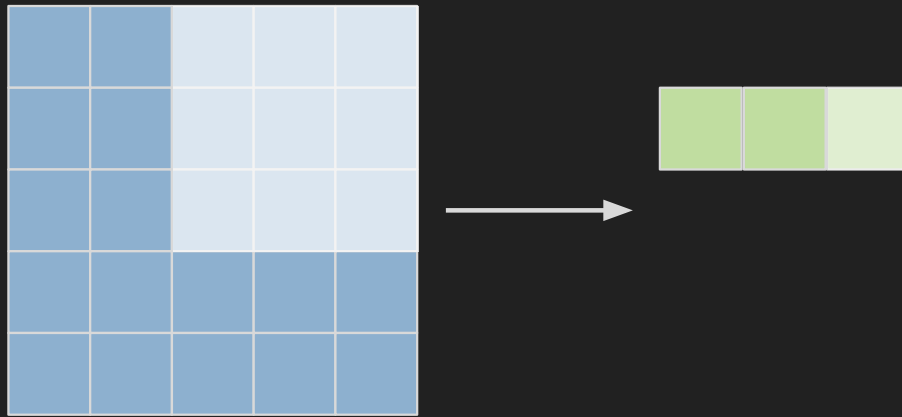
Input image $\otimes$ morphological feature $\rightarrow$ map of features

$$(x_0, x_1, \dots)$$

$$(w_0, w_1, \dots)$$

$$f(\sum_j w_{i-j} x_j + b)$$

Convolutional layers are just morphological feature finders



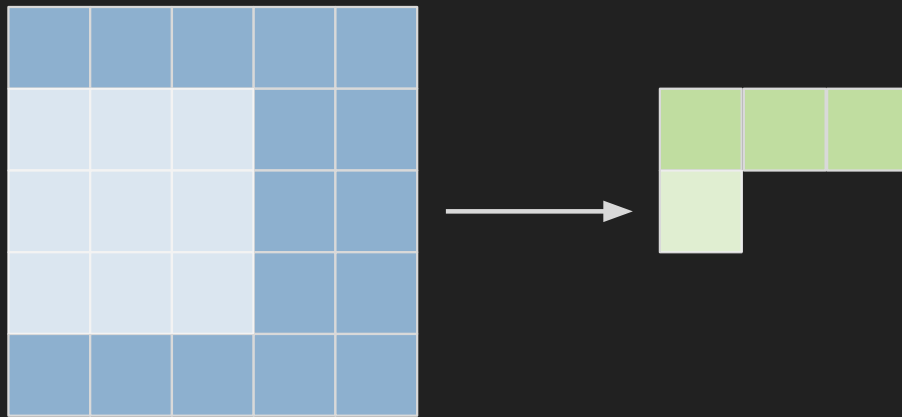
Input image $\otimes$ morphological feature $\rightarrow$ map of features

$$(x_0, x_1, \dots)$$

$$(w_0, w_1, \dots)$$

$$f(\sum_j w_{i-j} x_j + b)$$

Convolutional layers are just morphological feature finders



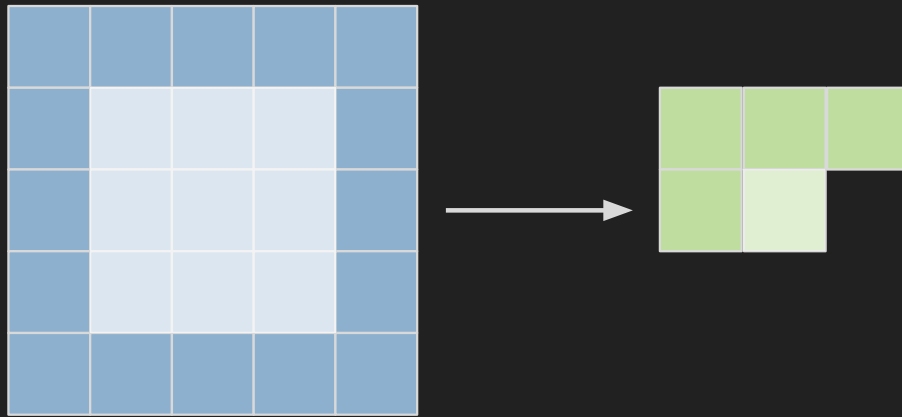
Input image $\otimes$ morphological feature $\rightarrow$ map of features

$$(x_0, x_1, \dots)$$

$$(w_0, w_1, \dots)$$

$$f(\sum_j w_{i-j} x_j + b)$$

Convolutional layers are just morphological feature finders



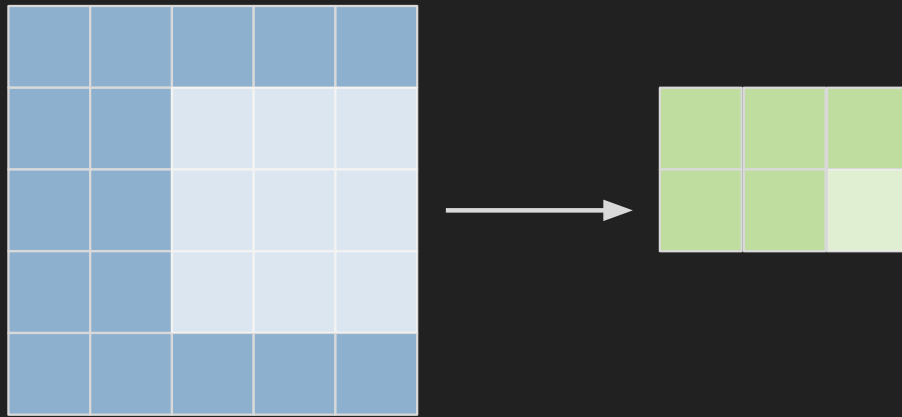
Input image $\otimes$ morphological feature $\rightarrow$ map of features

$(x_0, x_1, \dots)$

$(w_0, w_1, \dots)$

$f(\sum_j w_{i-j} x_j + b)$

Convolutional layers are just morphological feature finders



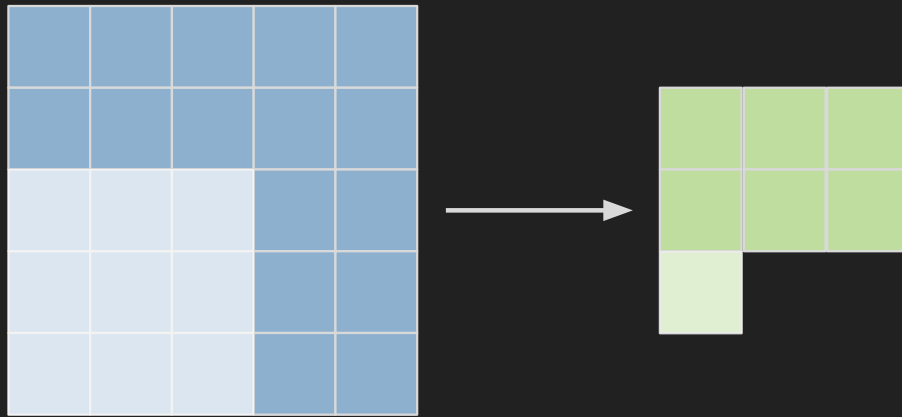
Input image $\otimes$ morphological feature $\rightarrow$ map of features

$$(x_0, x_1, \dots)$$

$$(w_0, w_1, \dots)$$

$$f(\sum_j w_{i-j} x_j + b)$$

Convolutional layers are just morphological feature finders



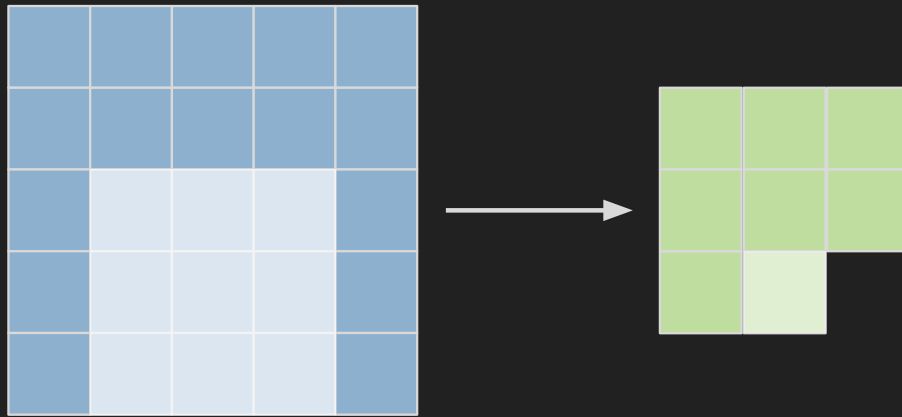
Input image $\otimes$ morphological feature $\rightarrow$ map of features

$(x_0, x_1, \dots)$

$(w_0, w_1, \dots)$

$f(\sum_j w_{i-j} x_j + b)$

Convolutional layers are just morphological feature finders



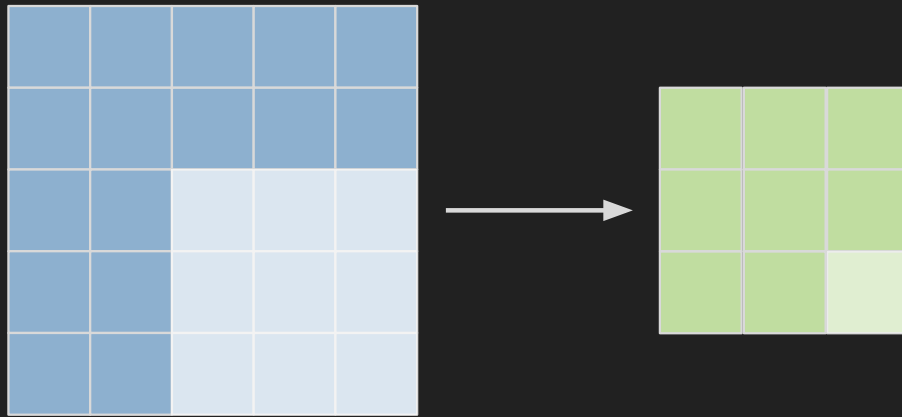
Input image $\otimes$ morphological feature $\rightarrow$ map of features

$$(x_0, x_1, \dots)$$

$$(w_0, w_1, \dots)$$

$$f(\sum_j w_{i-j} x_j + b)$$

Convolutional layers are just morphological feature finders



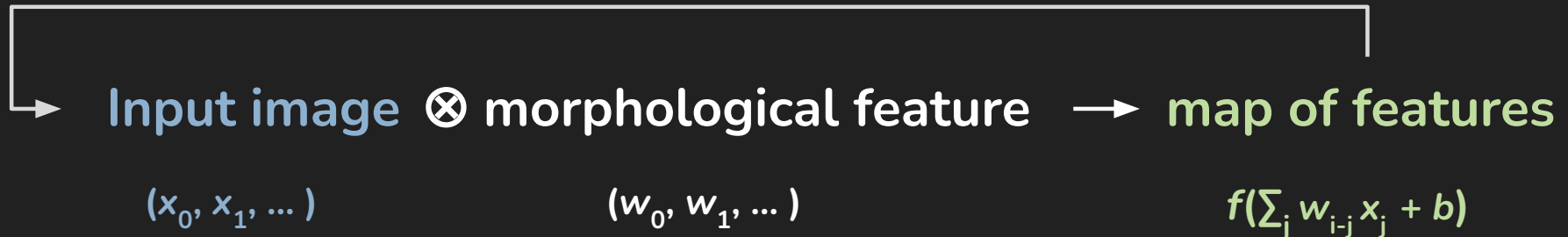
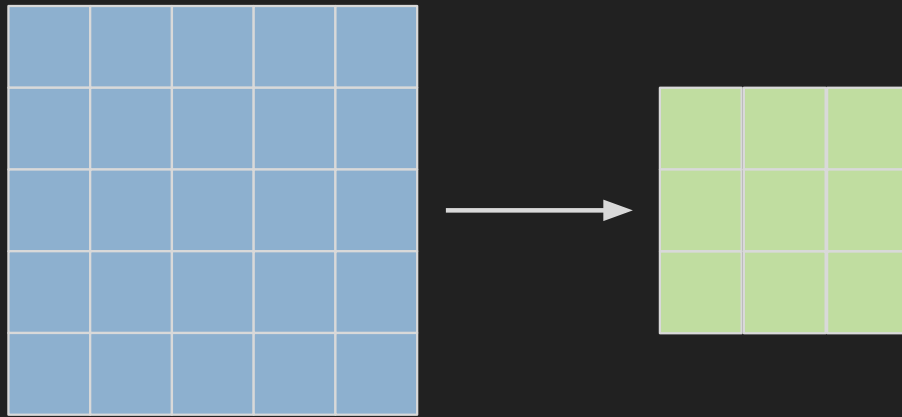
Input image $\otimes$ morphological feature $\rightarrow$ map of features

$$(x_0, x_1, \dots)$$

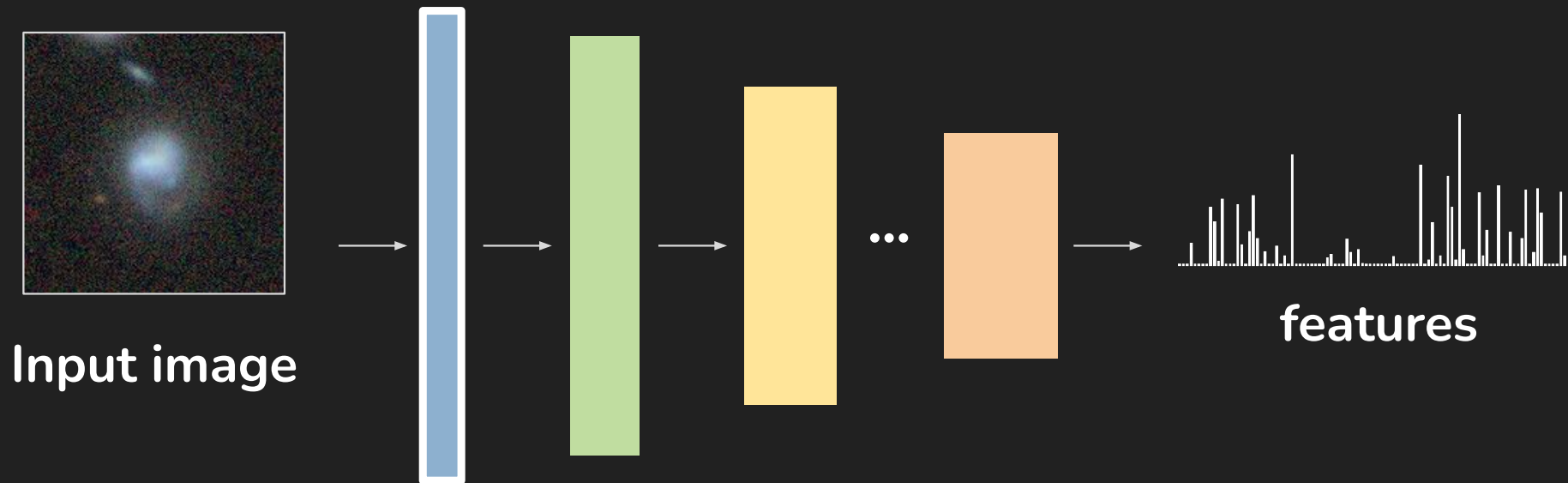
$$(w_0, w_1, \dots)$$

$$f(\sum_j w_{i-j} x_j + b)$$

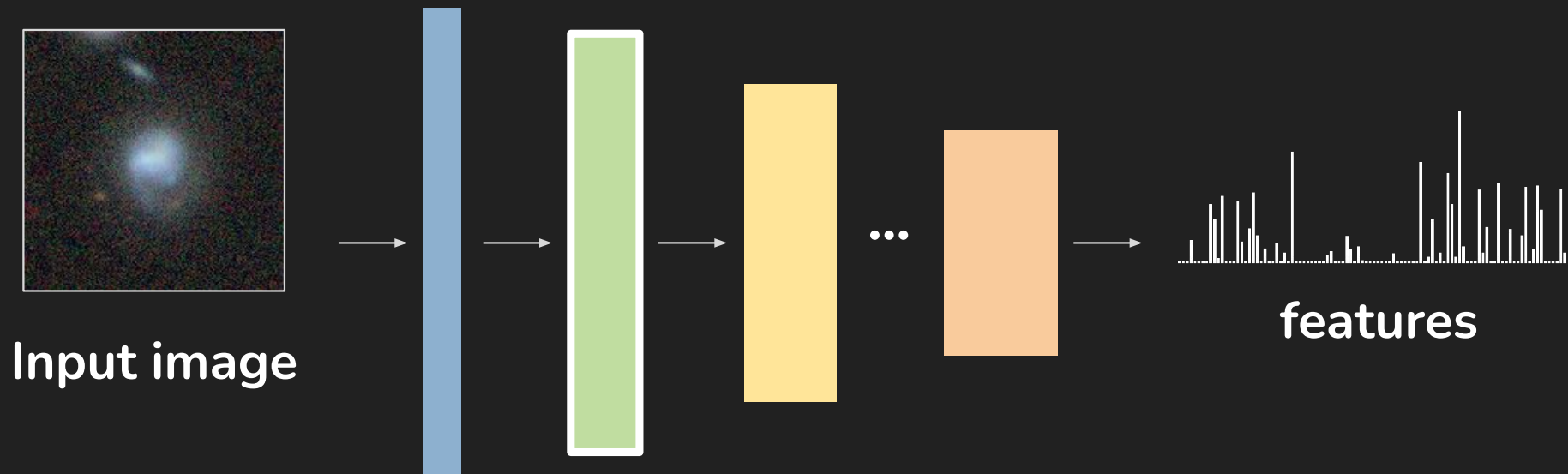
CNNs are just sequential morphological feature finders



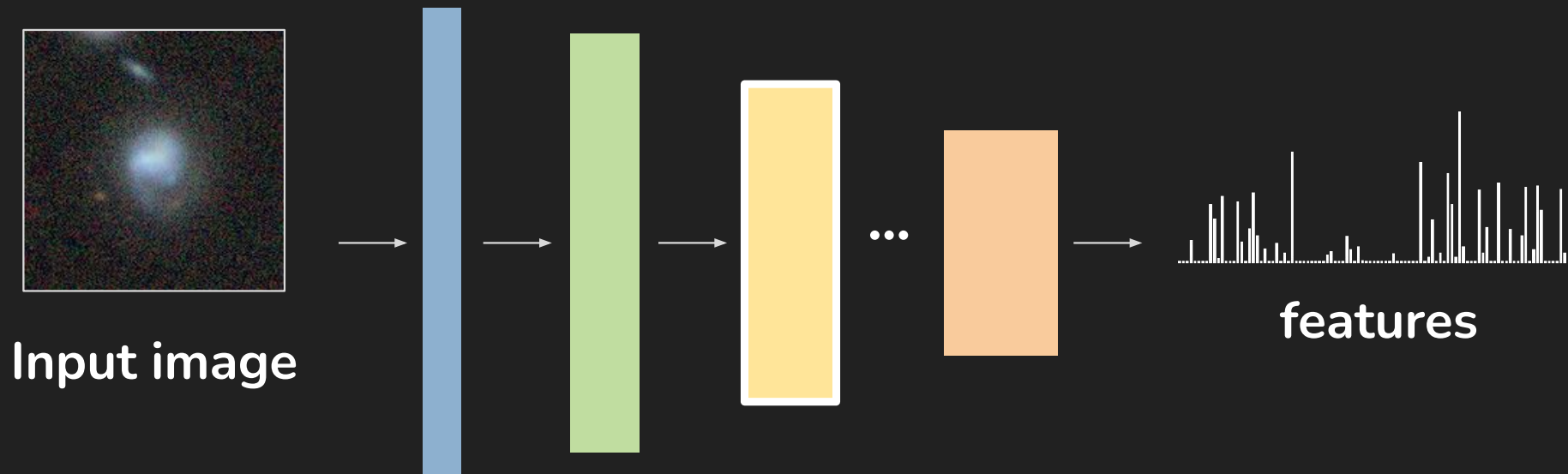
CNNs are just sequential morphological feature finders



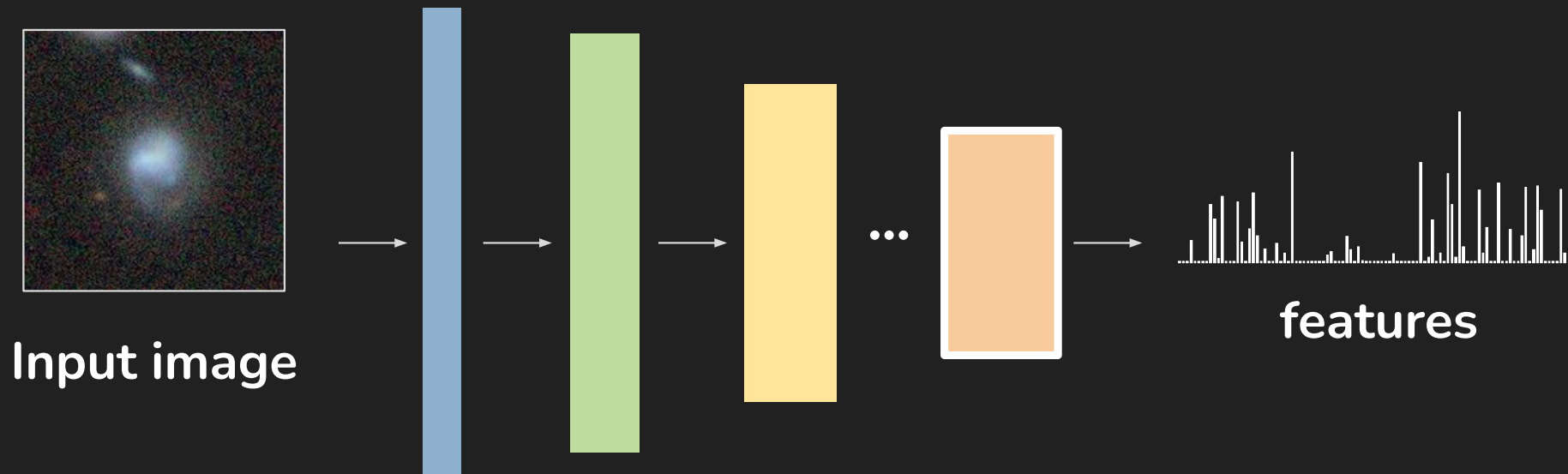
CNNs are just sequential morphological feature finders



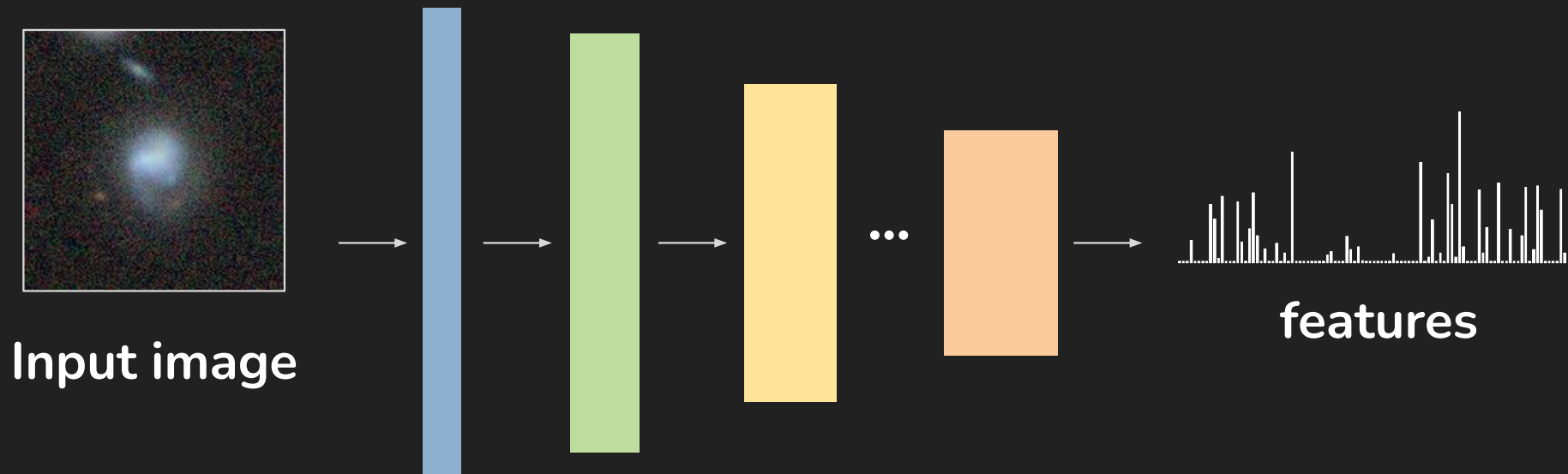
CNNs are just sequential morphological feature finders



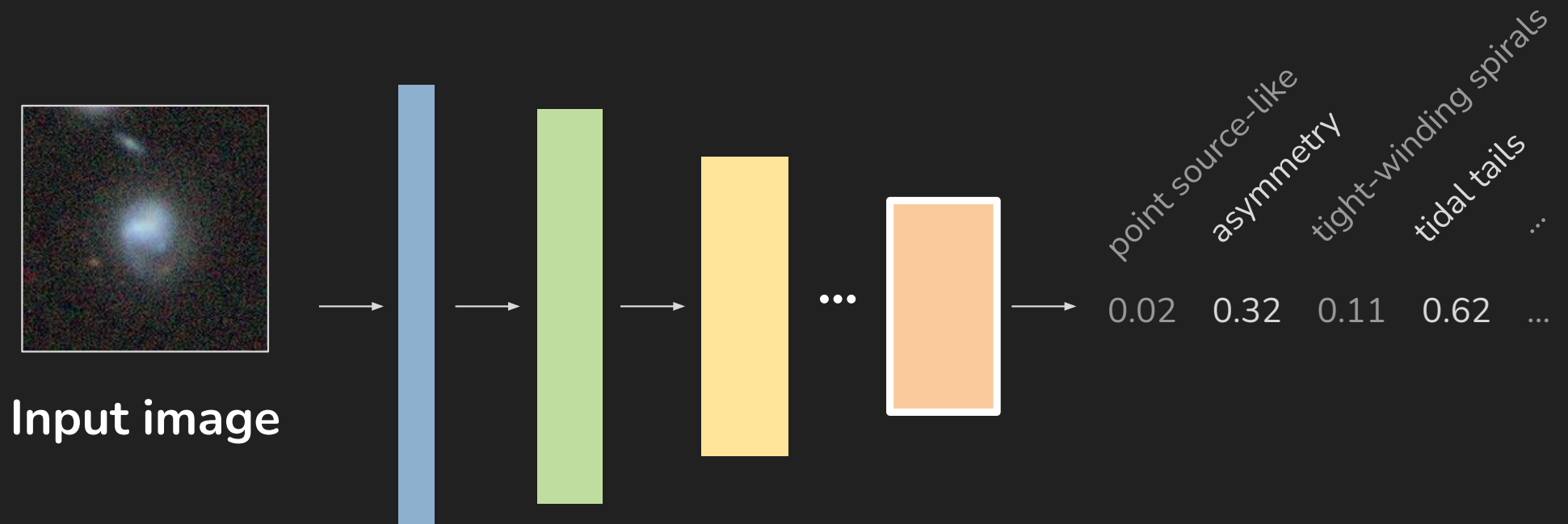
CNNs are just sequential morphological feature finders



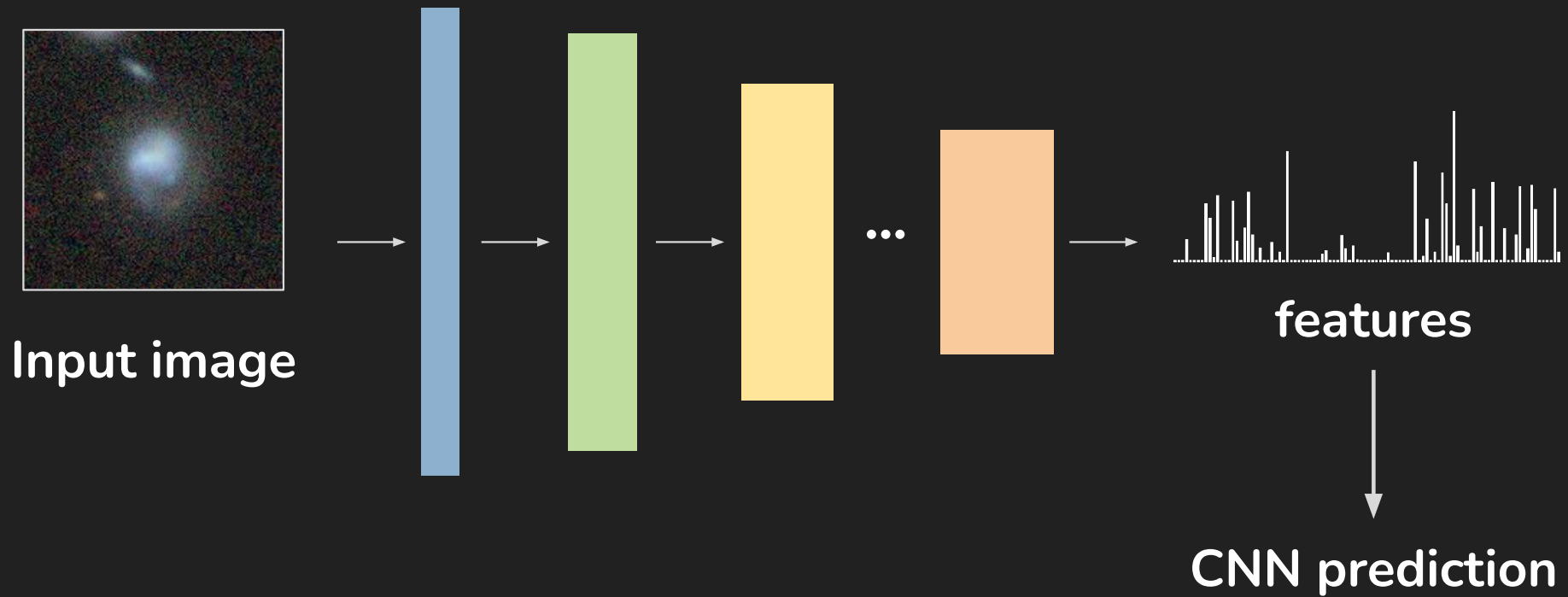
CNNs are just sequential morphological feature finders



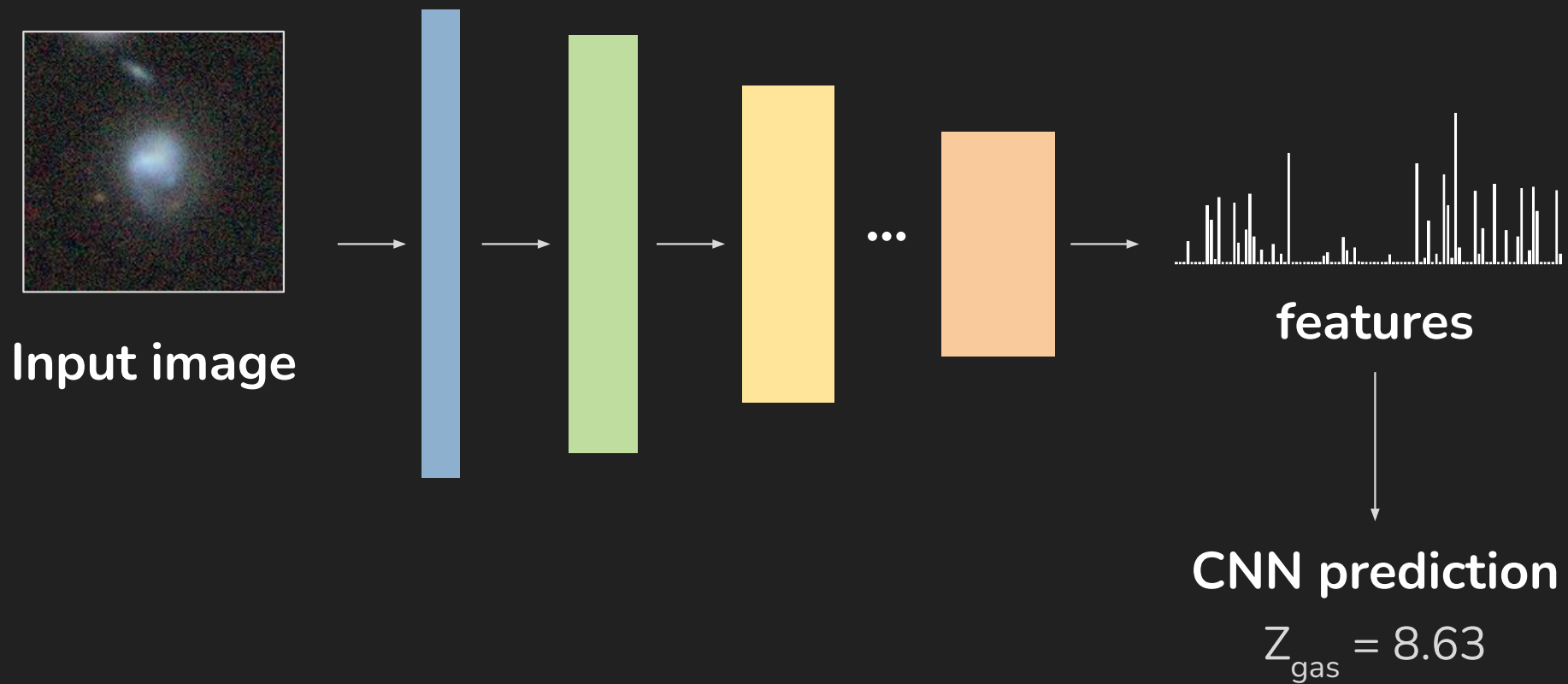
CNNs are just sequential morphological feature finders



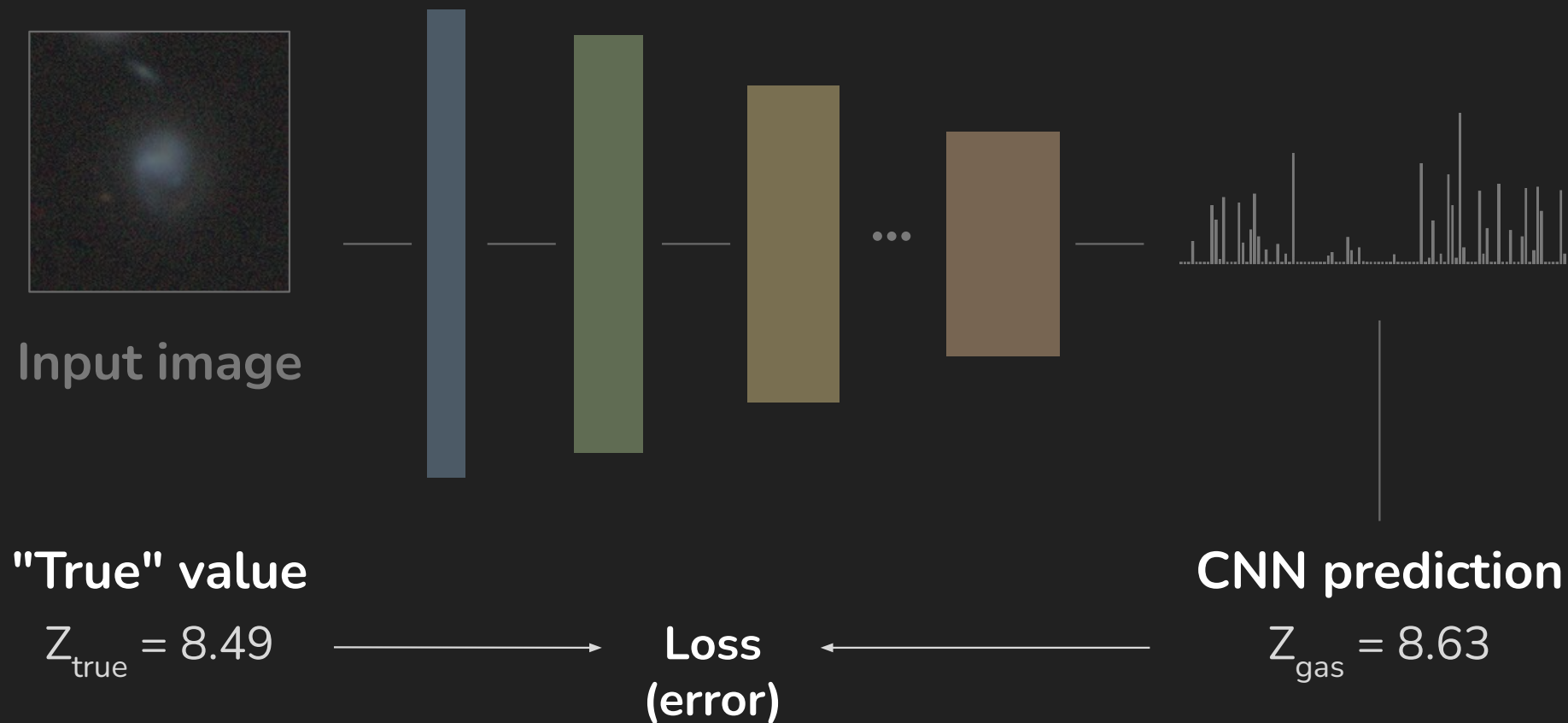
CNNs identify features to make predictions



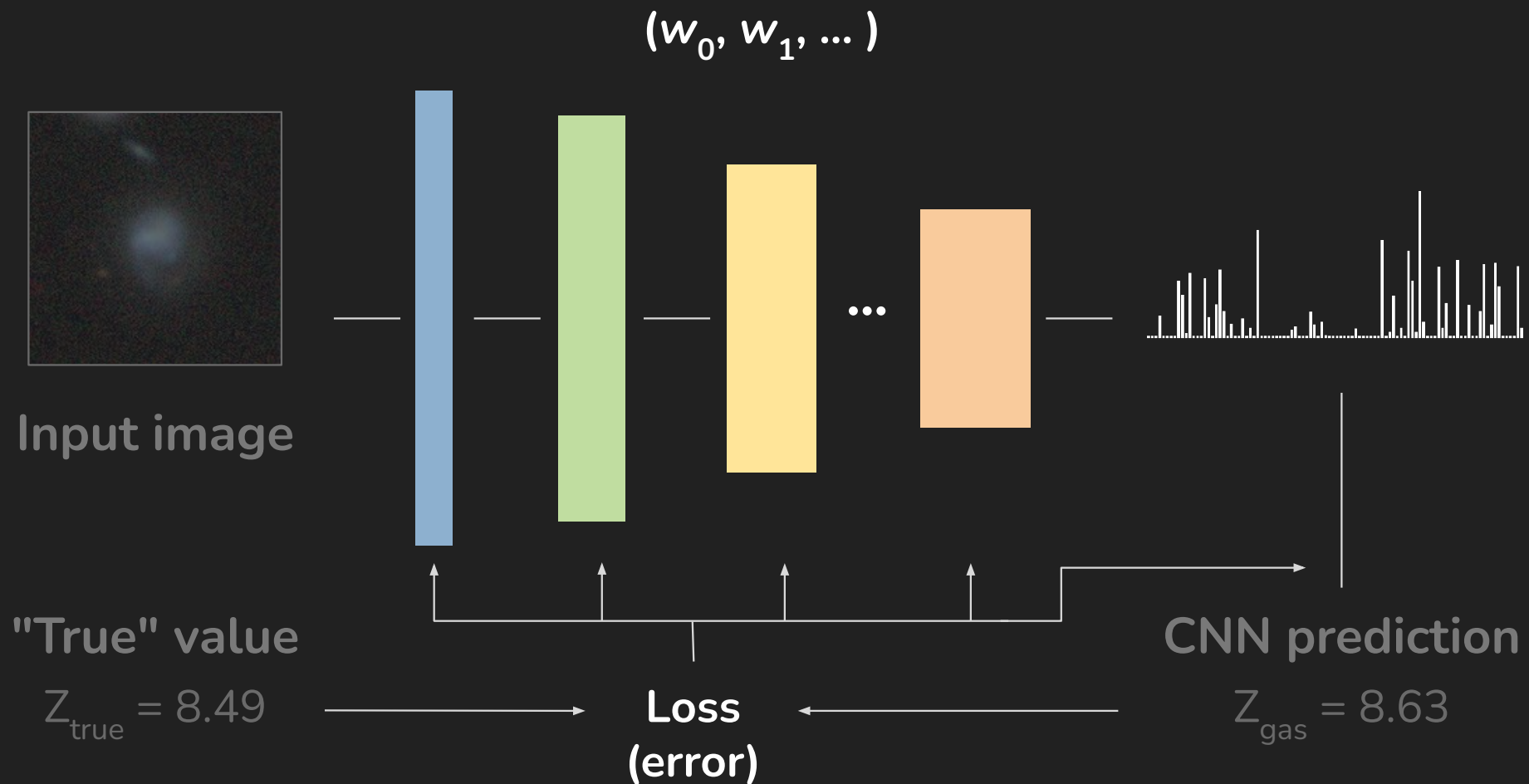
CNNs identify features to make predictions



Update CNN parameters in the direction that minimizes error



Update CNN parameters in the direction that minimizes error



ASIAA Summer Student Program 2026

Author: John F. Wu

Date: July 2, 2026

Open in Colab:

<https://colab.research.google.com/drive/1RxVEIOsMEyVvOWQjgRG6IfYM9qpg27a6>

