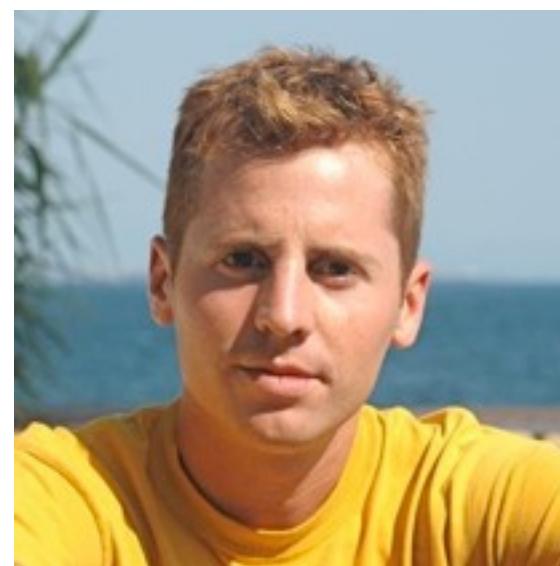


How transferable are features in deep neural networks?

9 December 2014
Jason Yosinski



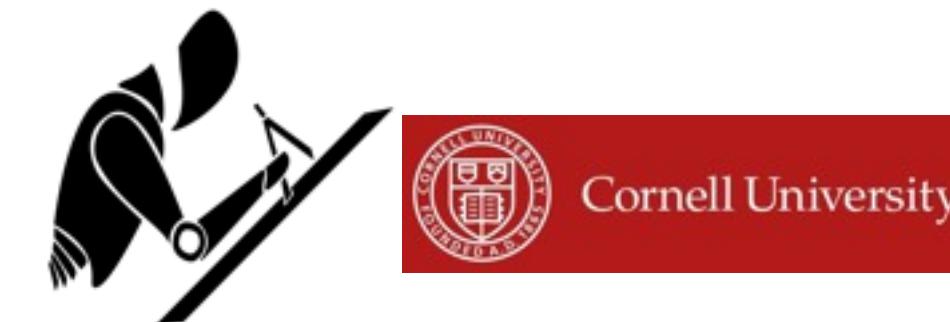
Jeff Clune



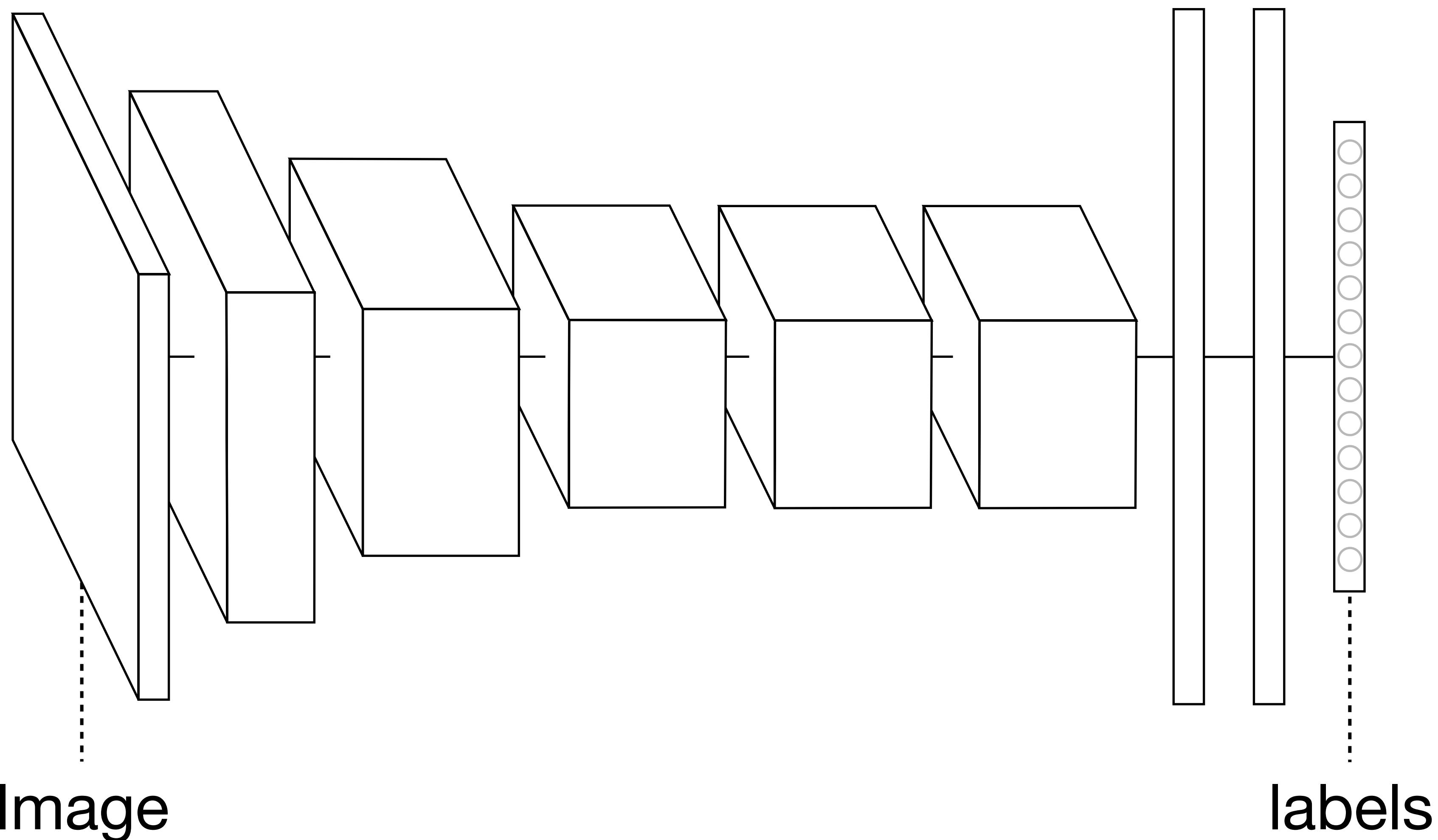
Yoshua Bengio



Hod Lipson

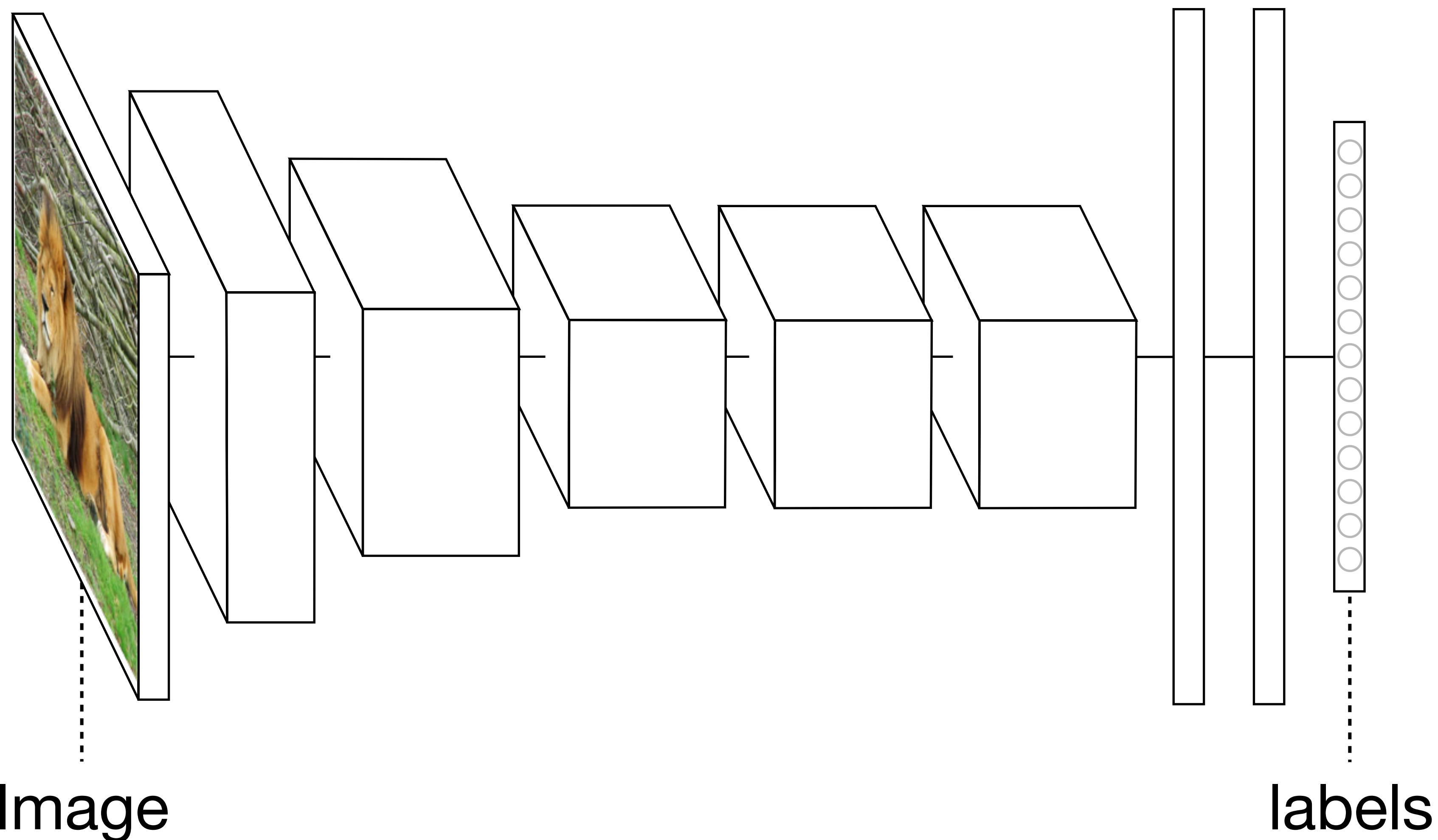


AlexNet



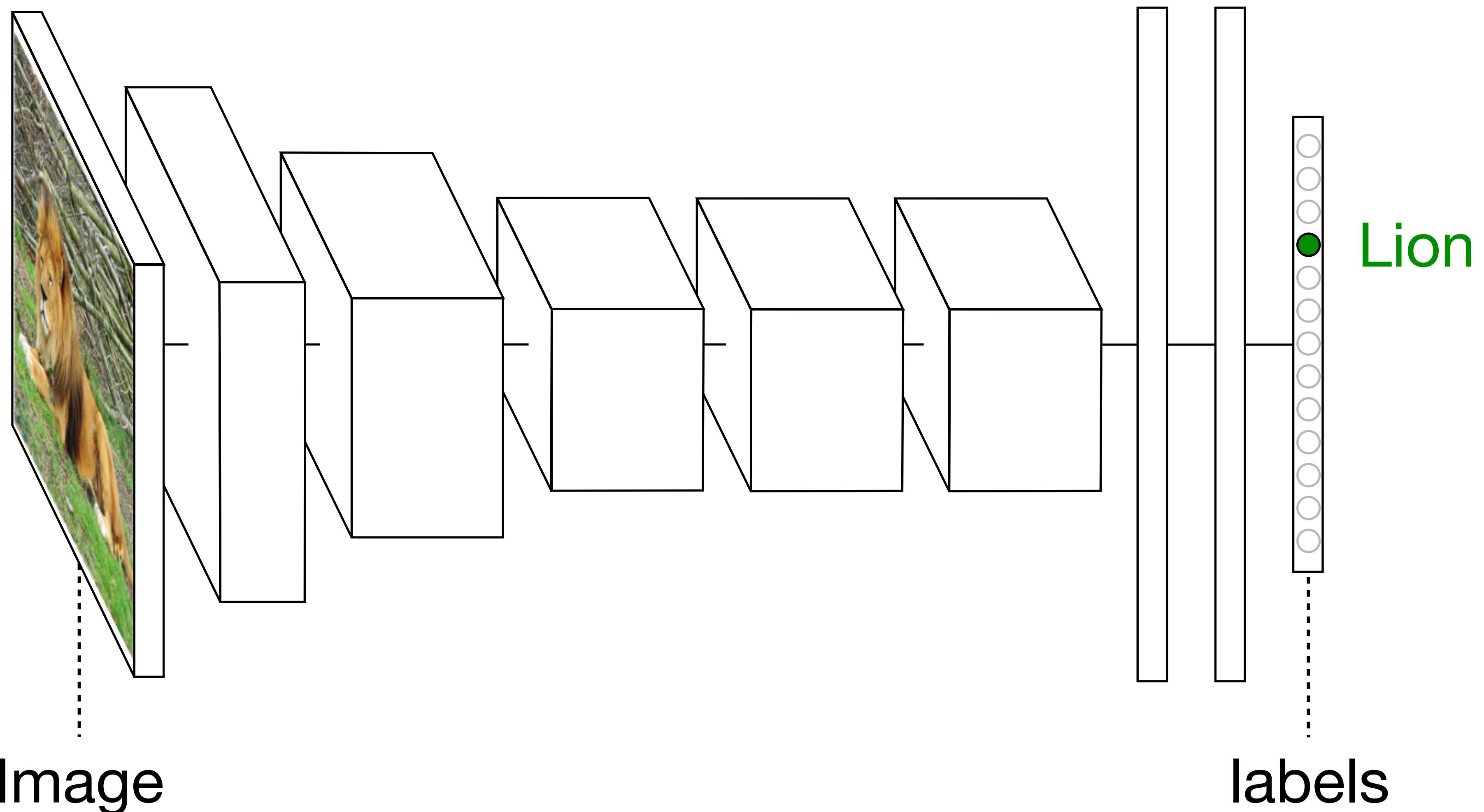
Krizhevsky, Sutskever, Hinton – NIPS 2012

AlexNet



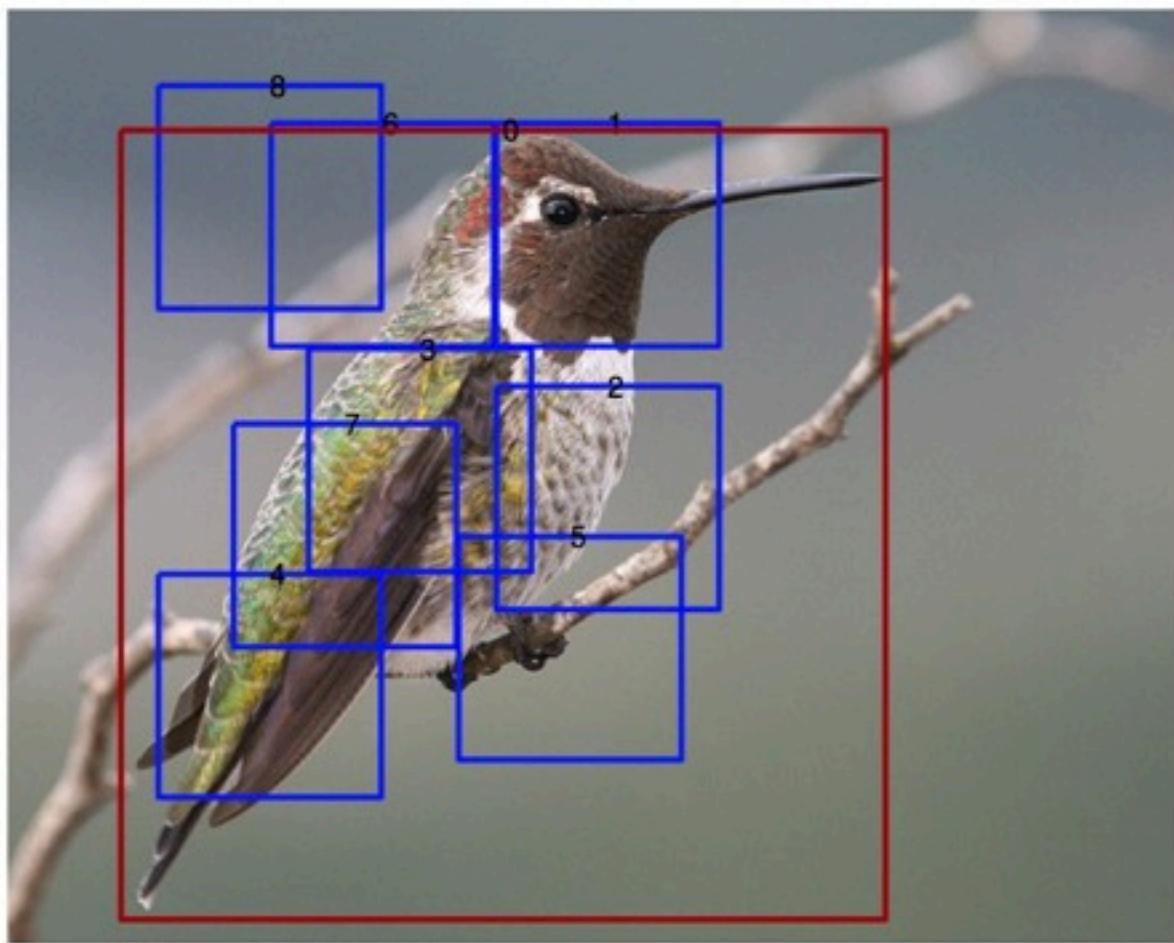
Krizhevsky, Sutskever, Hinton – NIPS 2012

AlexNet

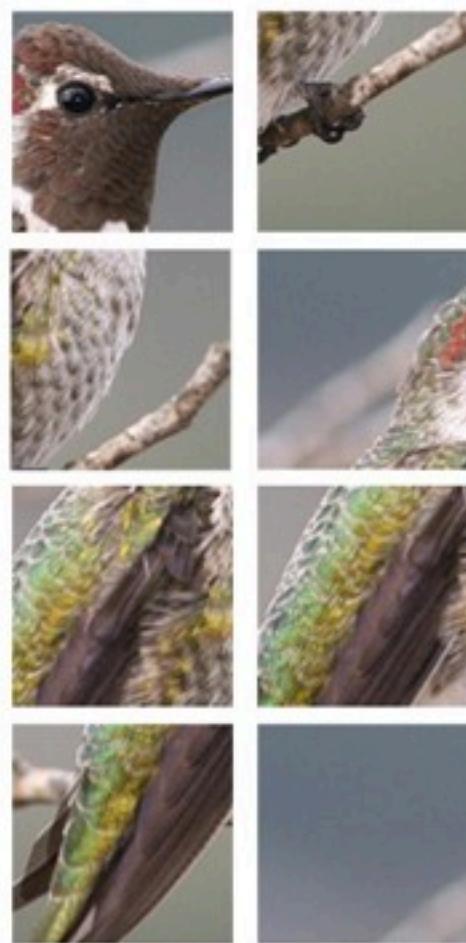


DeCAF

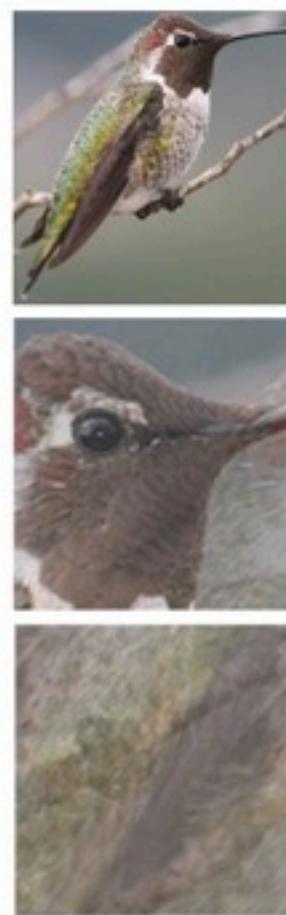
Donahue, Jia, et al. arXiv 2013



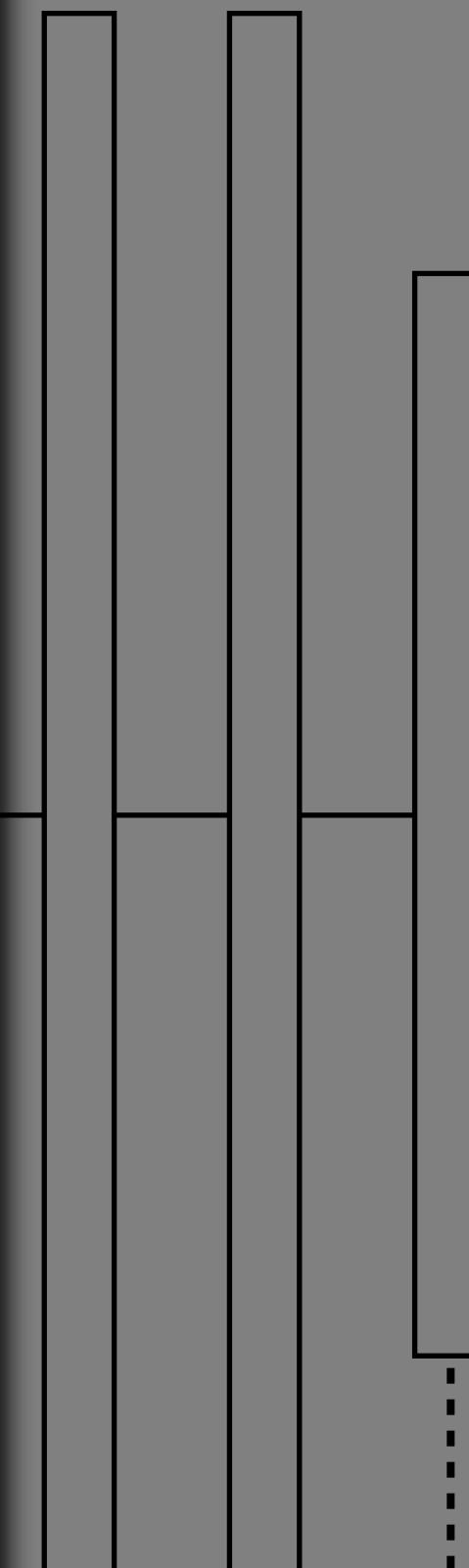
(a) DPM detections



(b) Parts



(c) DPD

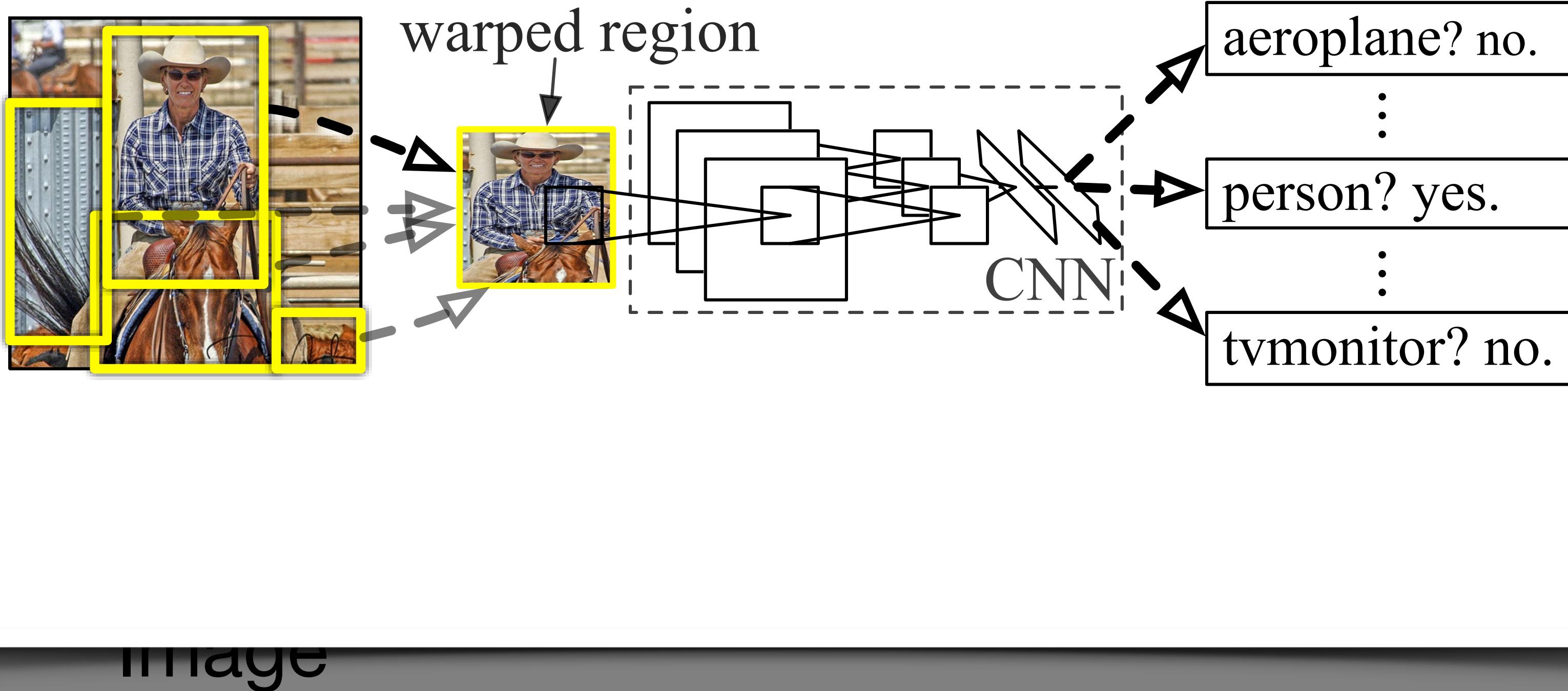


Image

labels

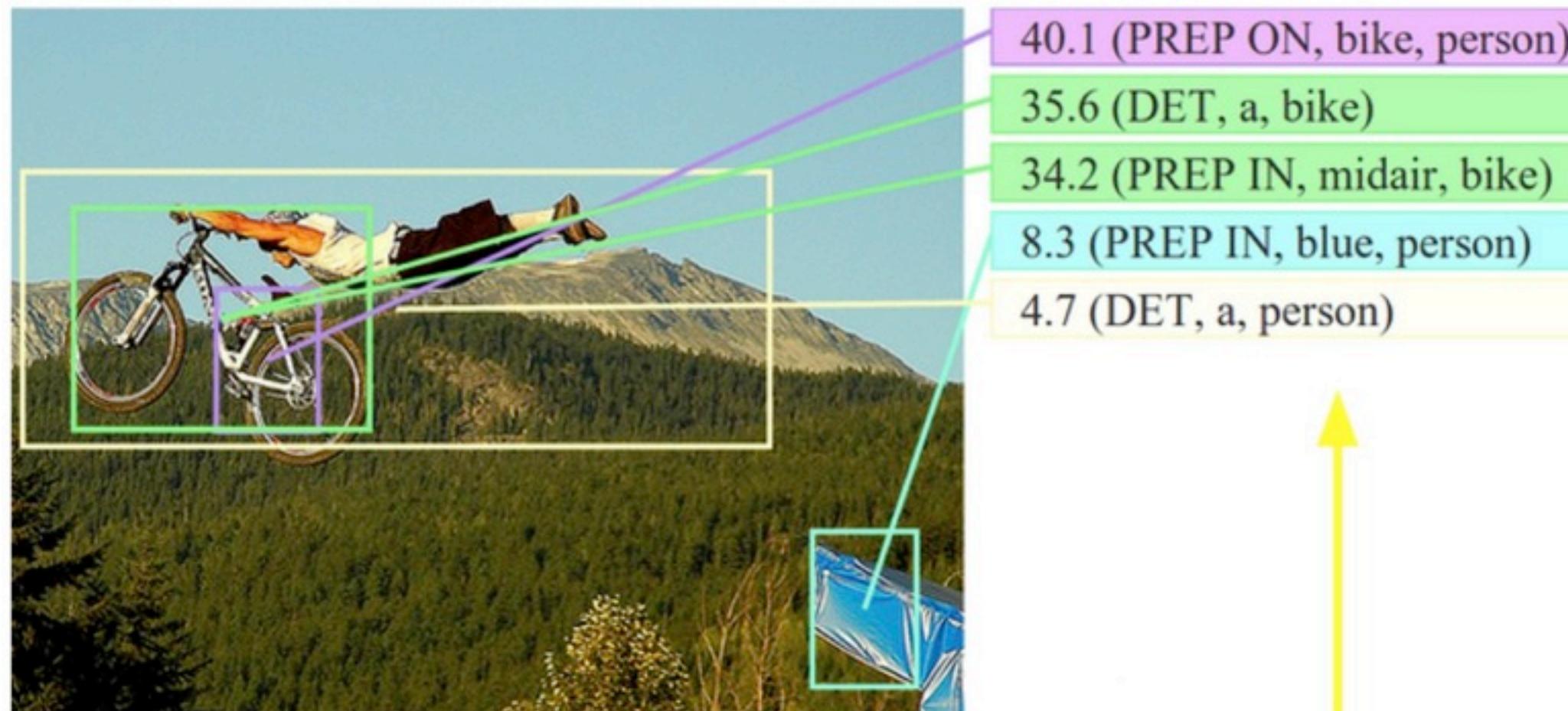
R-CNN

Girshick et al., CVPR 2014



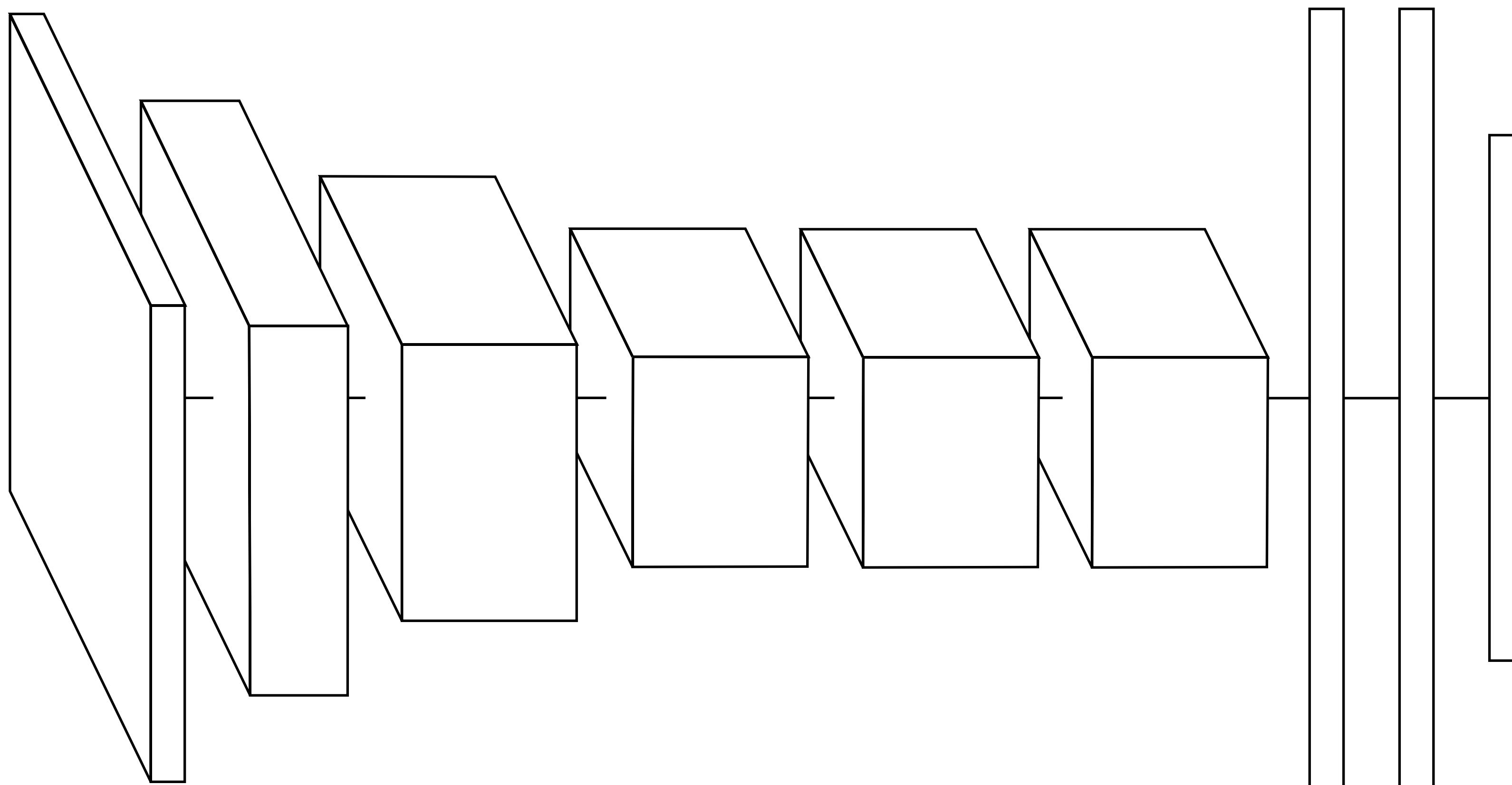
Deep Fragment Embeddings

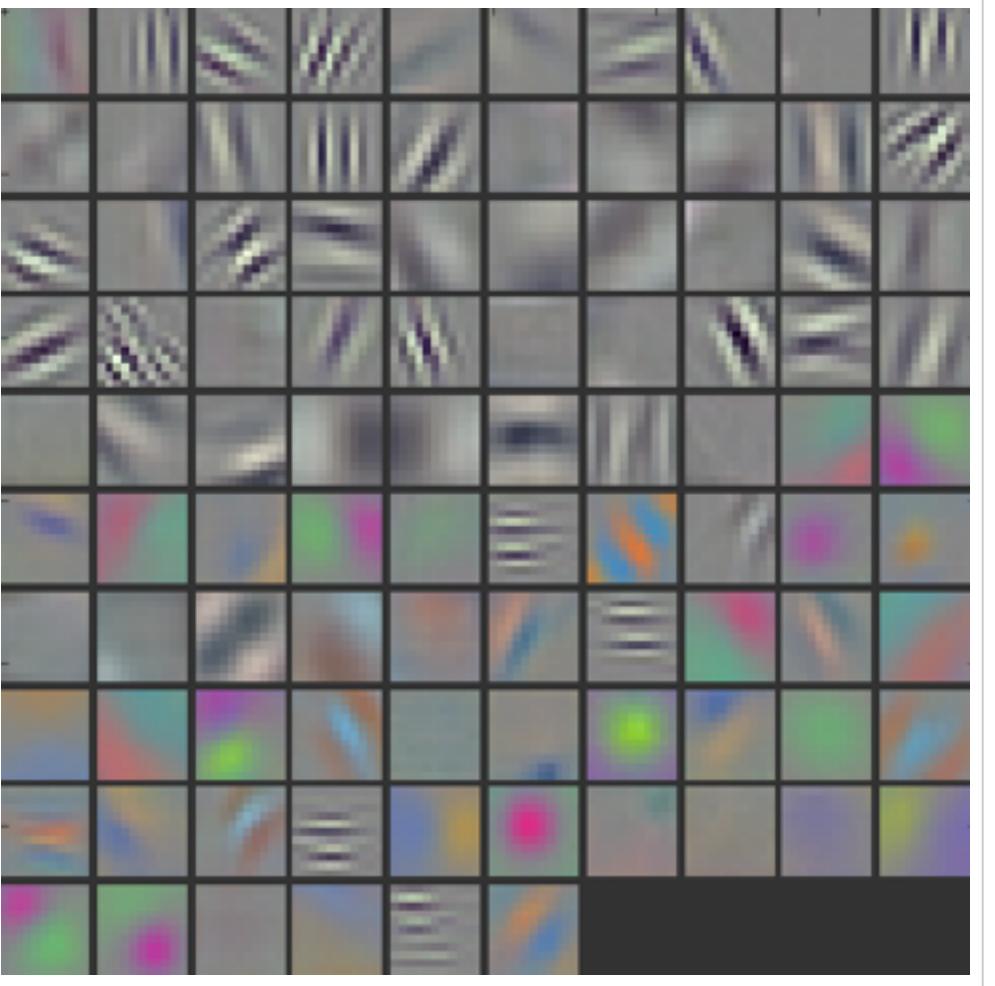
Karpathy et al. NIPS 2014



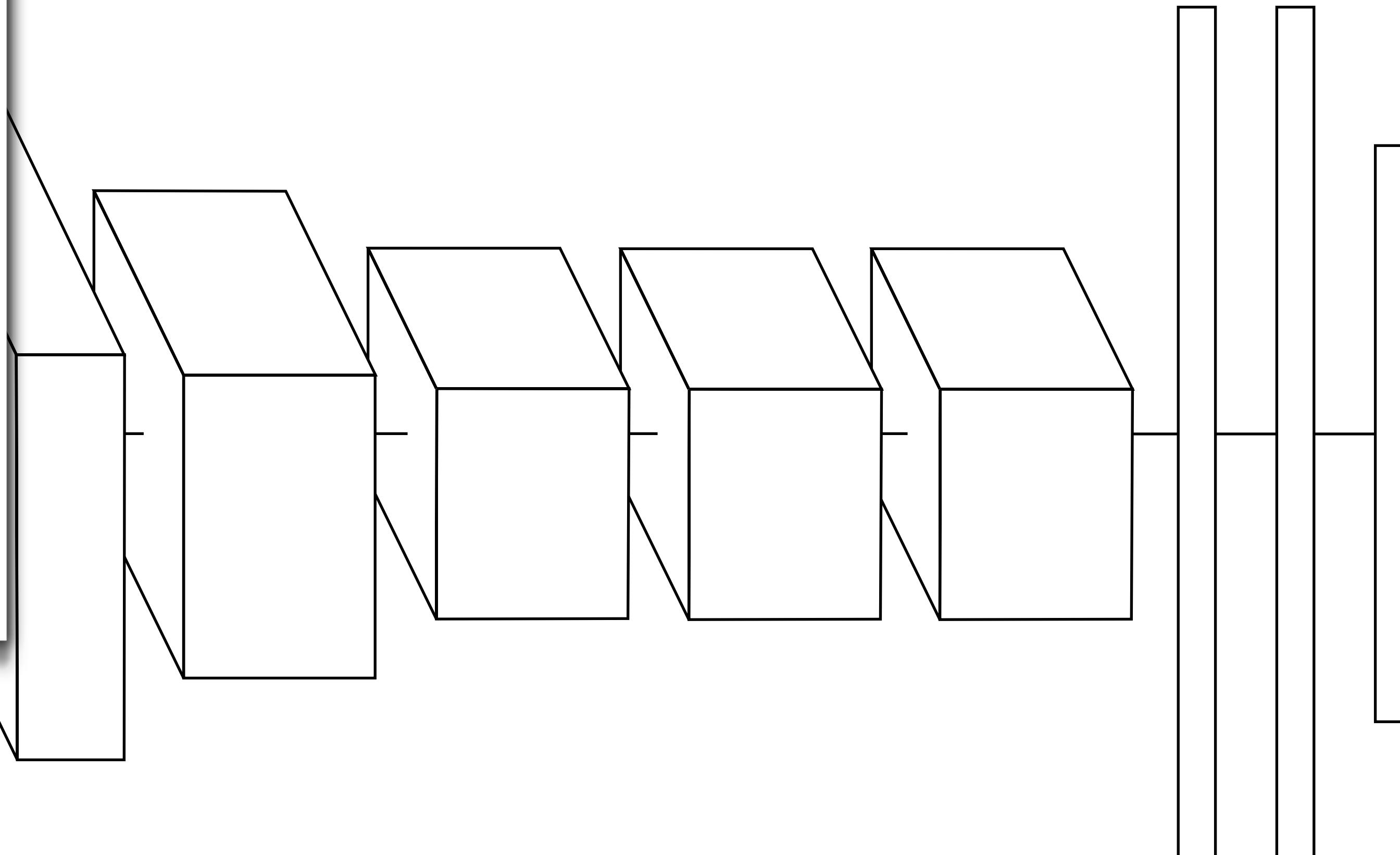
1. A person in blue on a bike in midair
2. Man on a dirt bike
3. A dirt biker flies through the air
4. A person on a dirt bike soaring through the air sideways
5. A dirt biker leaps through the air

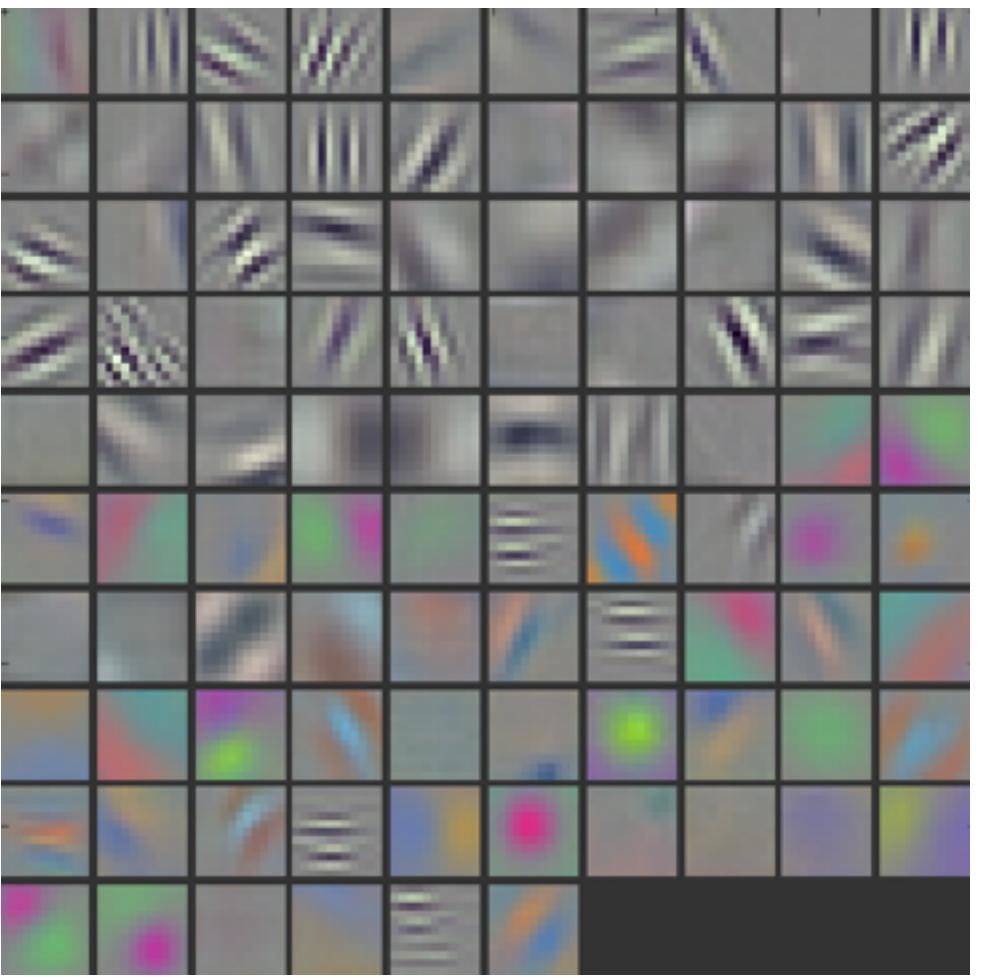
bel



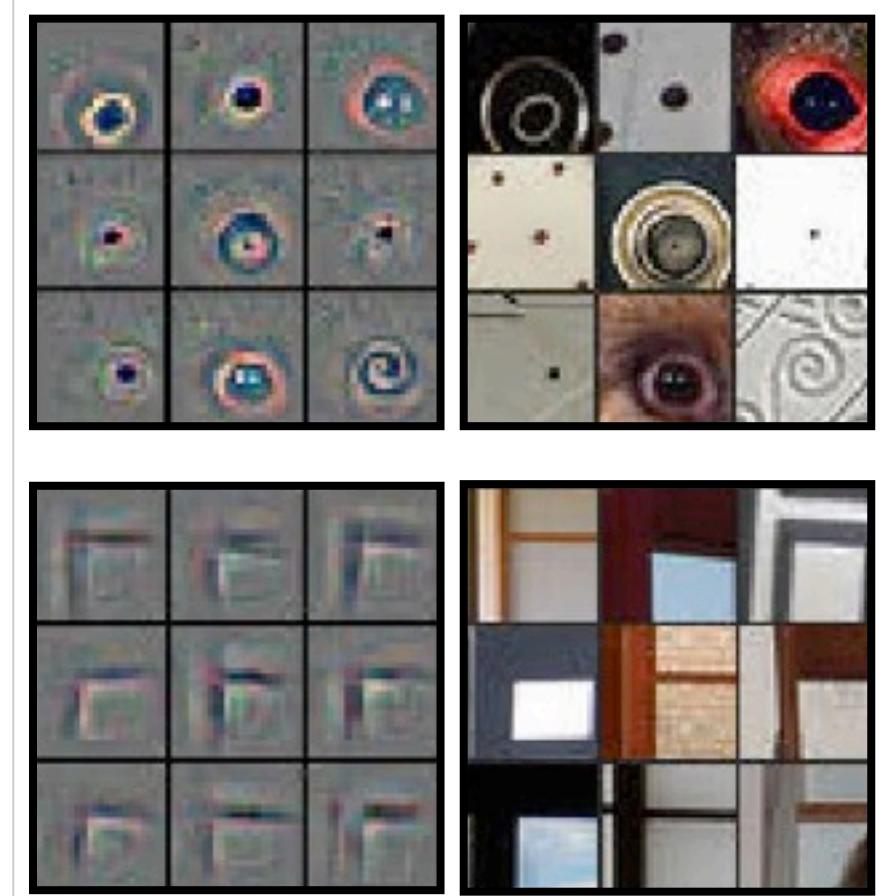


Layer 1
Gabor +
color blobs

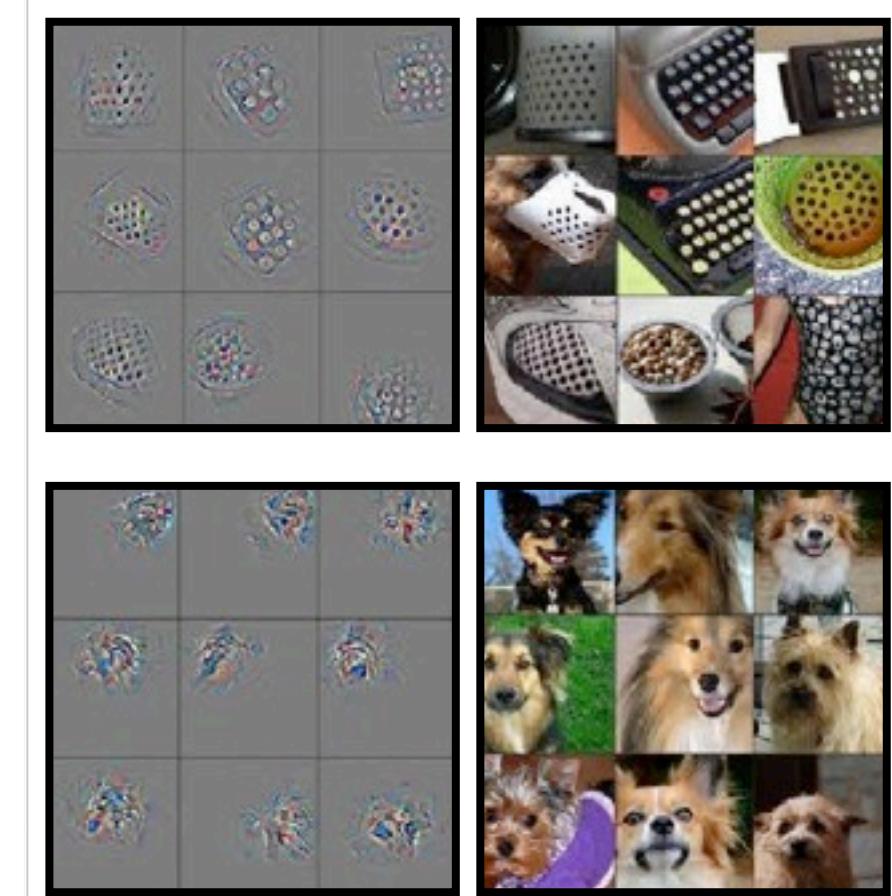




Layer 1
Gabor +
color blobs

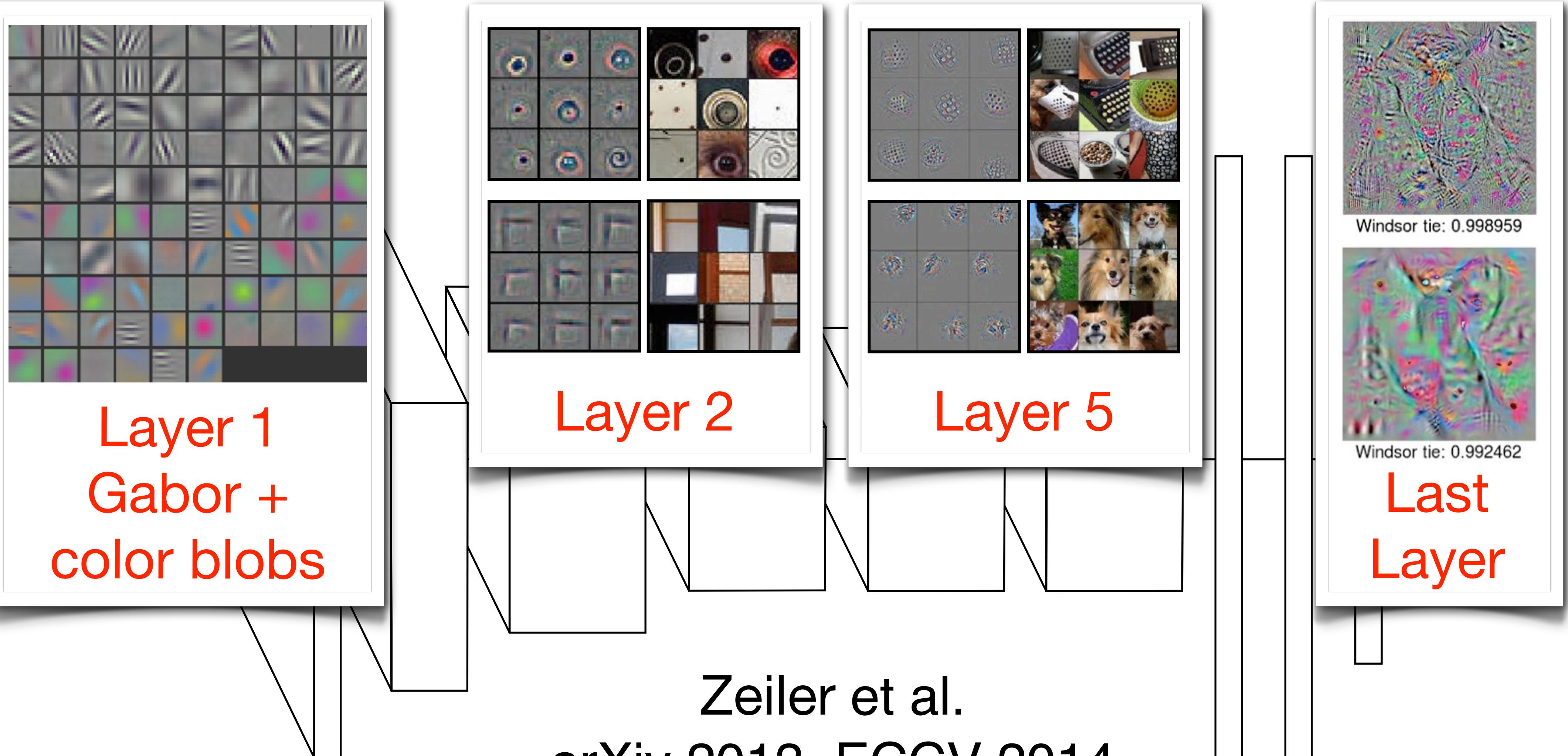


Layer 2



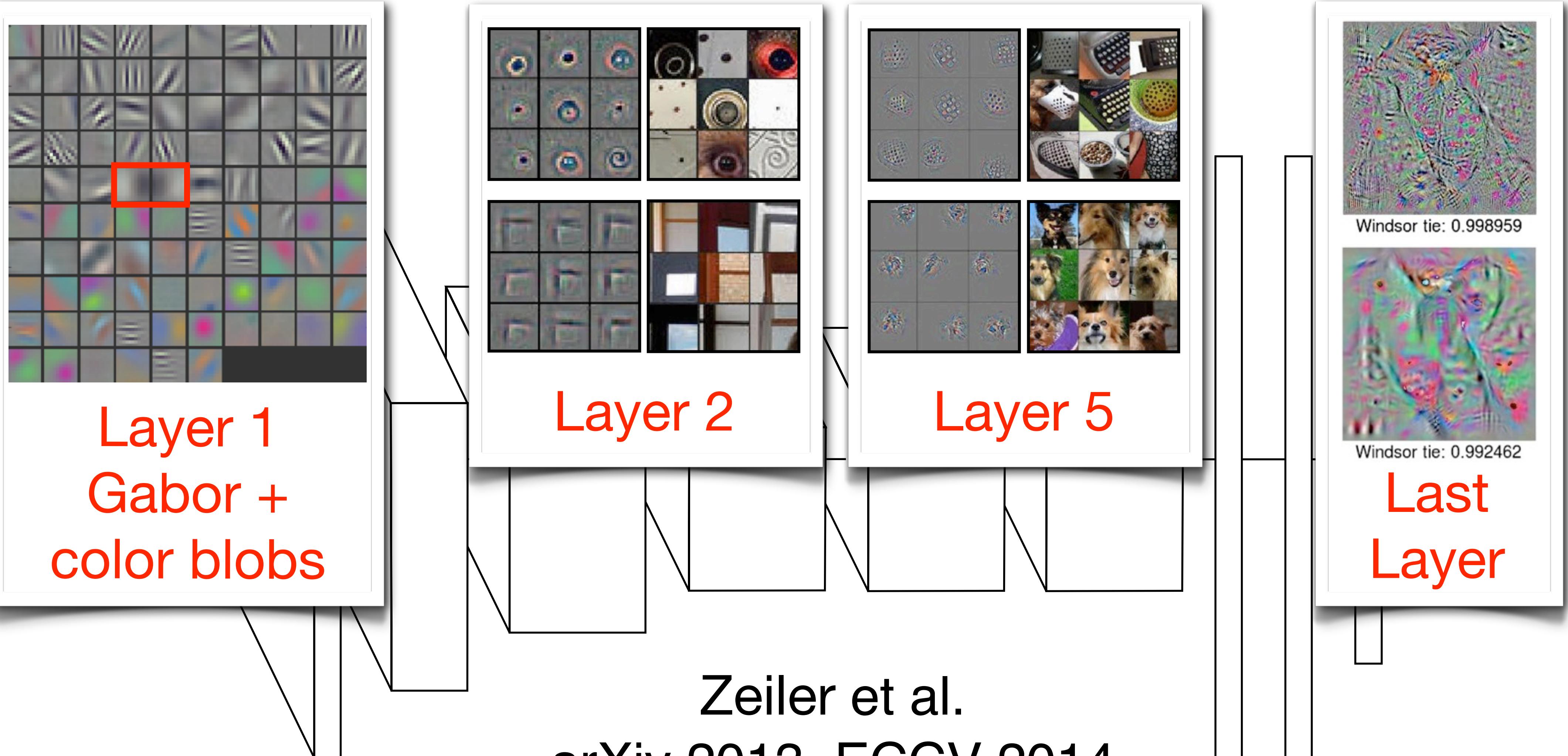
Layer 5

Zeiler et al.
arXiv 2013, ECCV 2014



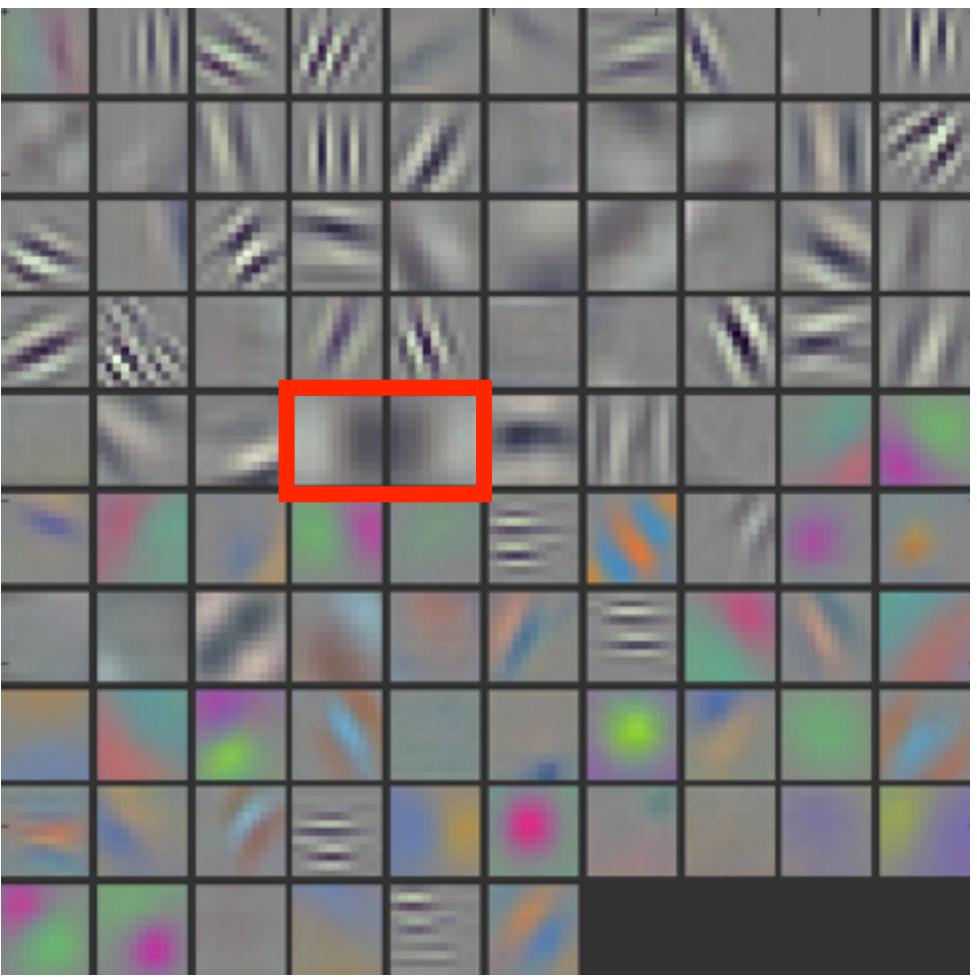
Zeiler et al.
arXiv 2013, ECCV 2014

Nguyen et al.
arXiv 2014

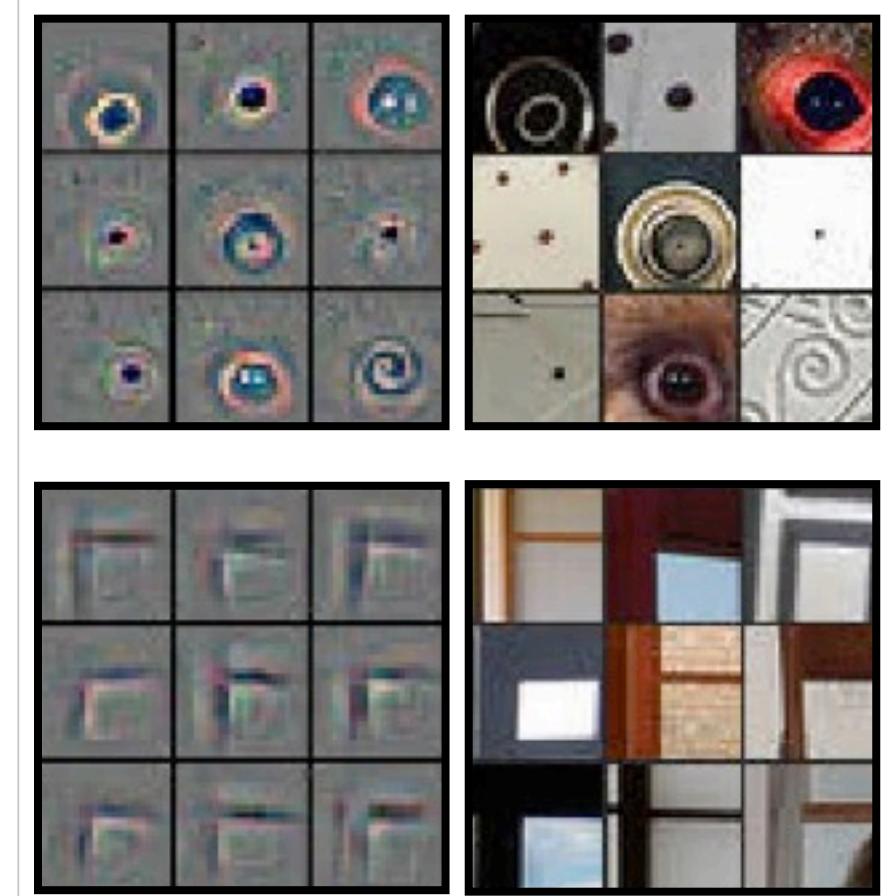


Zeiler et al.
arXiv 2013, ECCV 2014

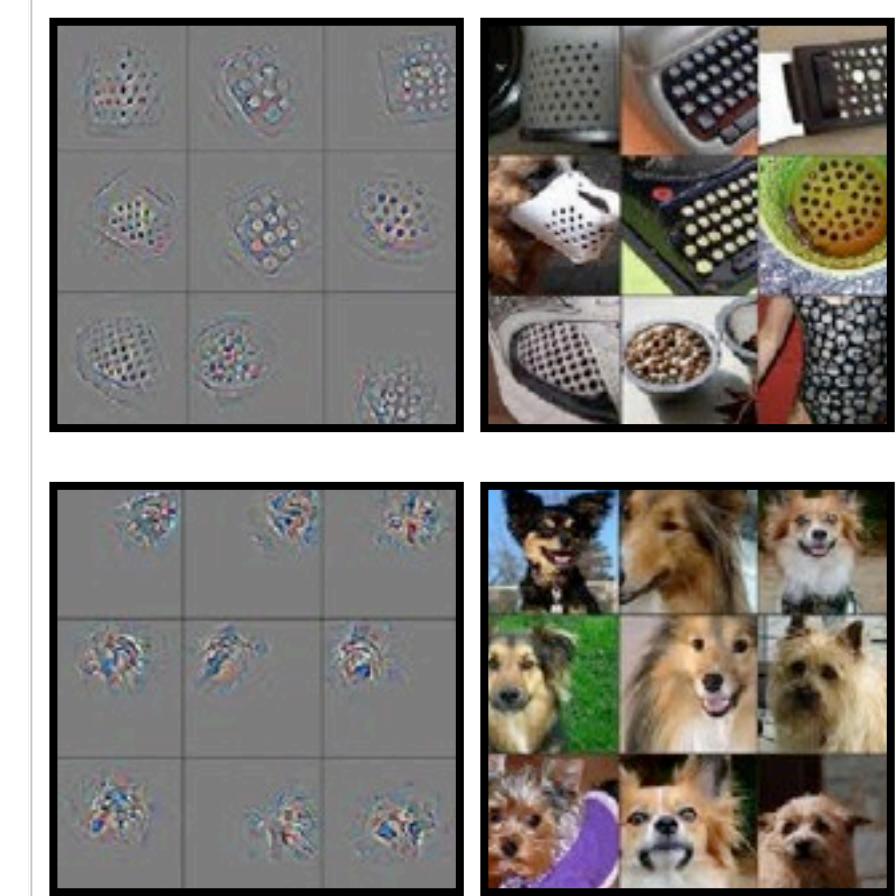
Nguyen et al.
arXiv 2014



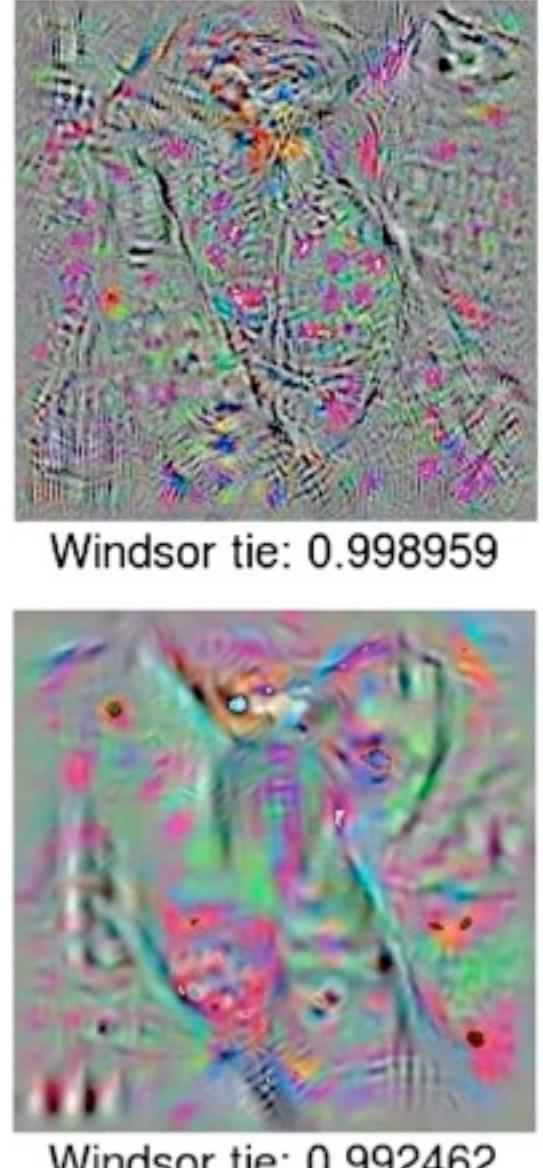
Layer 1
Gabor +
color blobs



Layer 2



Layer 5

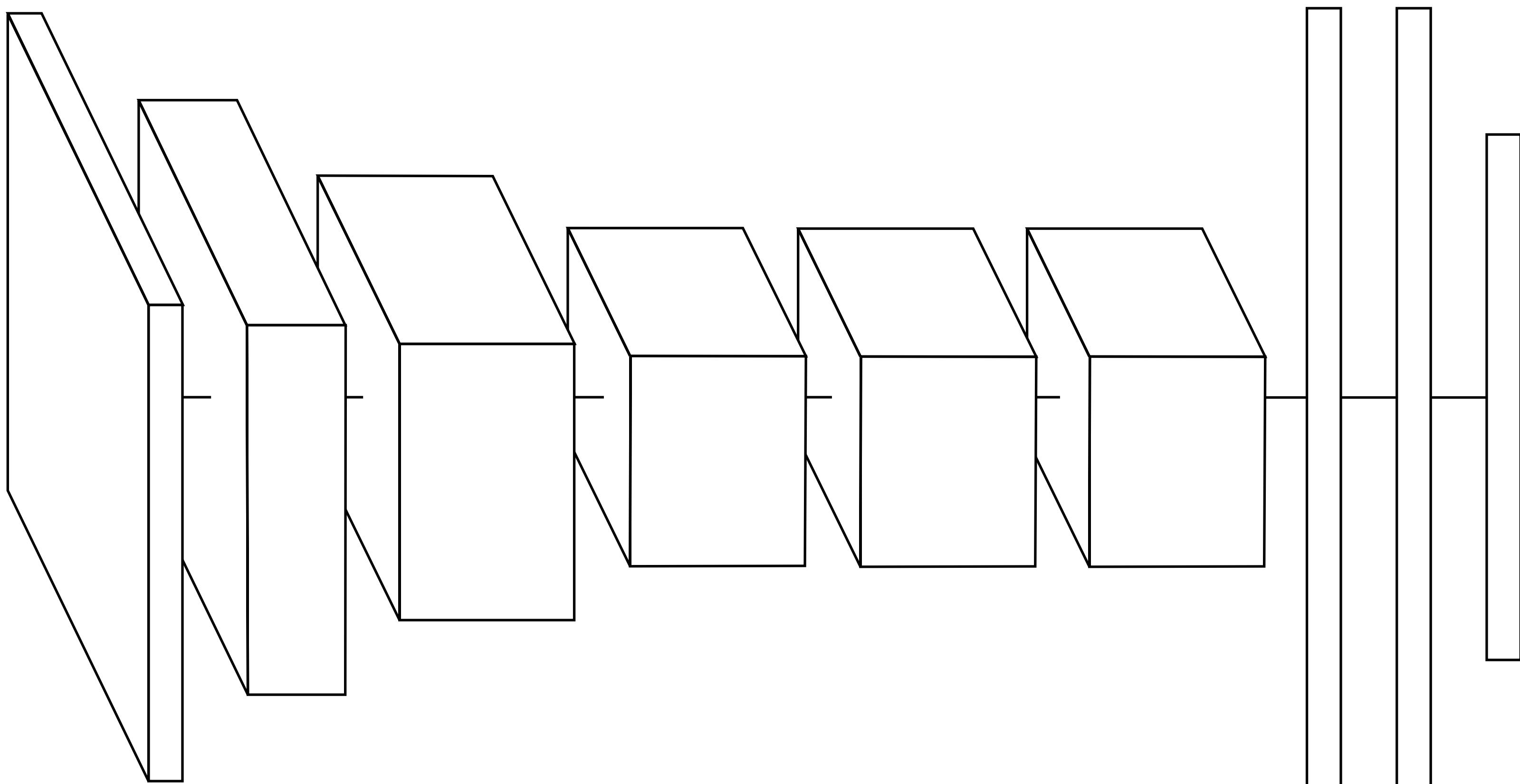


Last
Layer

Zeiler et al.
arXiv 2013, ECCV 2014

Demo
Tonight

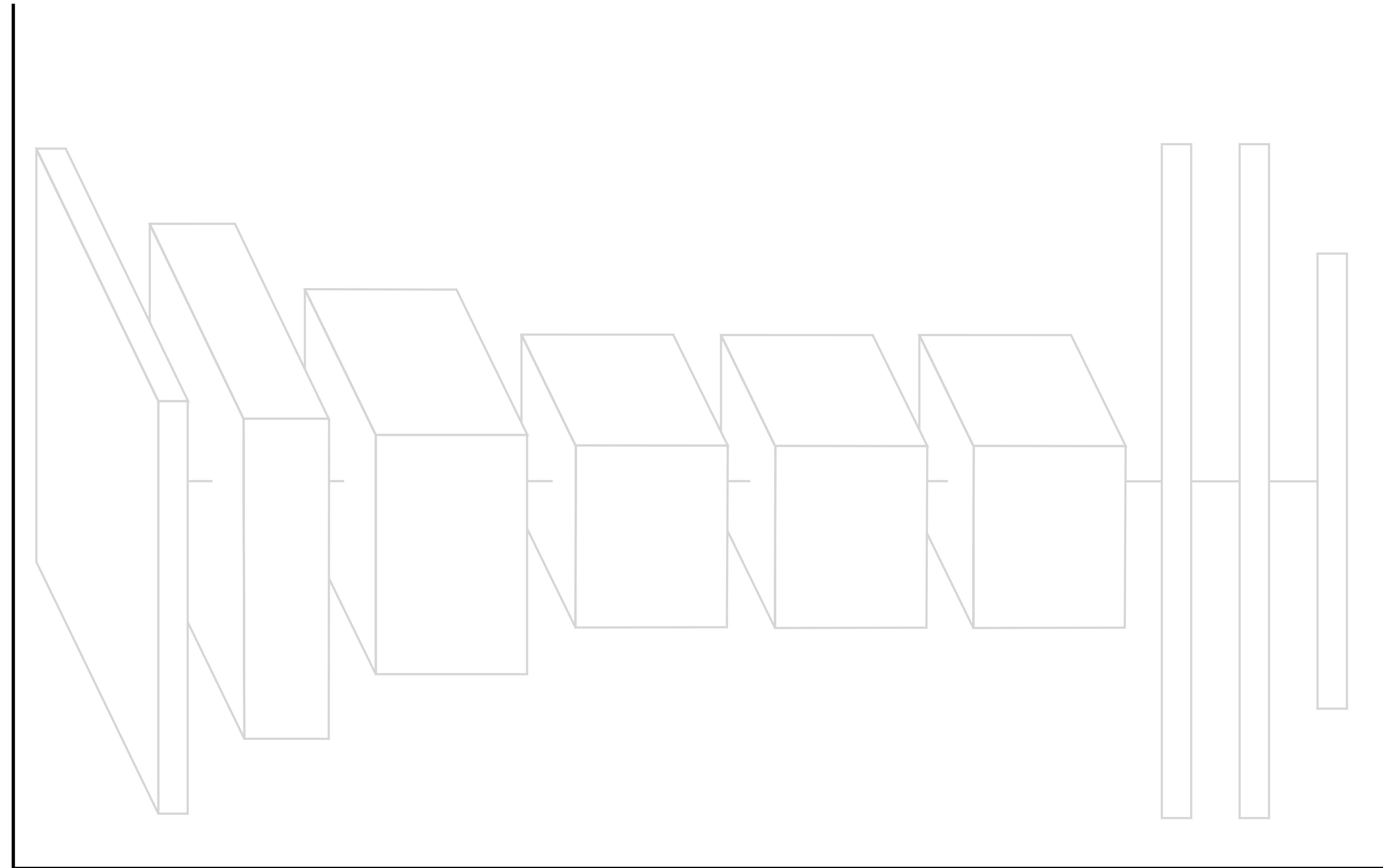
Nguyen et al.
arXiv 2014



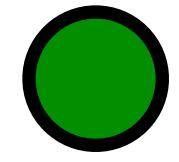
general

specific

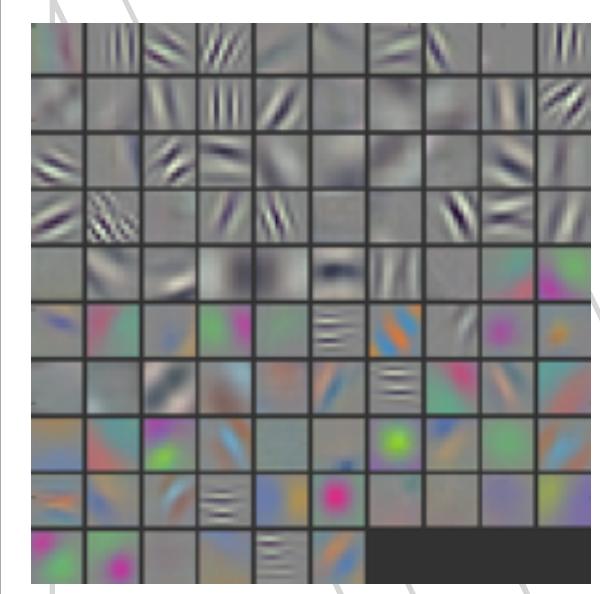
Layer number



general

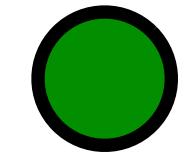


specific



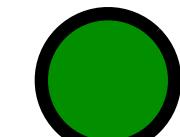
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general

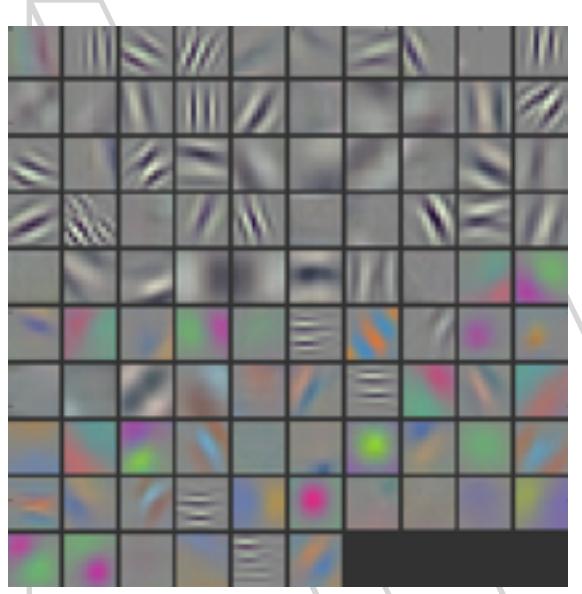


specific

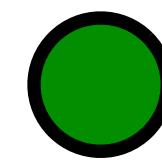
Lion



Layer number

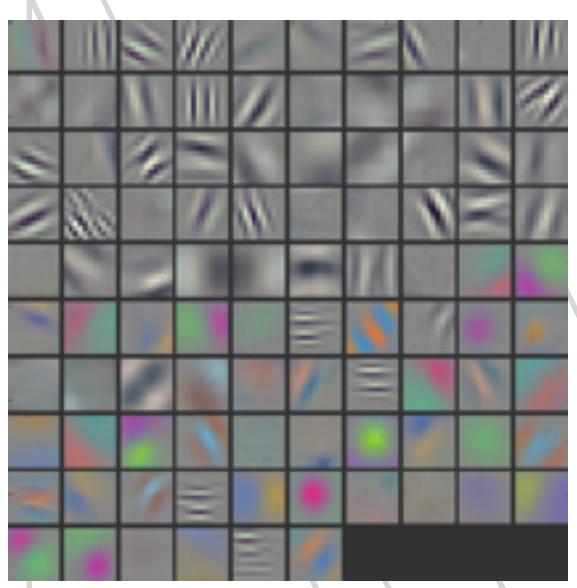
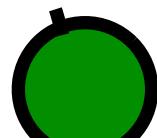


general



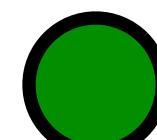
specific

Lion



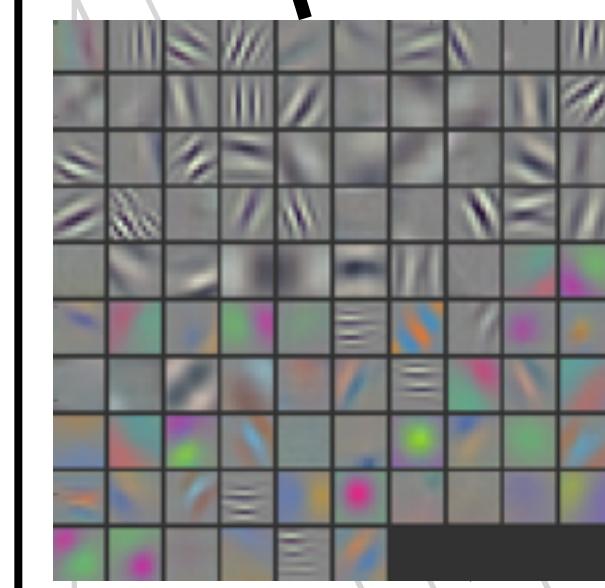
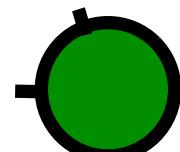
Layer number

general

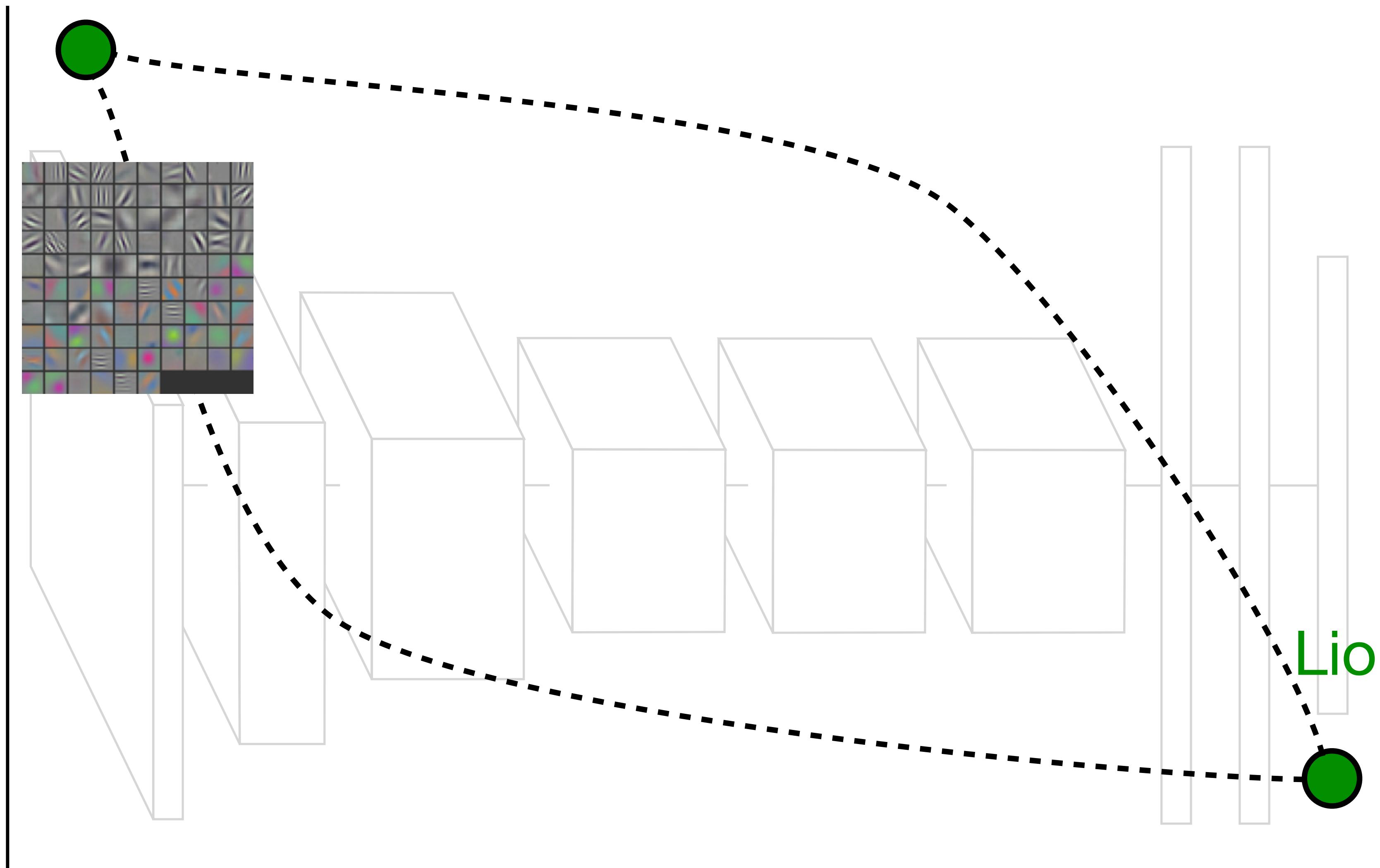


specific

Lion

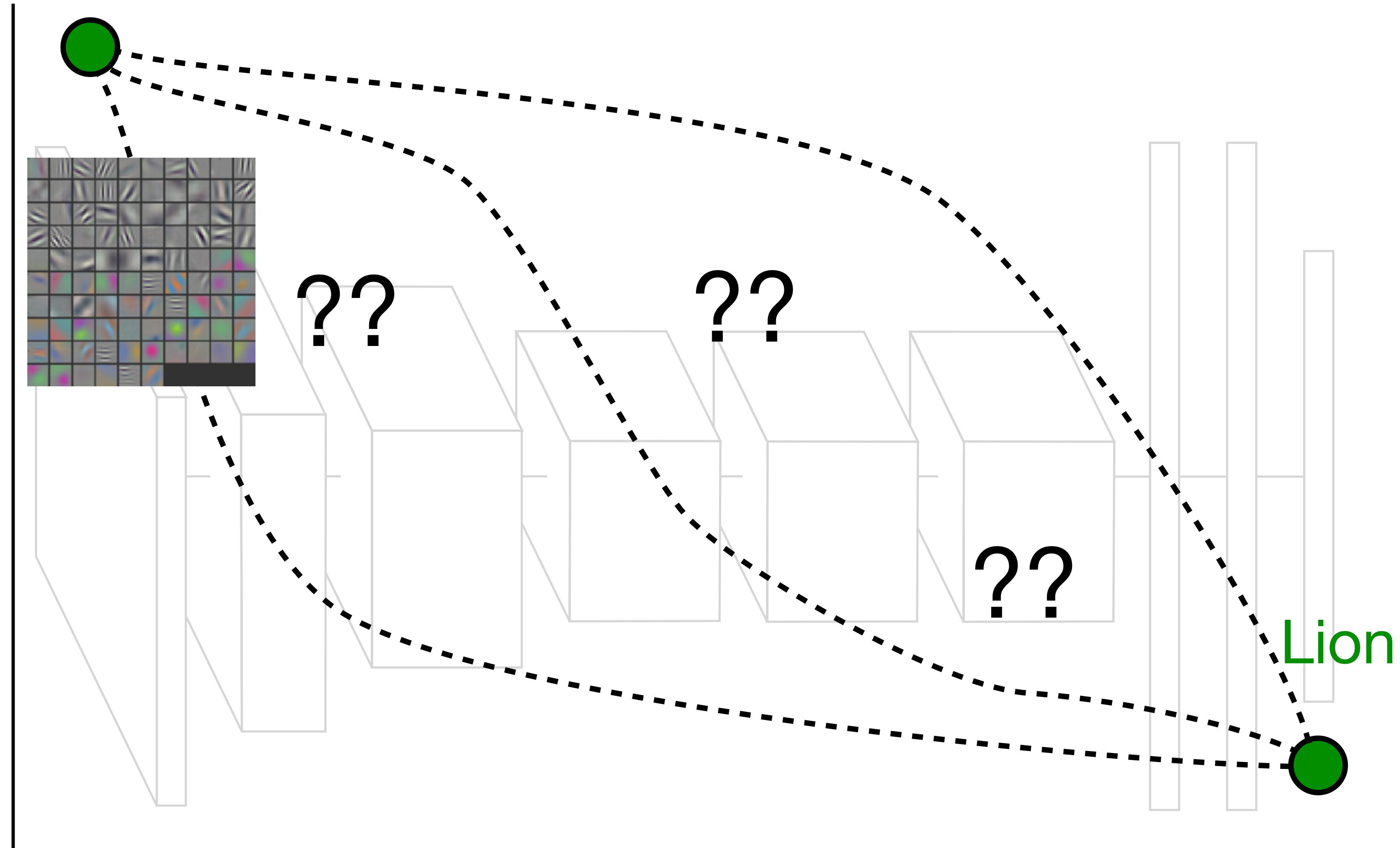


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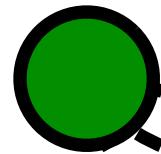
general

specific



Layer number

general



Main idea:
Quantify the *general* to *specific* transition
by using transfer learning.

specific

Lion

Layer number

general



Main idea:

Quantify the *general* to *specific* transition
by using transfer learning.

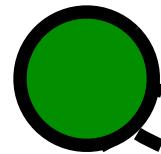
Depends on tasks A and B.

specific

Lion

Layer number

general



Main idea:

Quantify the *general* to *specific* transition
by using transfer learning.

Depends on tasks A and B.

Very useful to know!

specific

Lion

Layer number

ImageNet



1000 Classes

Deng et al., 2009

ImageNet



1000 Classes

dataset

A



500 Classes

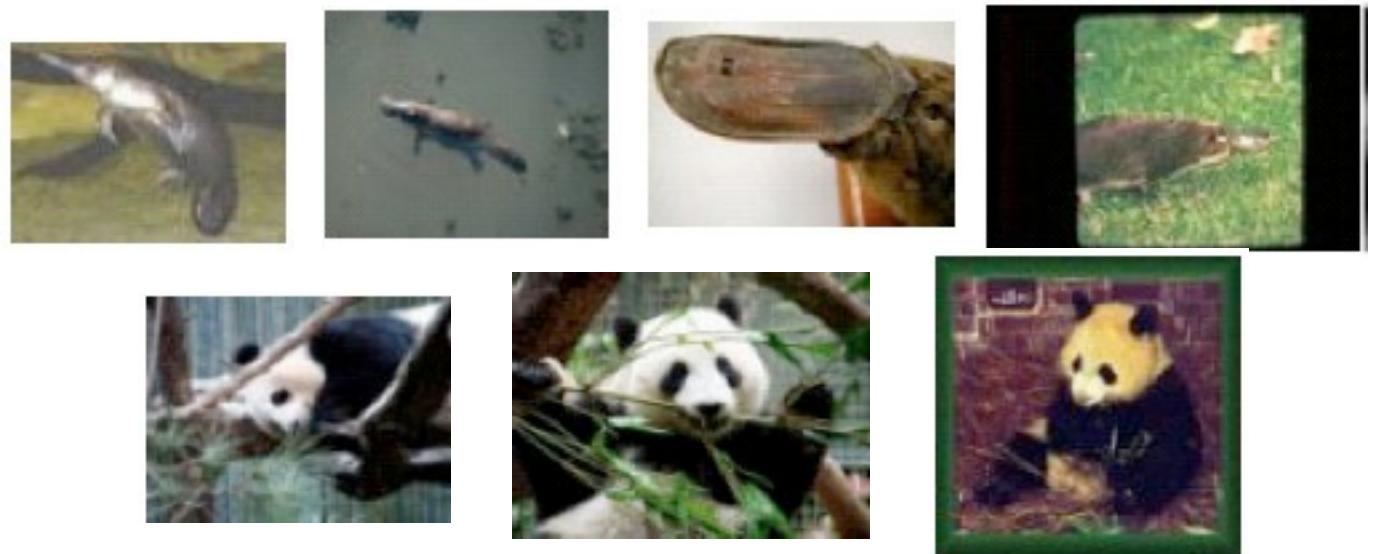
dataset

B



500 Classes

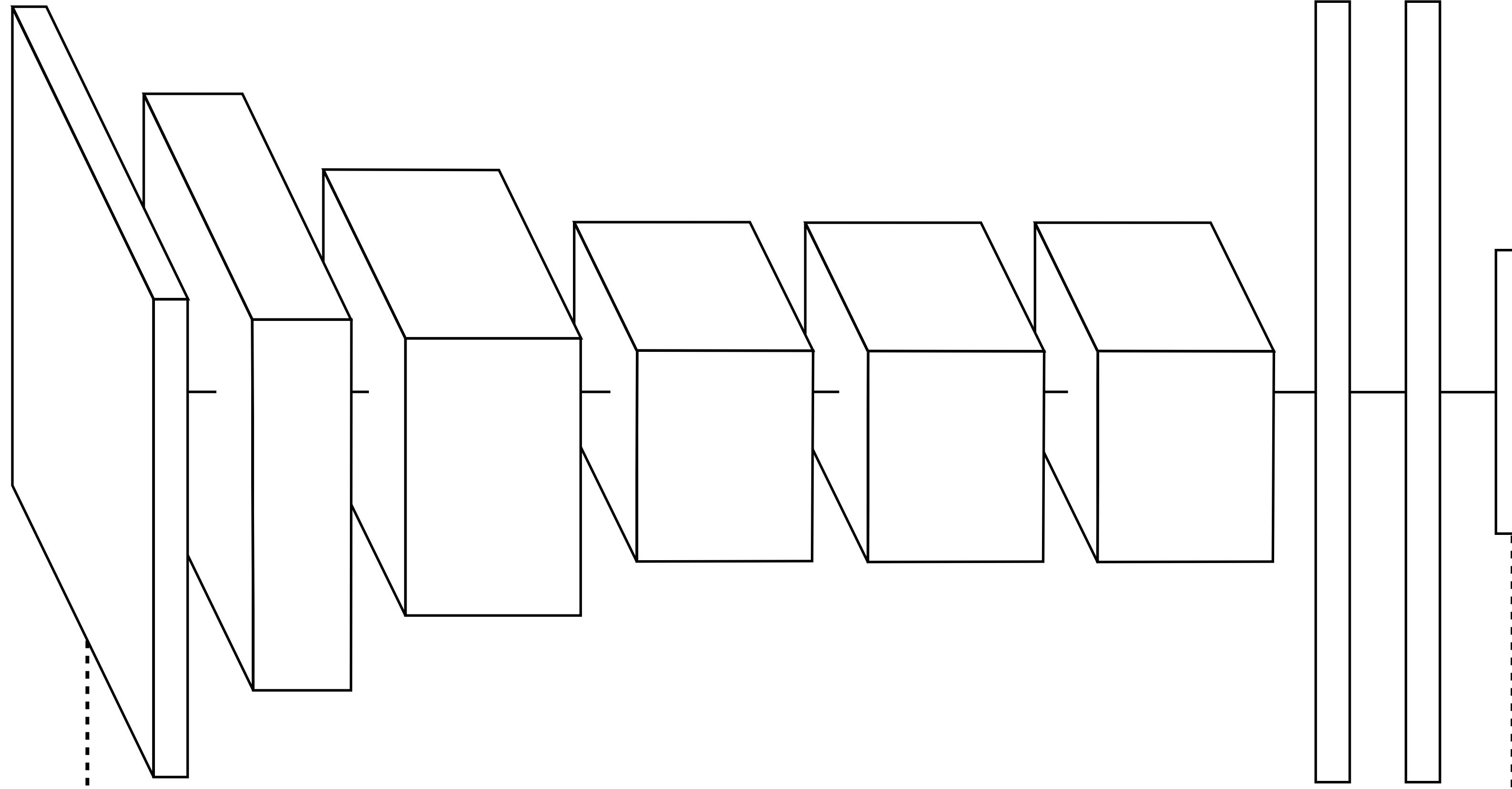
A Images



500 Classes

A Labels

Train using Caffe framework (Jia et al.)



A Images

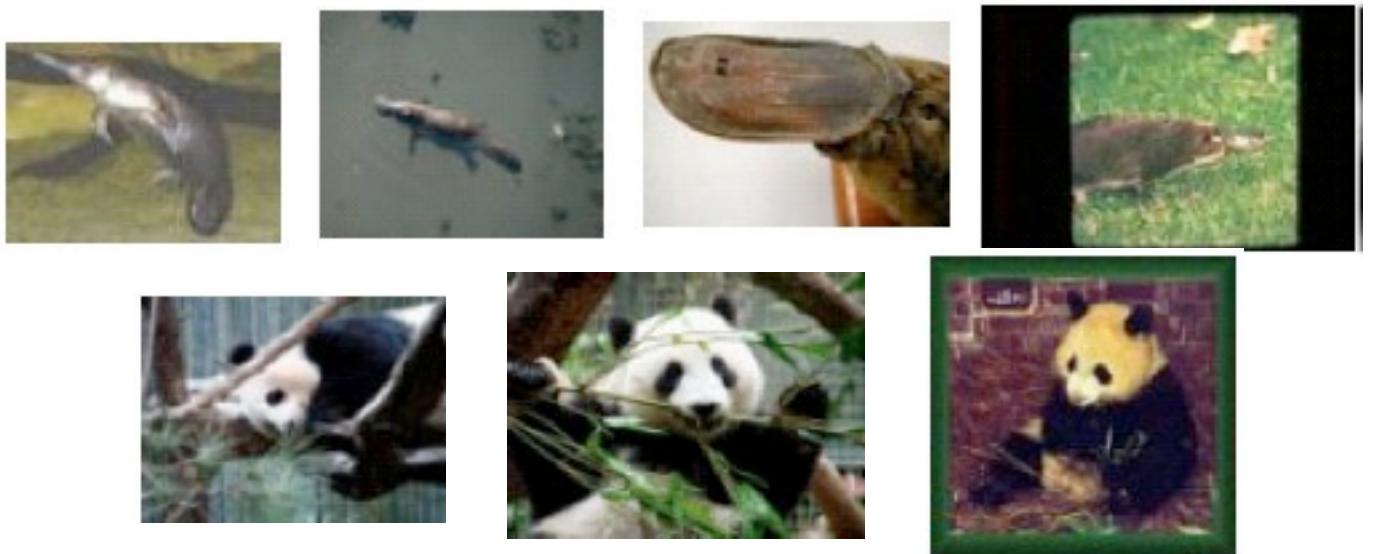


500 Classes

A Labels

Train using Caffe framework (Jia et al.)

A Images



500 Classes

A Labels

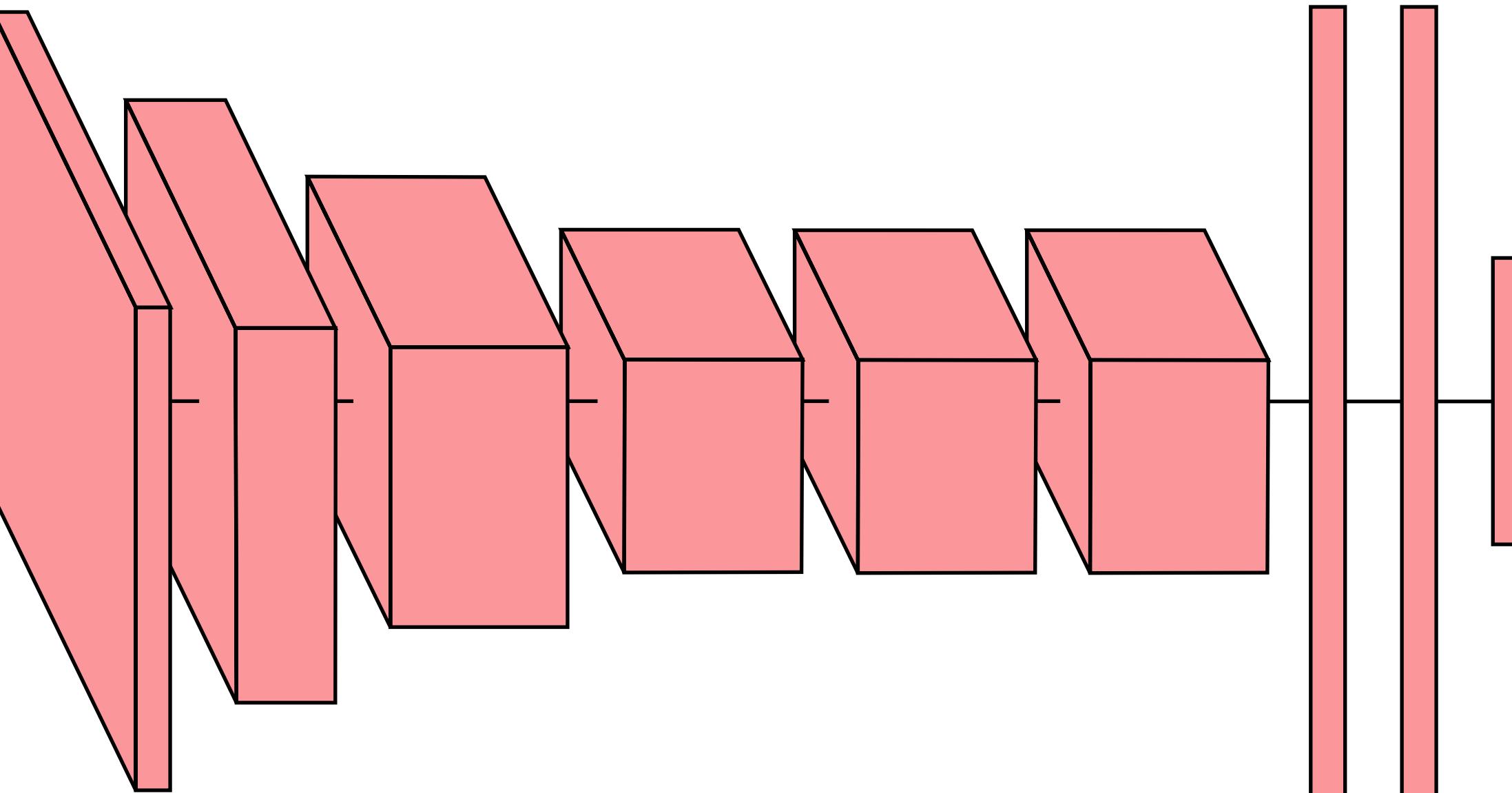
Train using Caffe framework (Jia et al.)



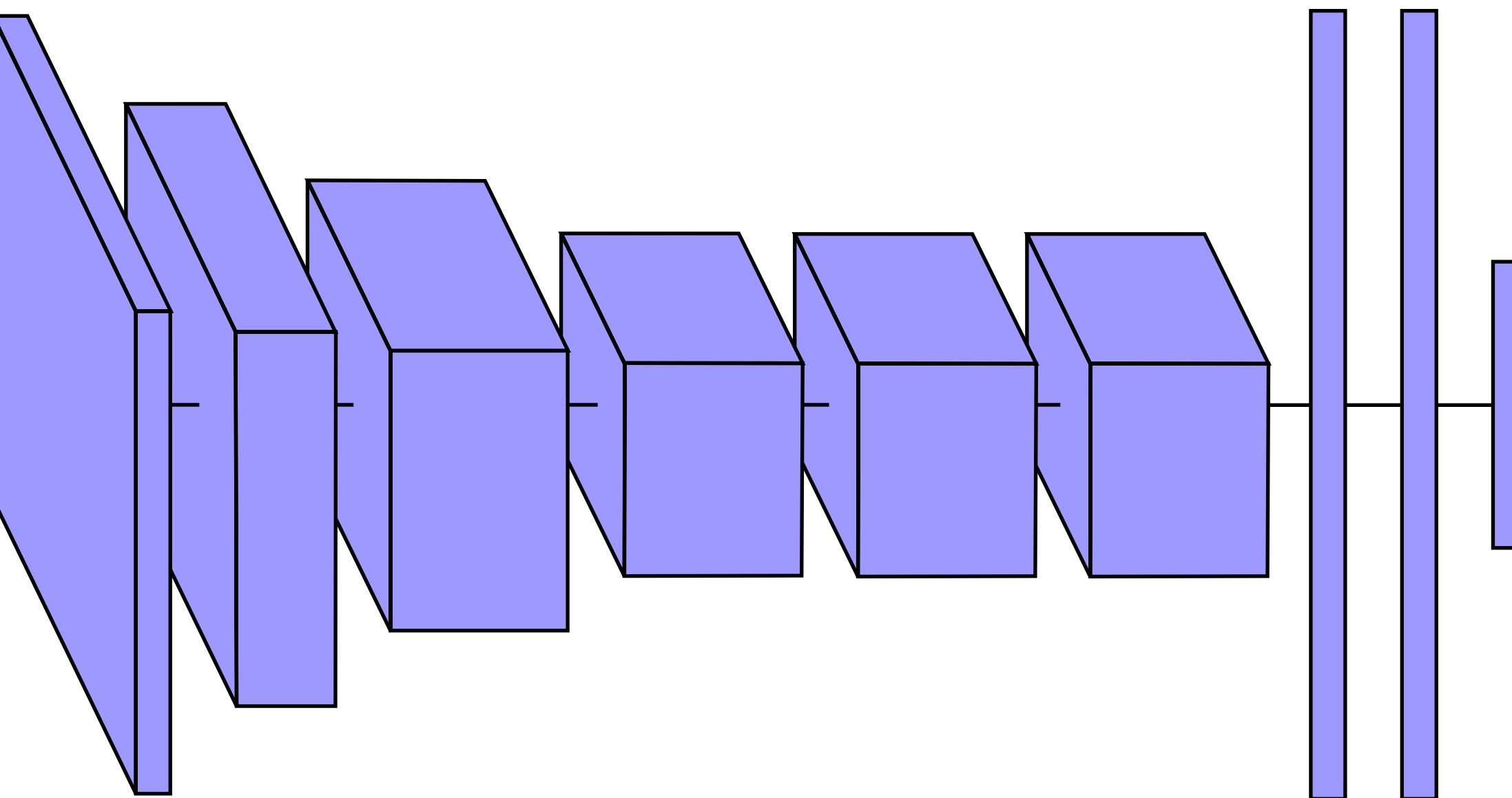
A Images



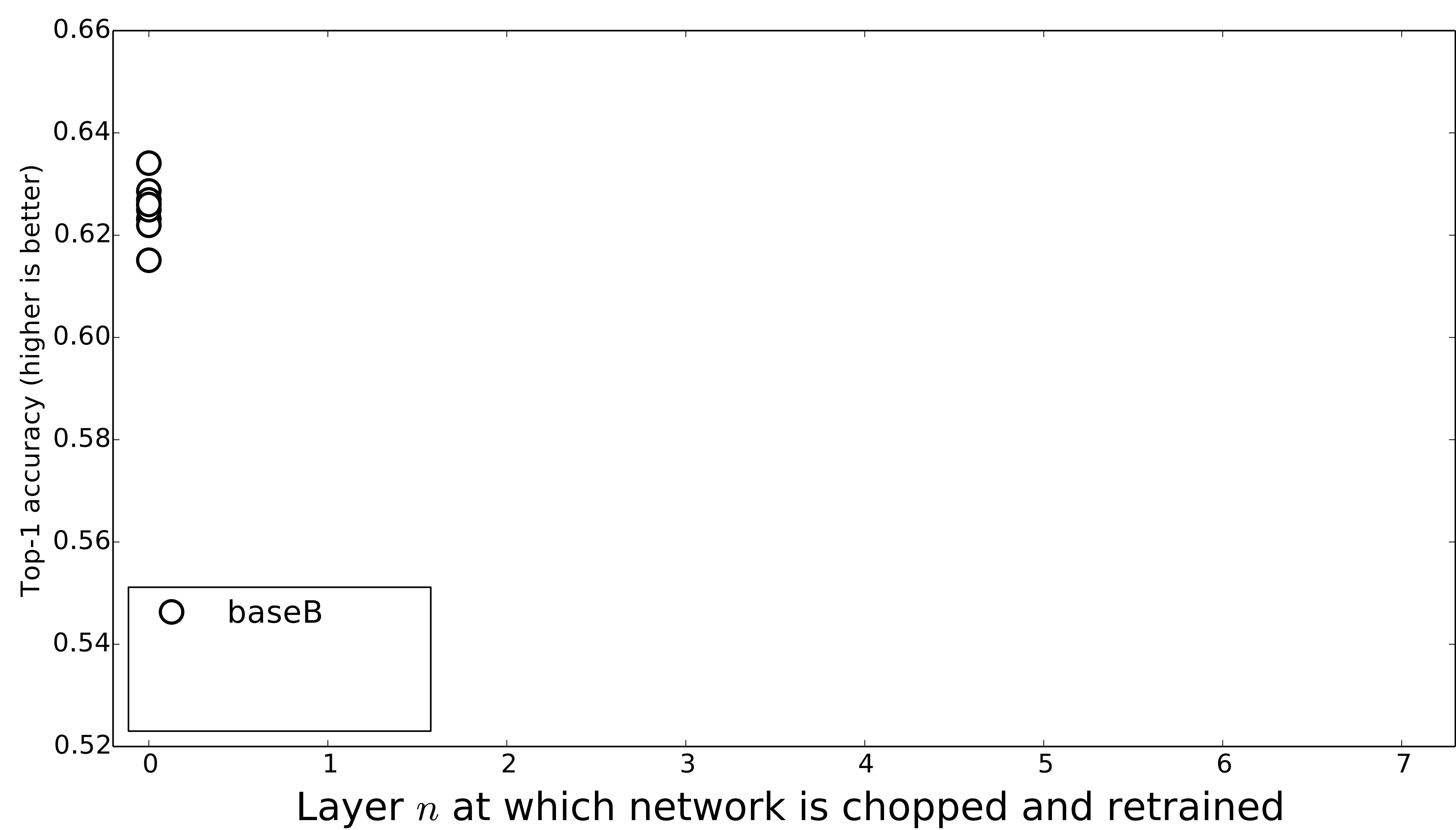
B Images

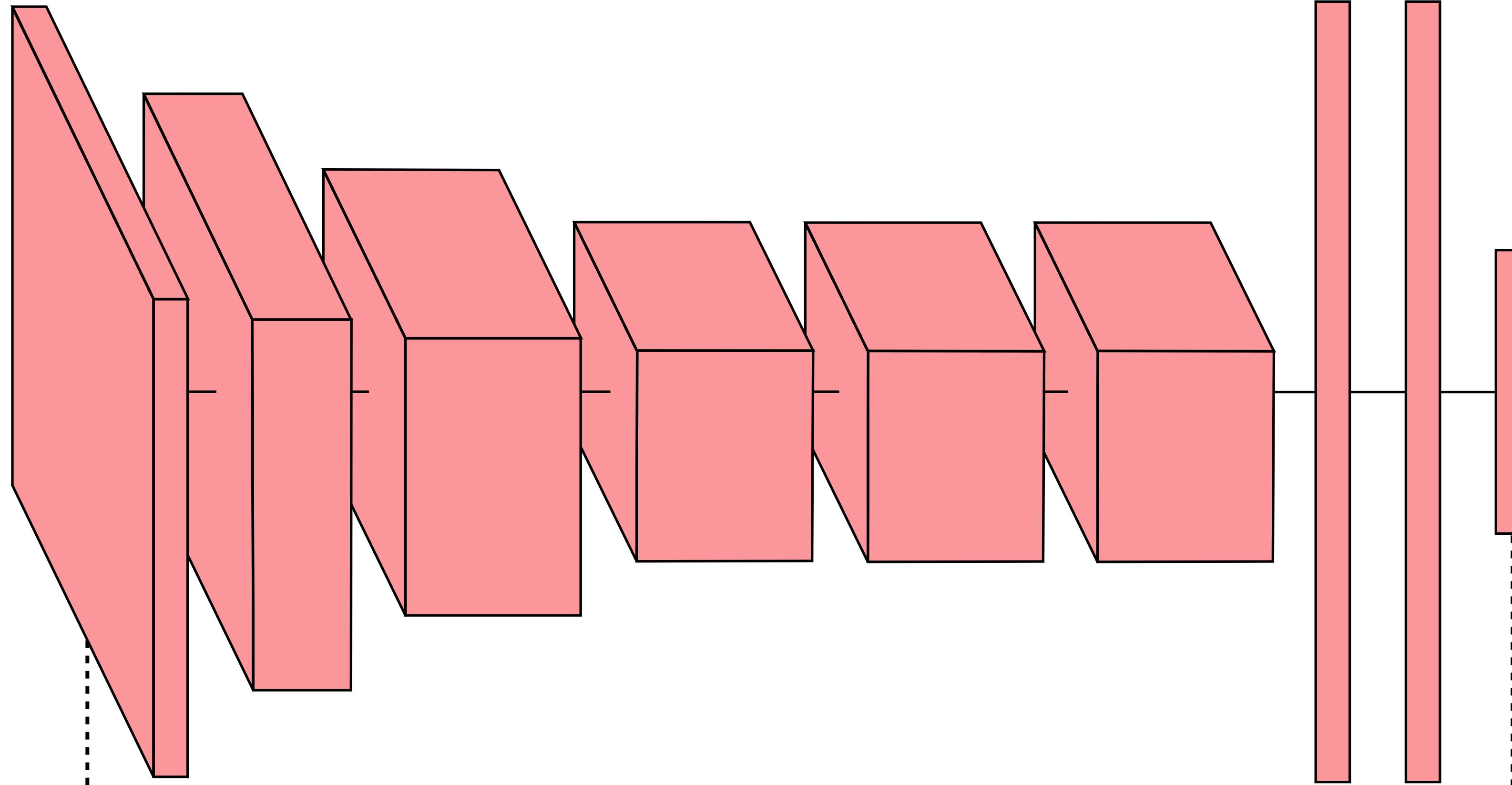


baseA



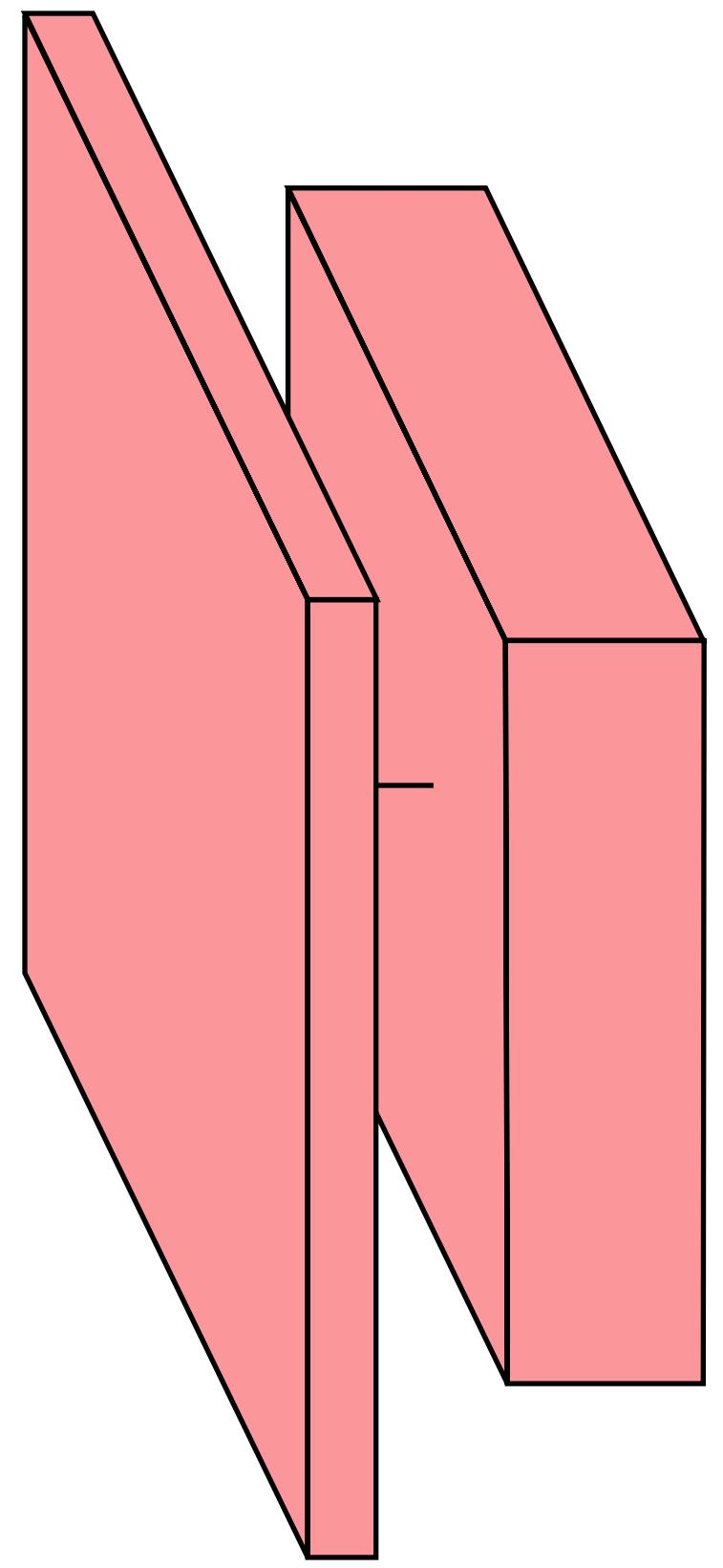
baseB

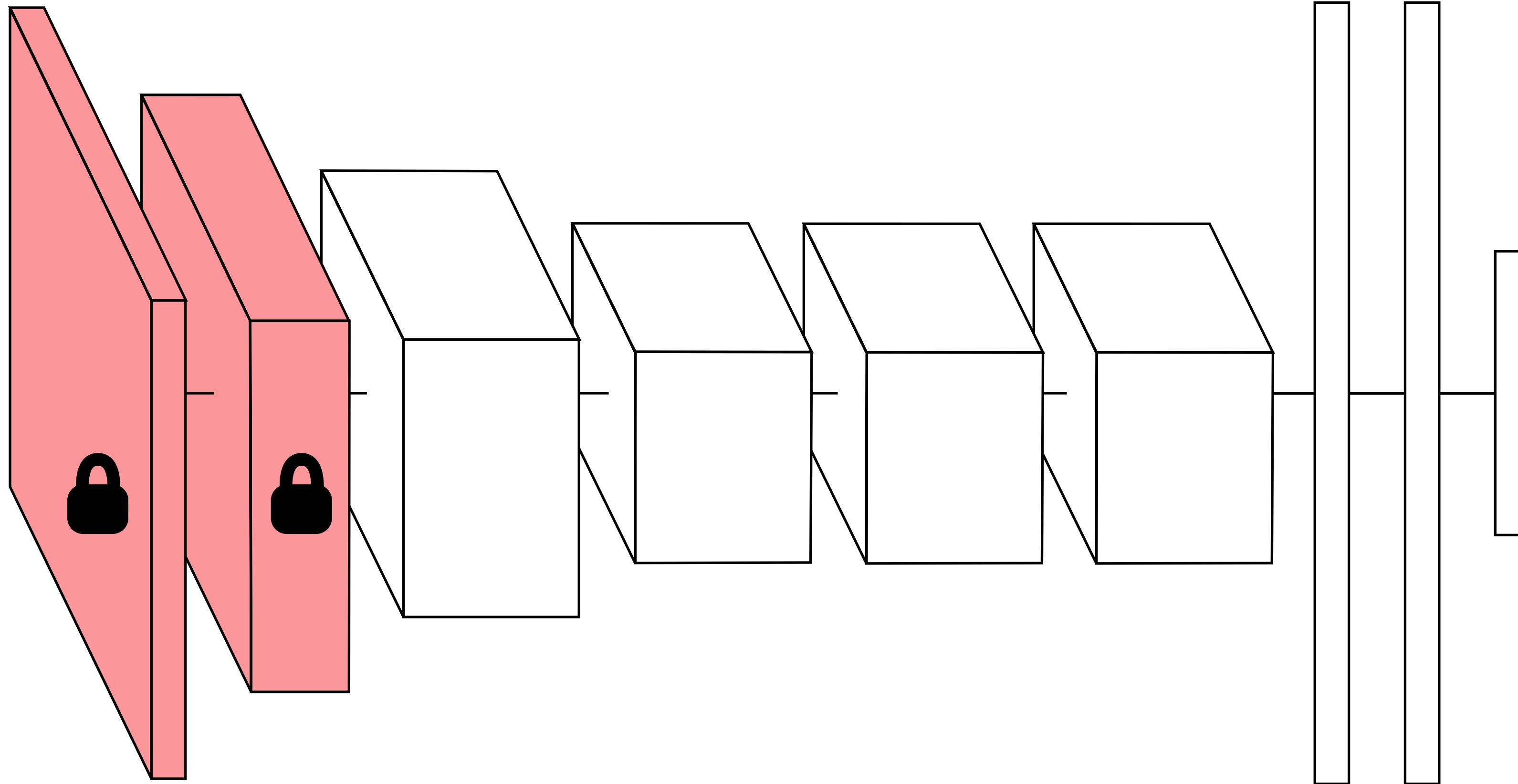


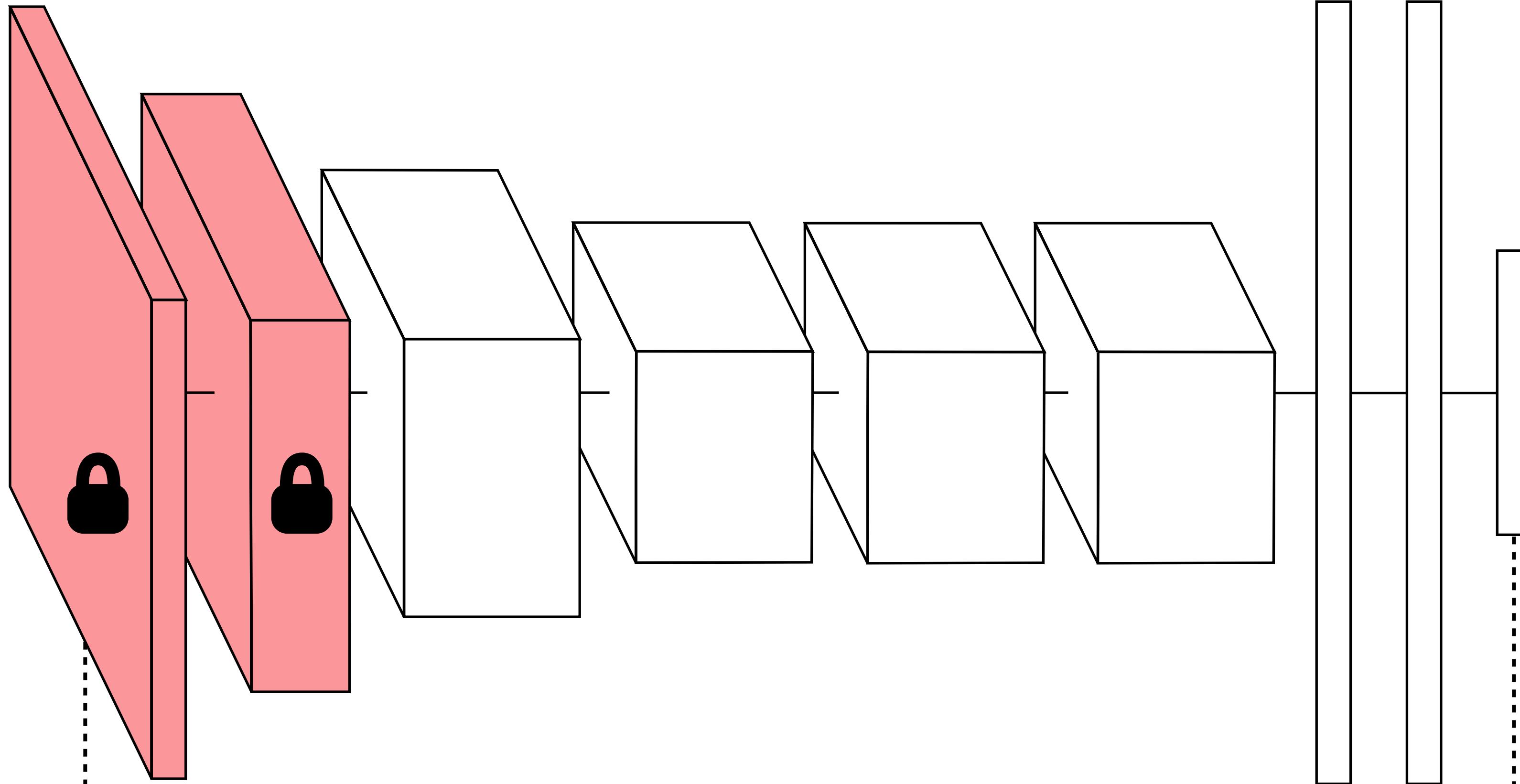


A Images

A Labels

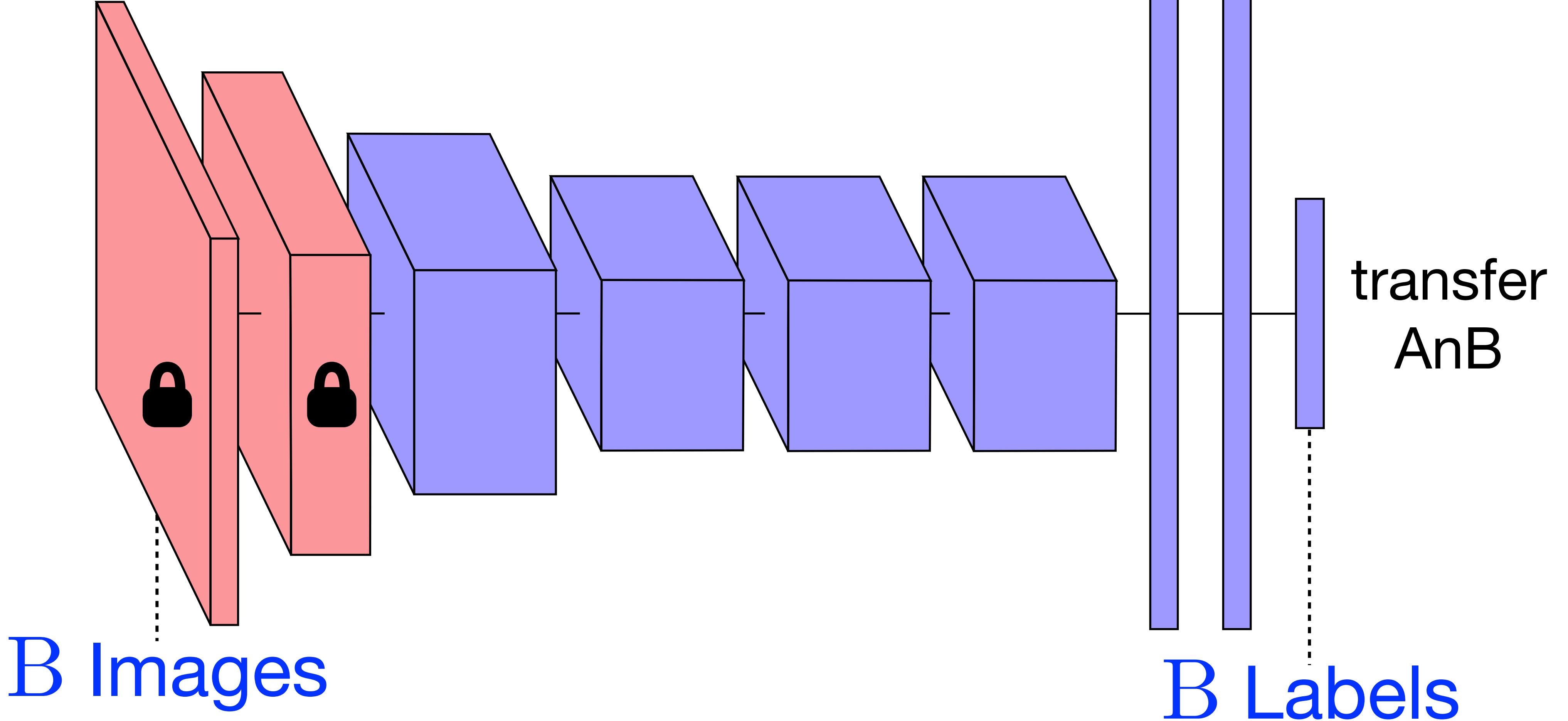


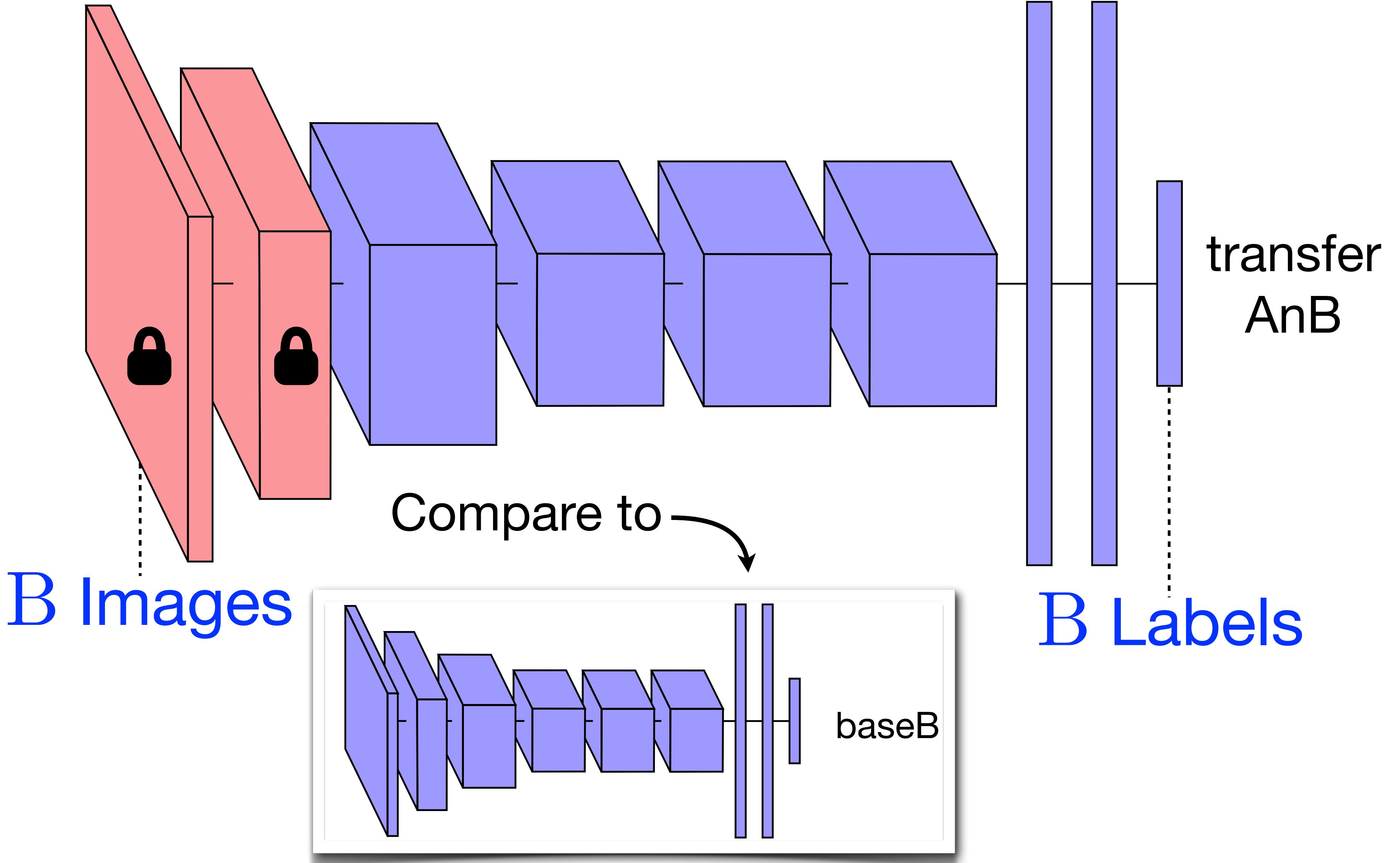


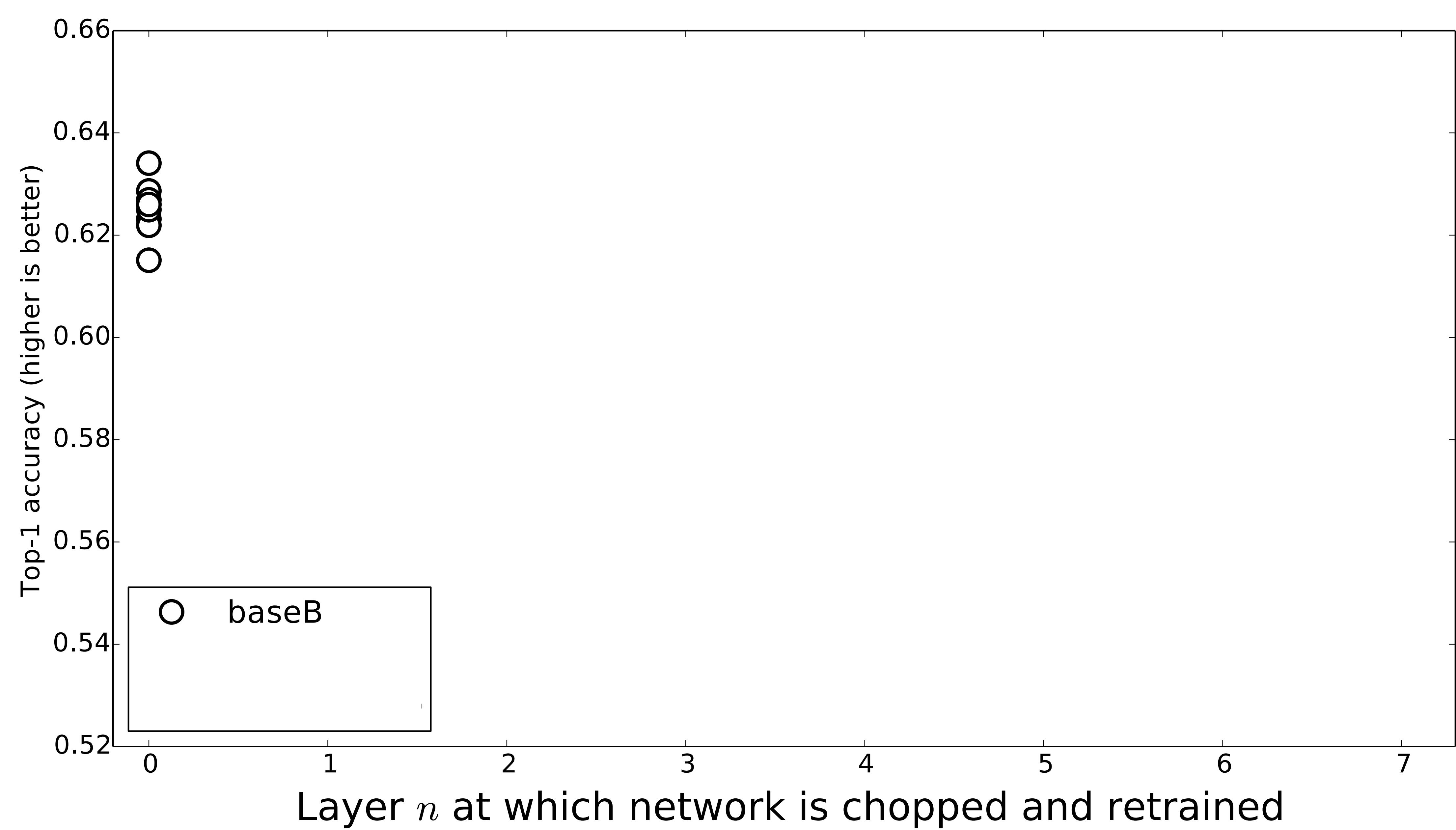


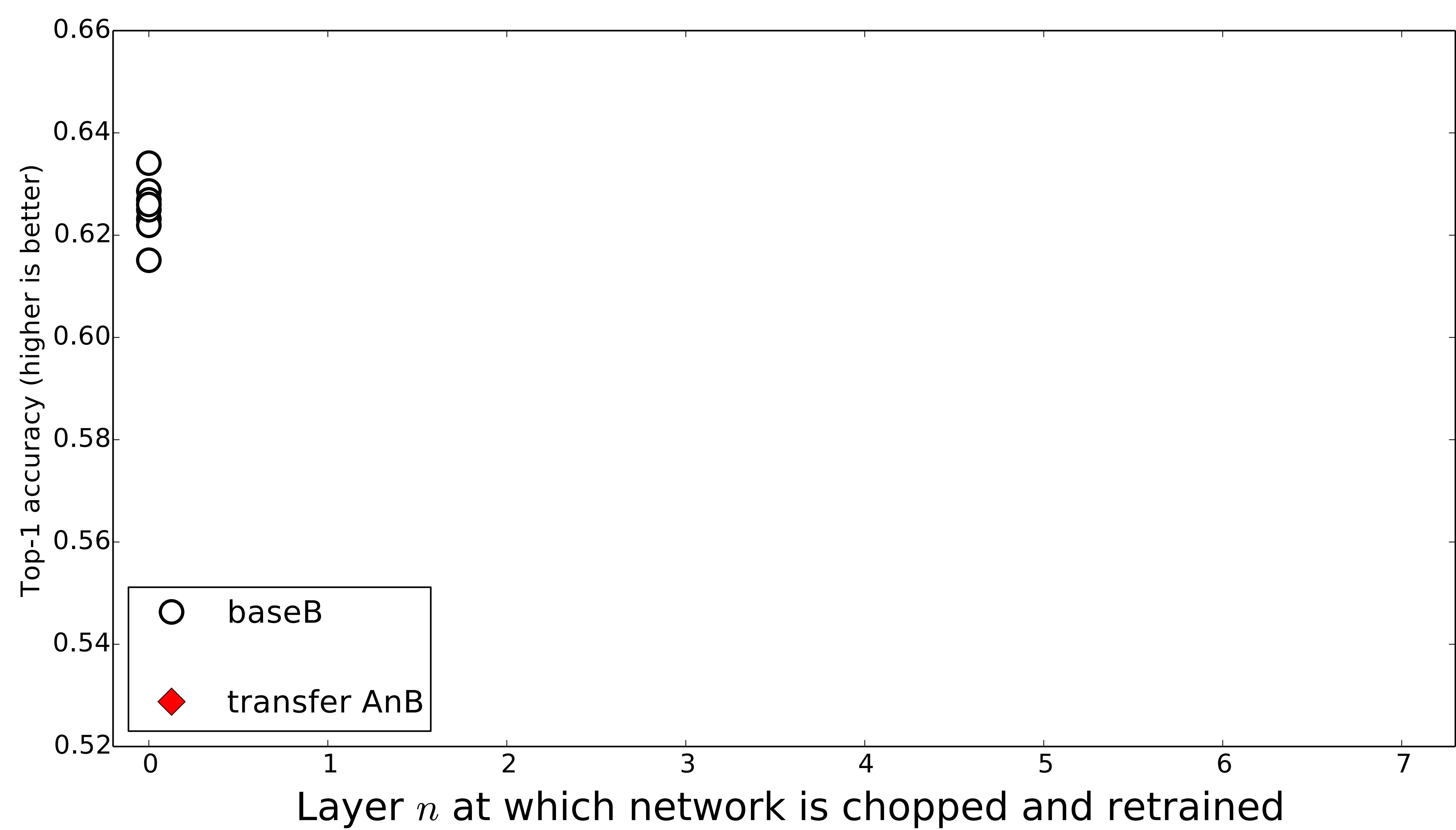
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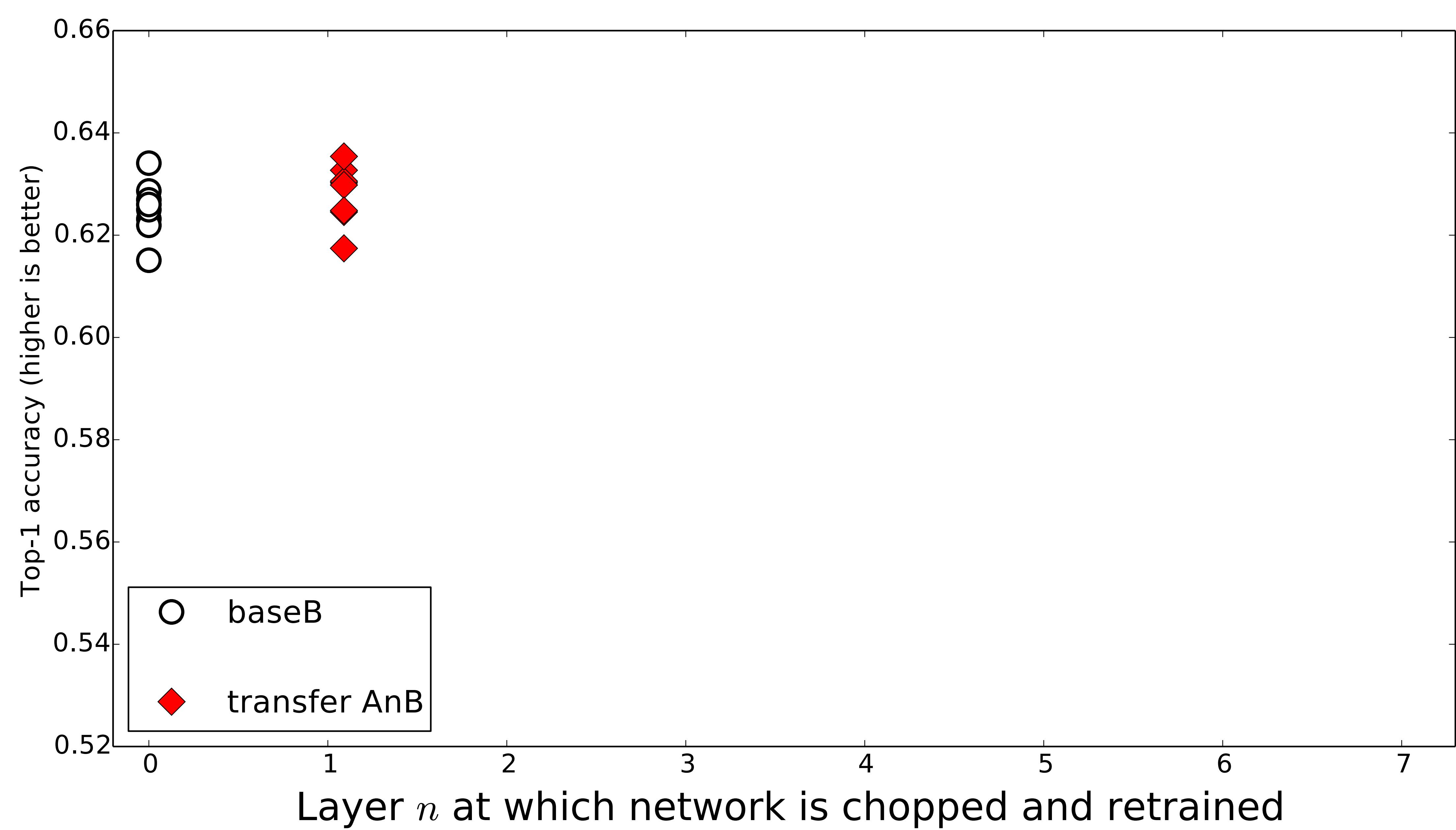
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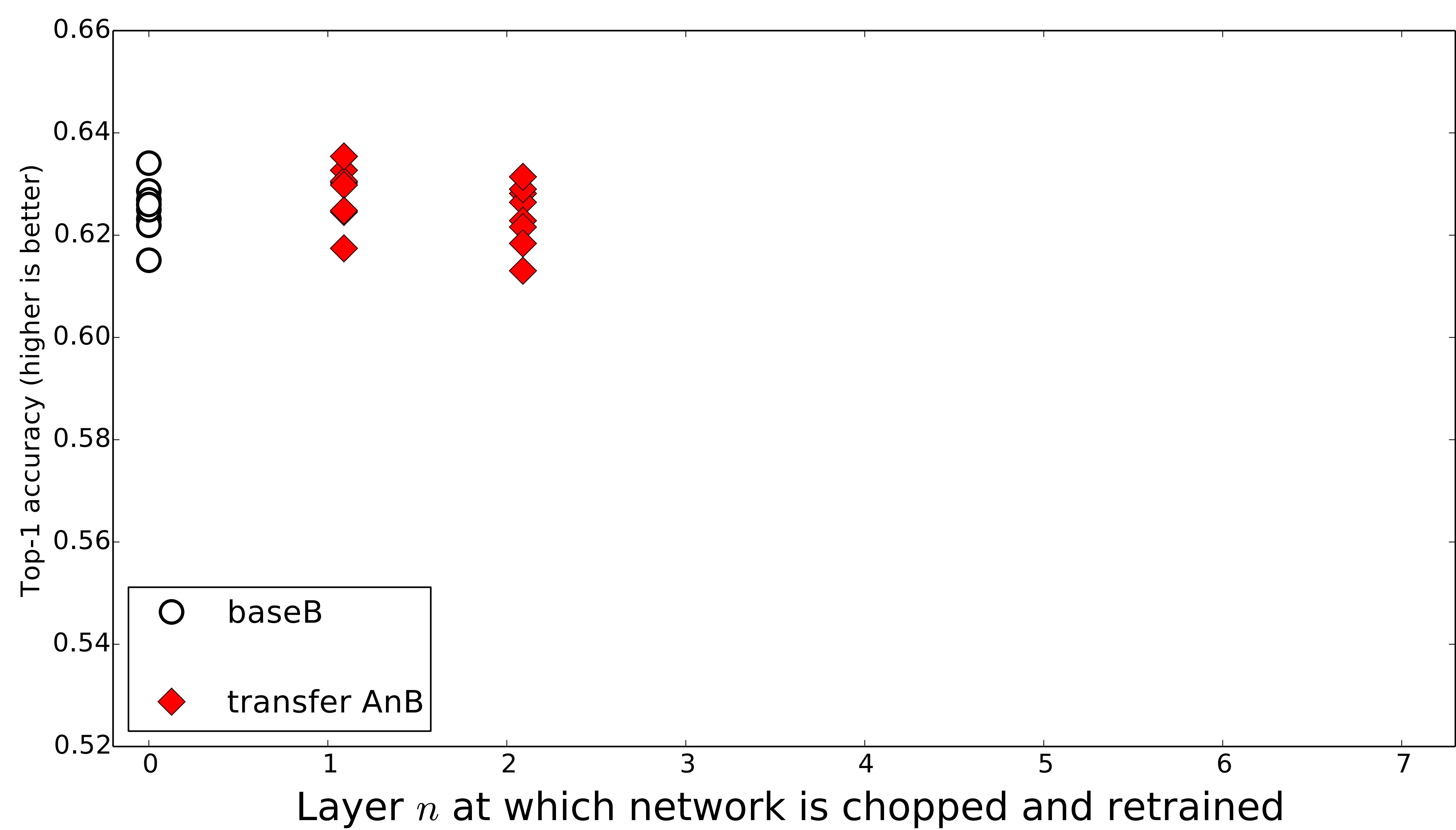


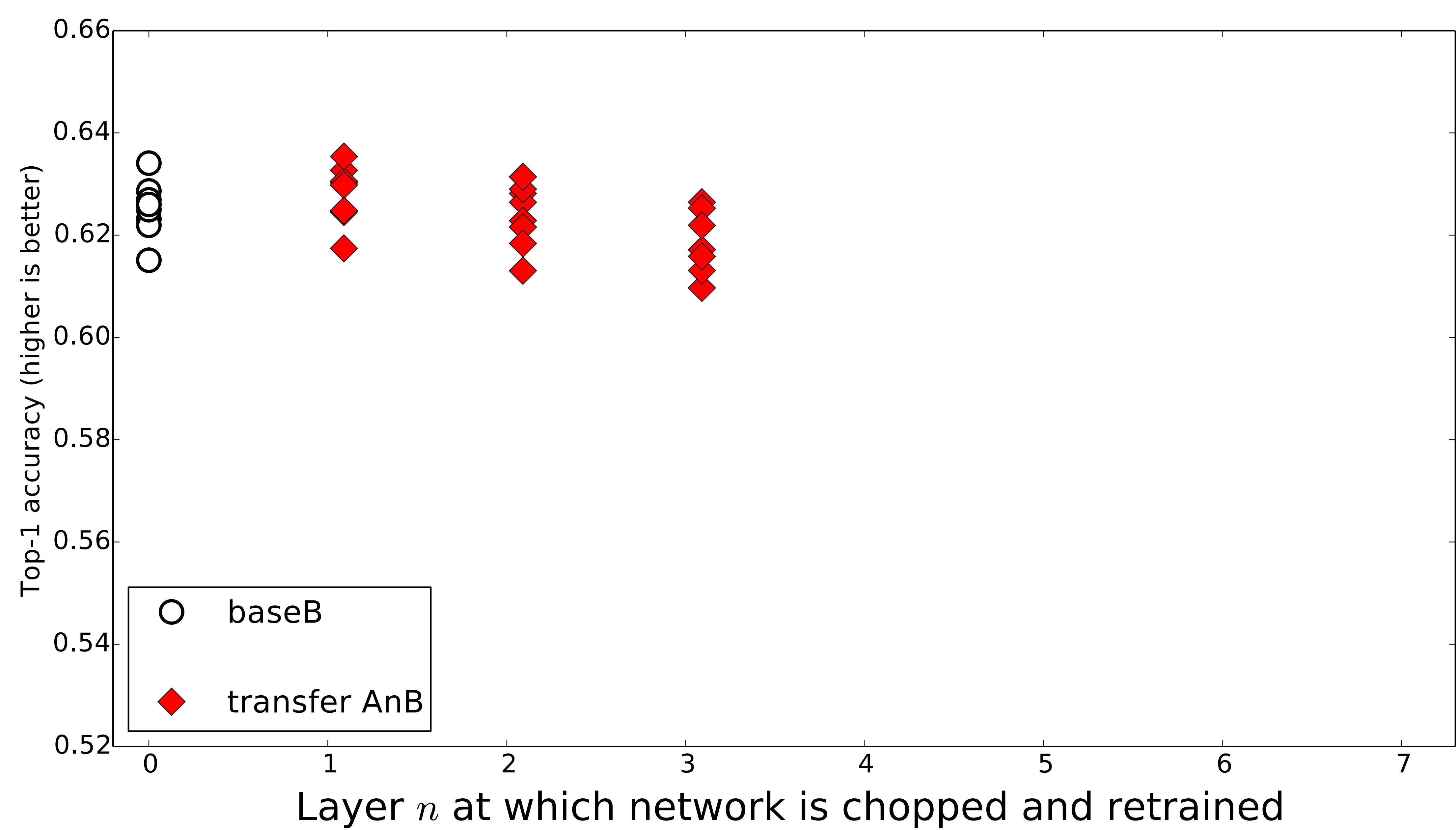


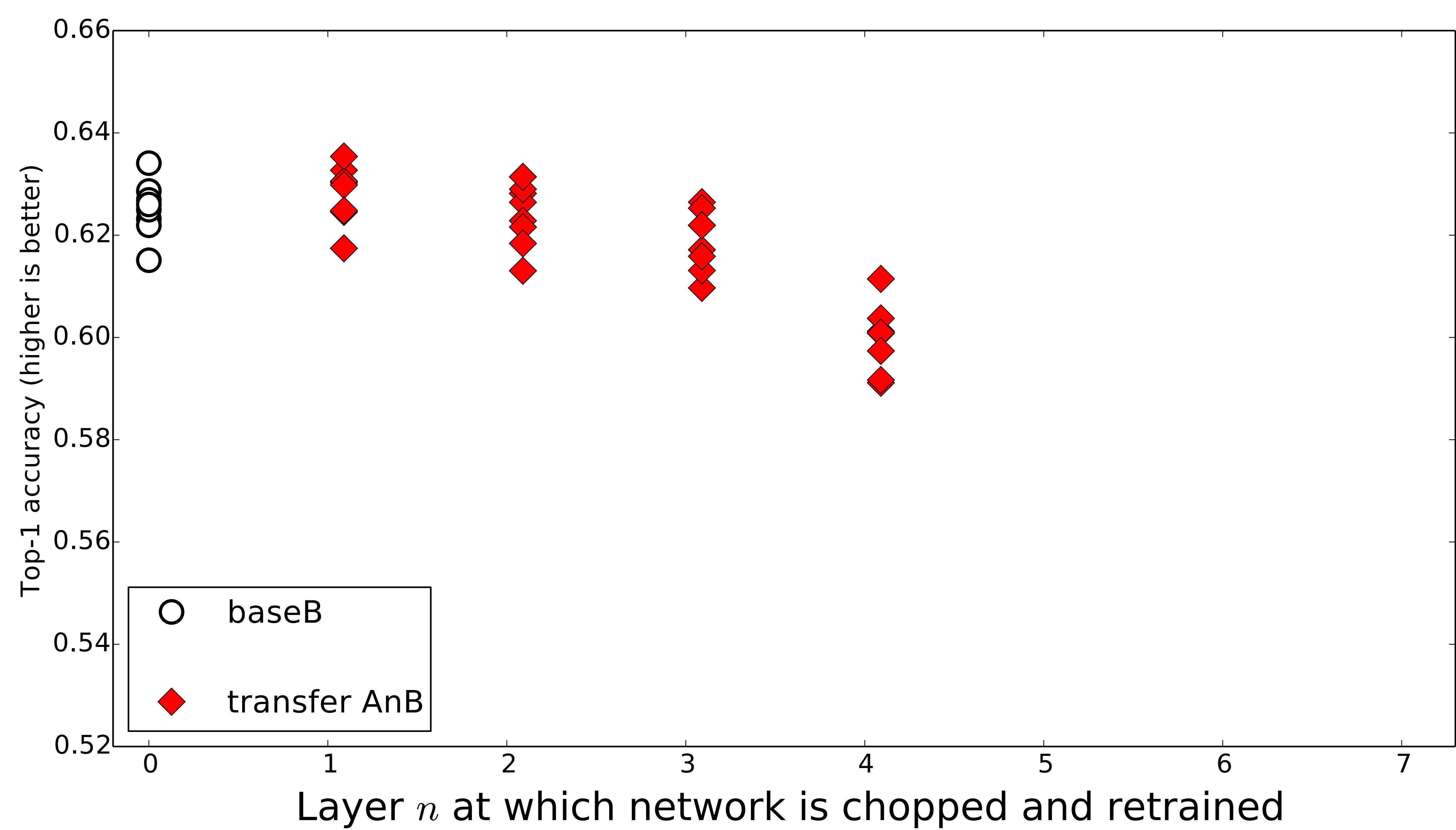


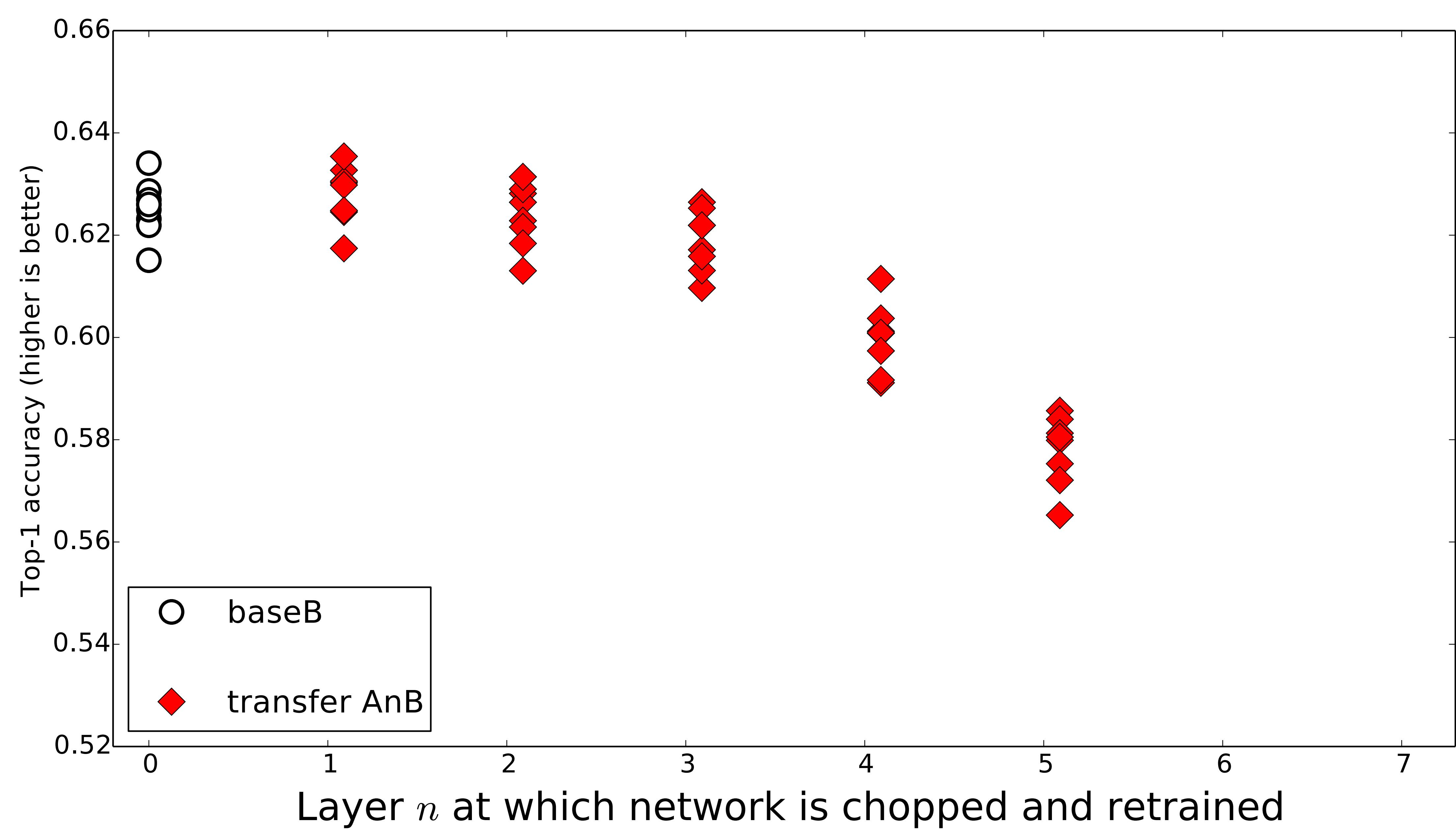


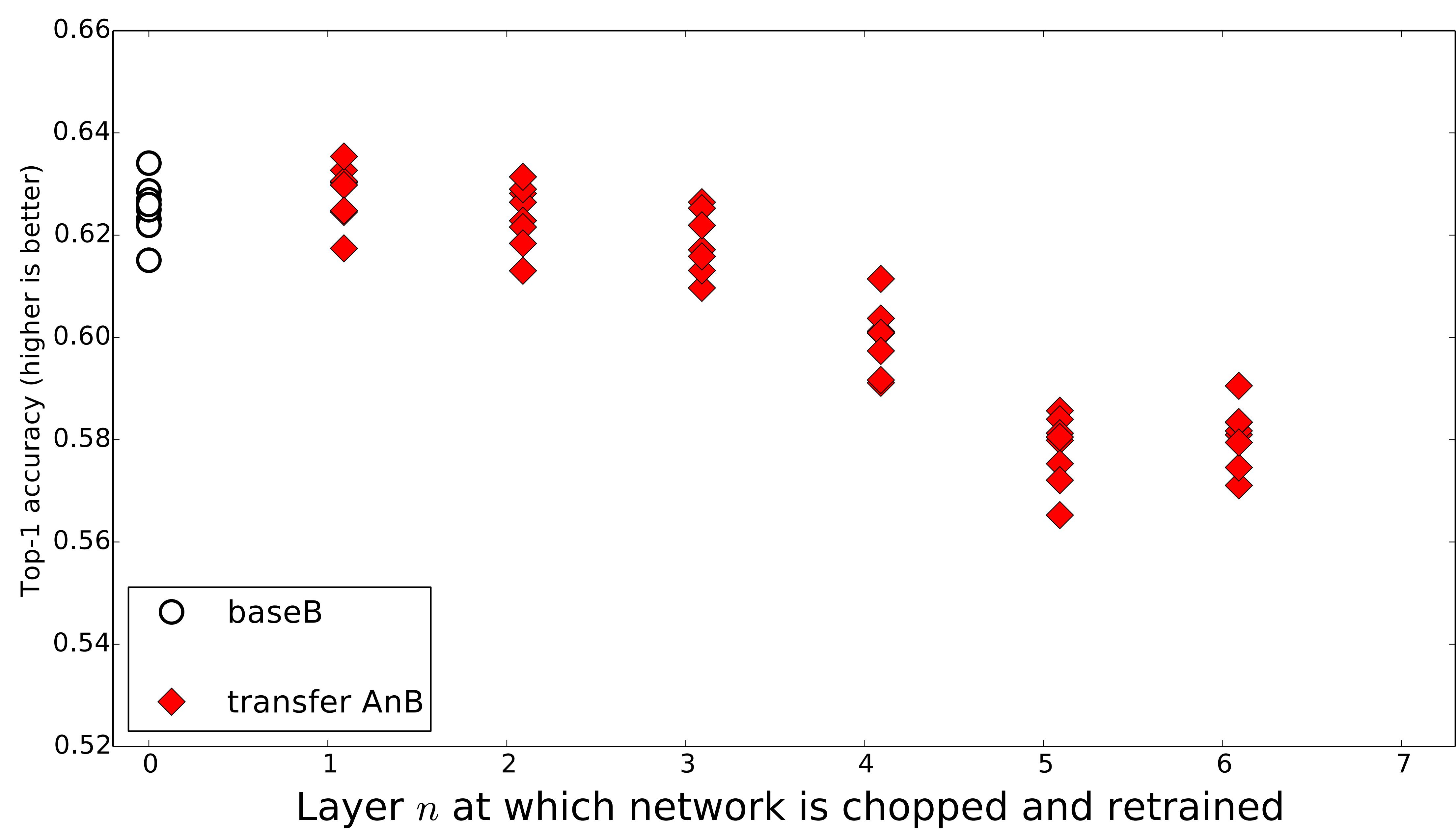


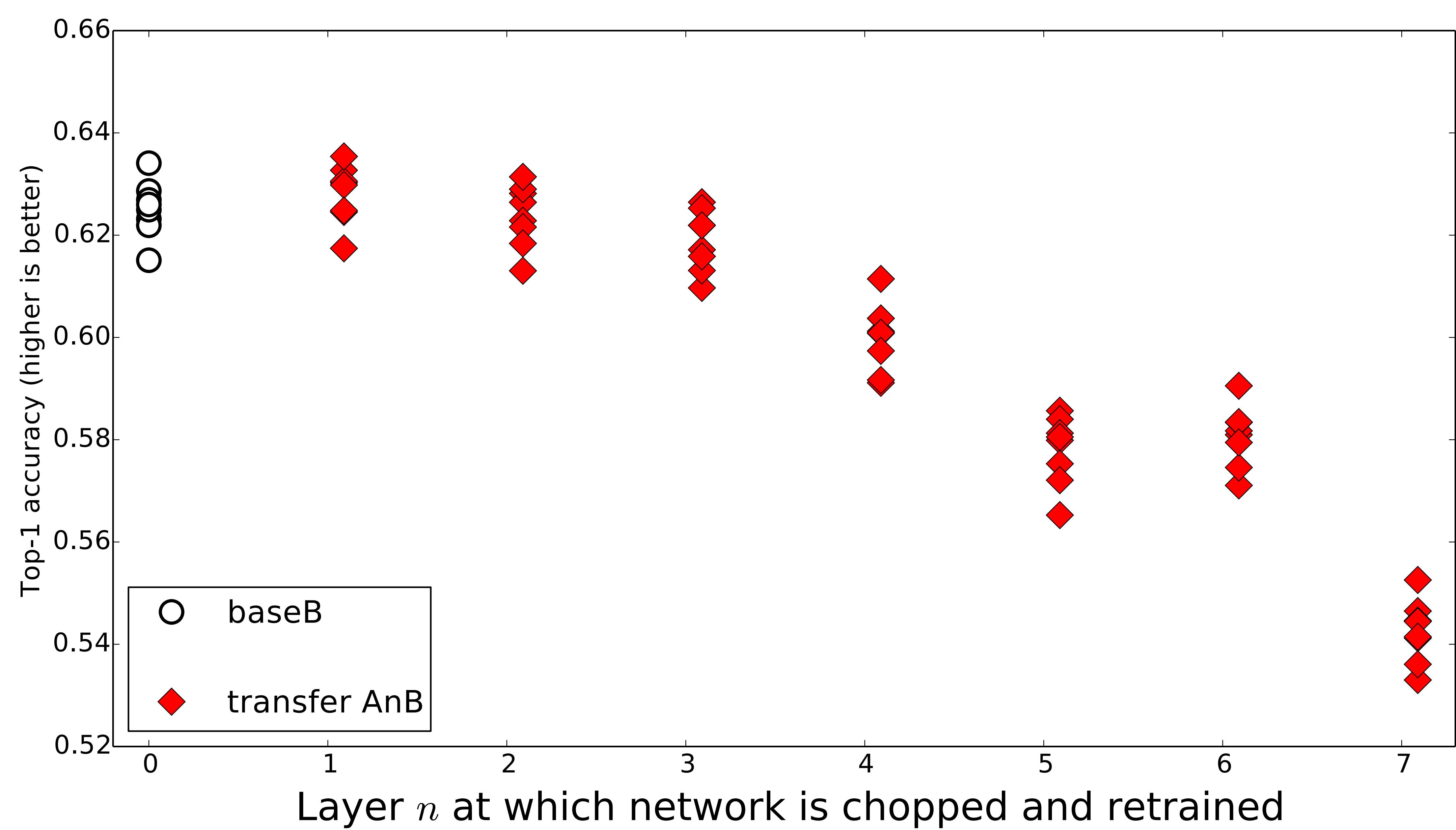


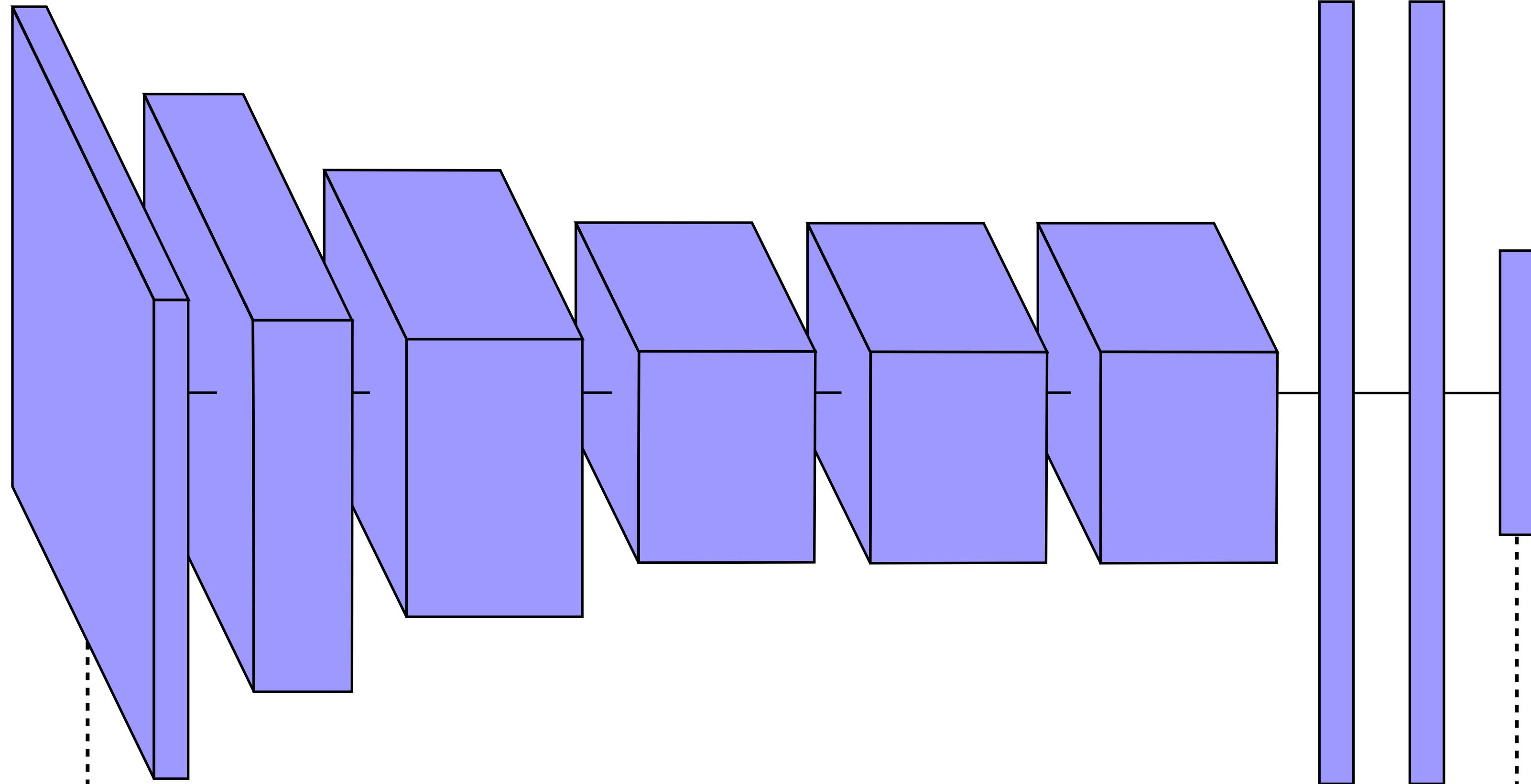






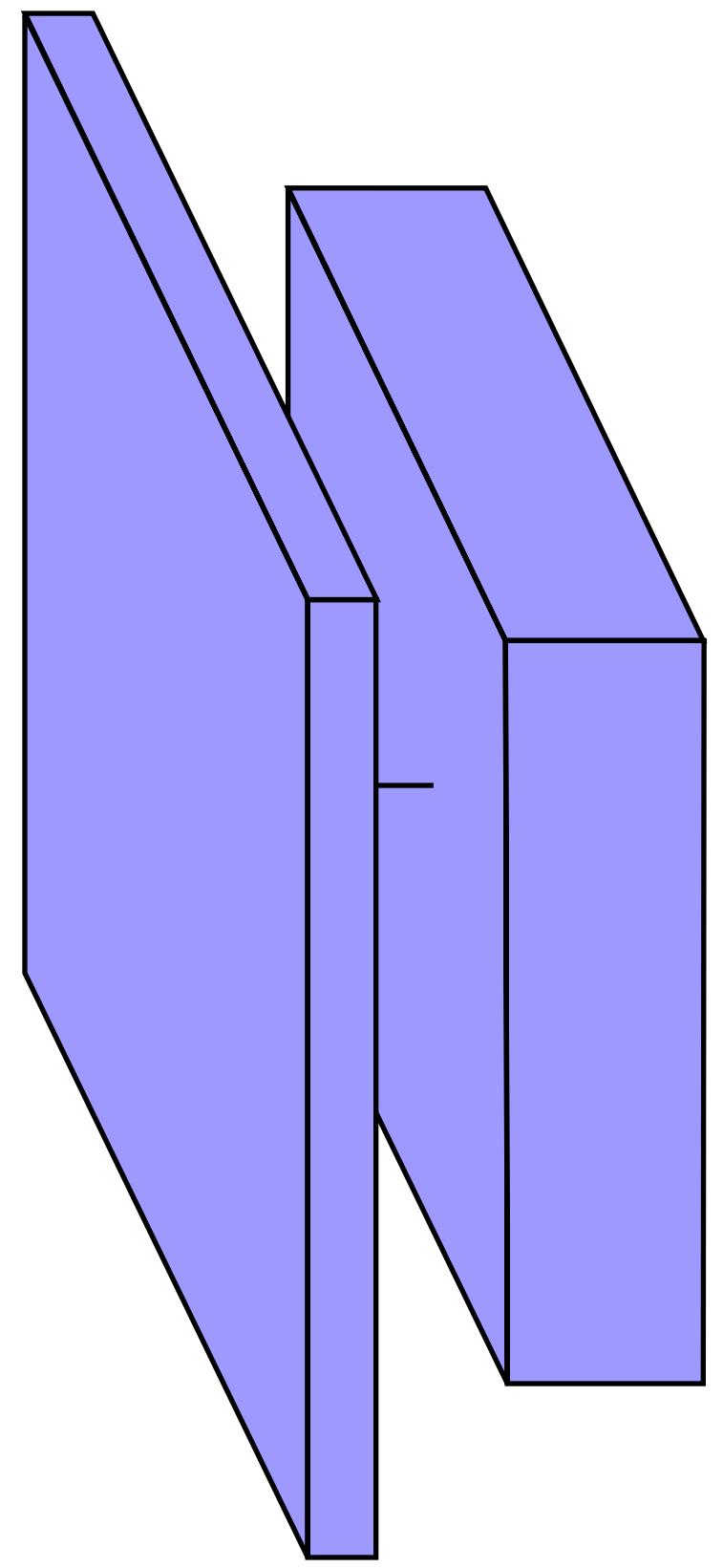


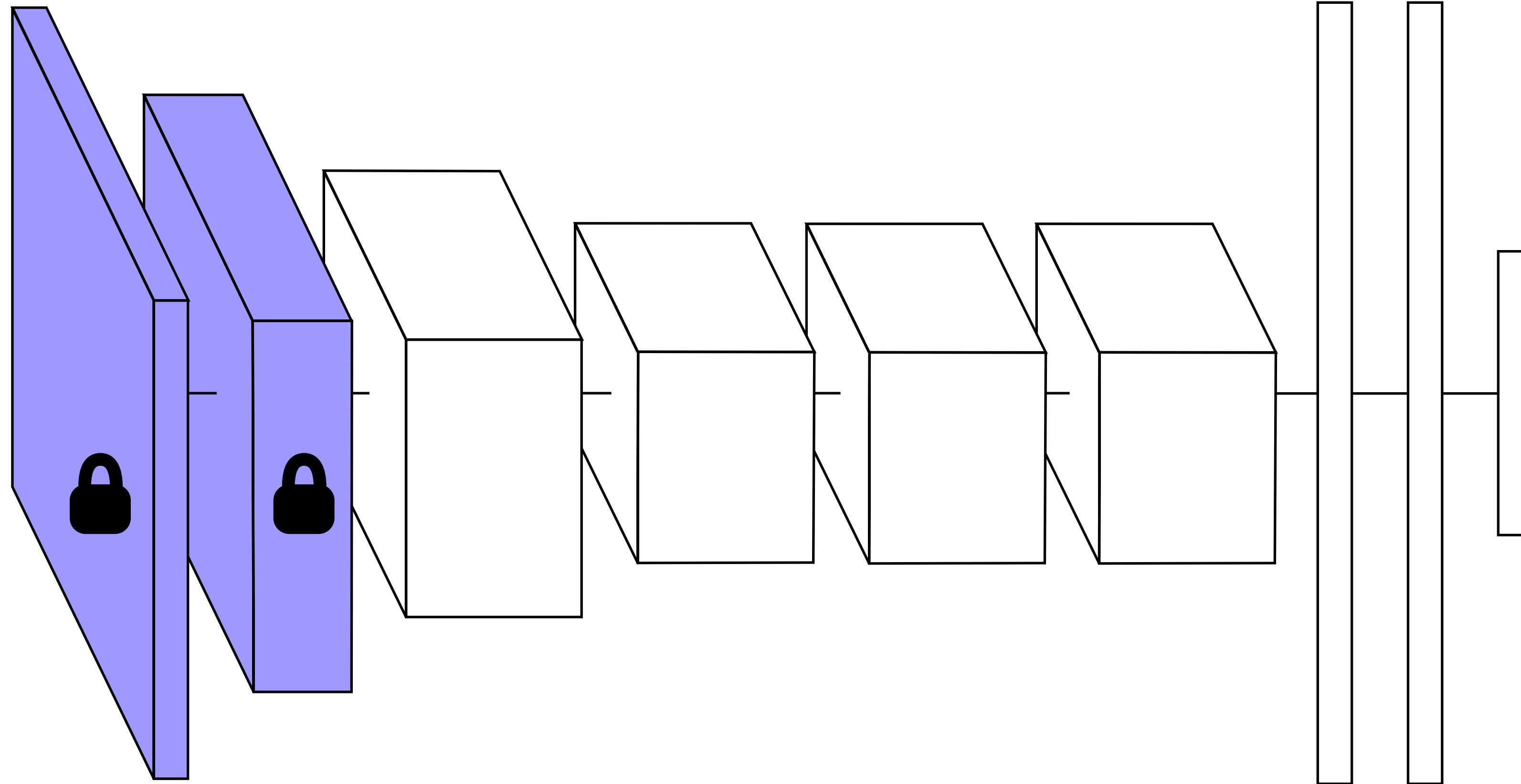




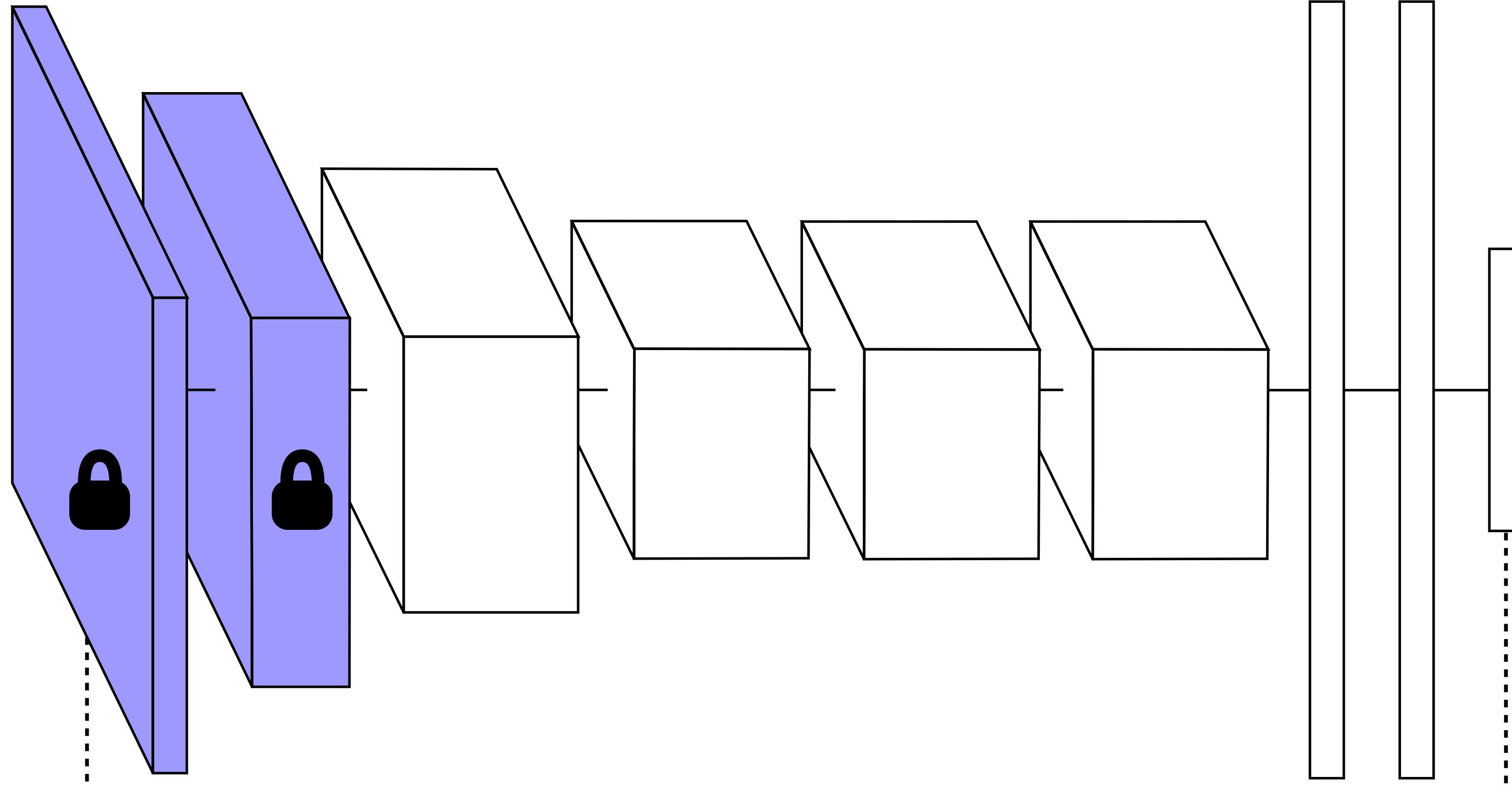
B Images

B Labels

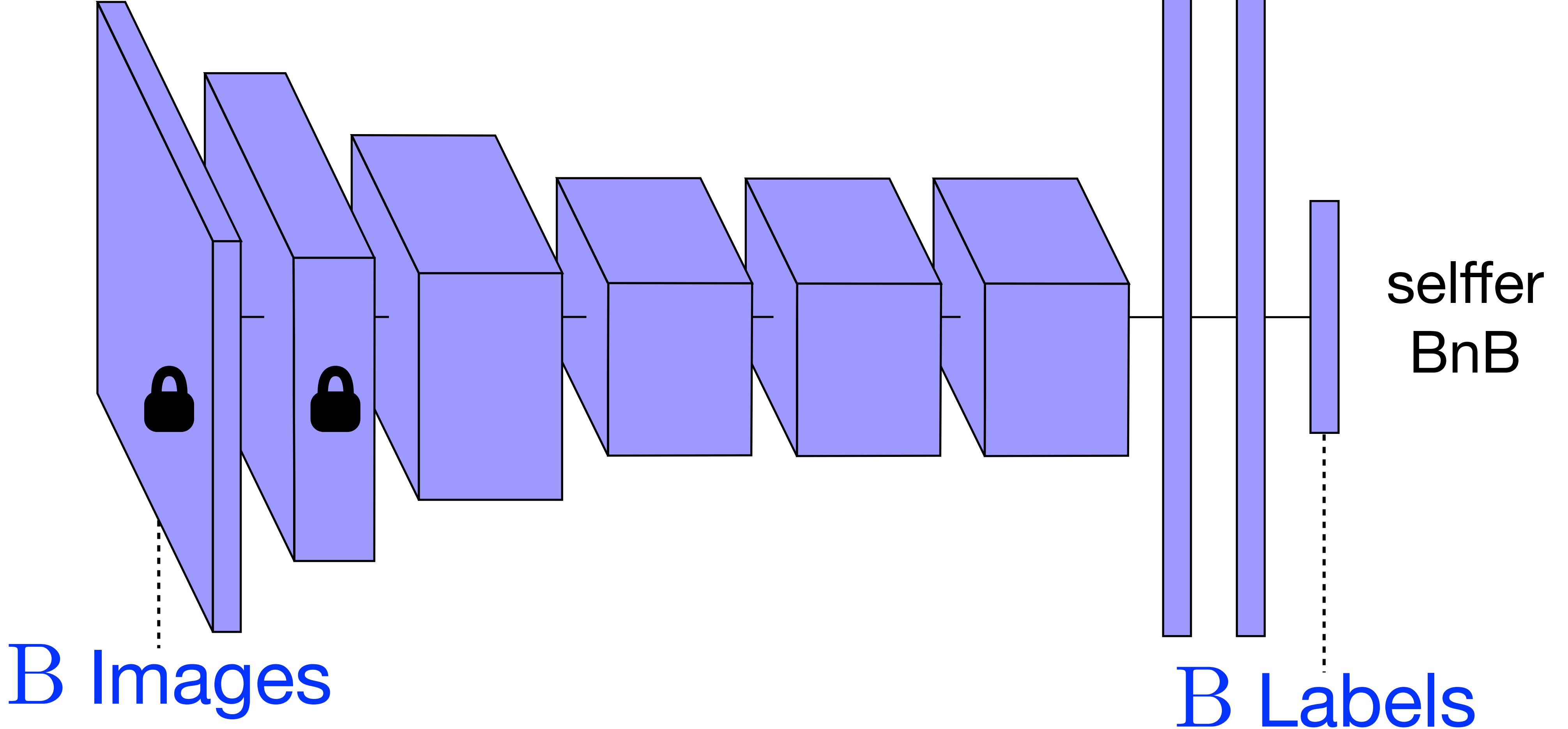


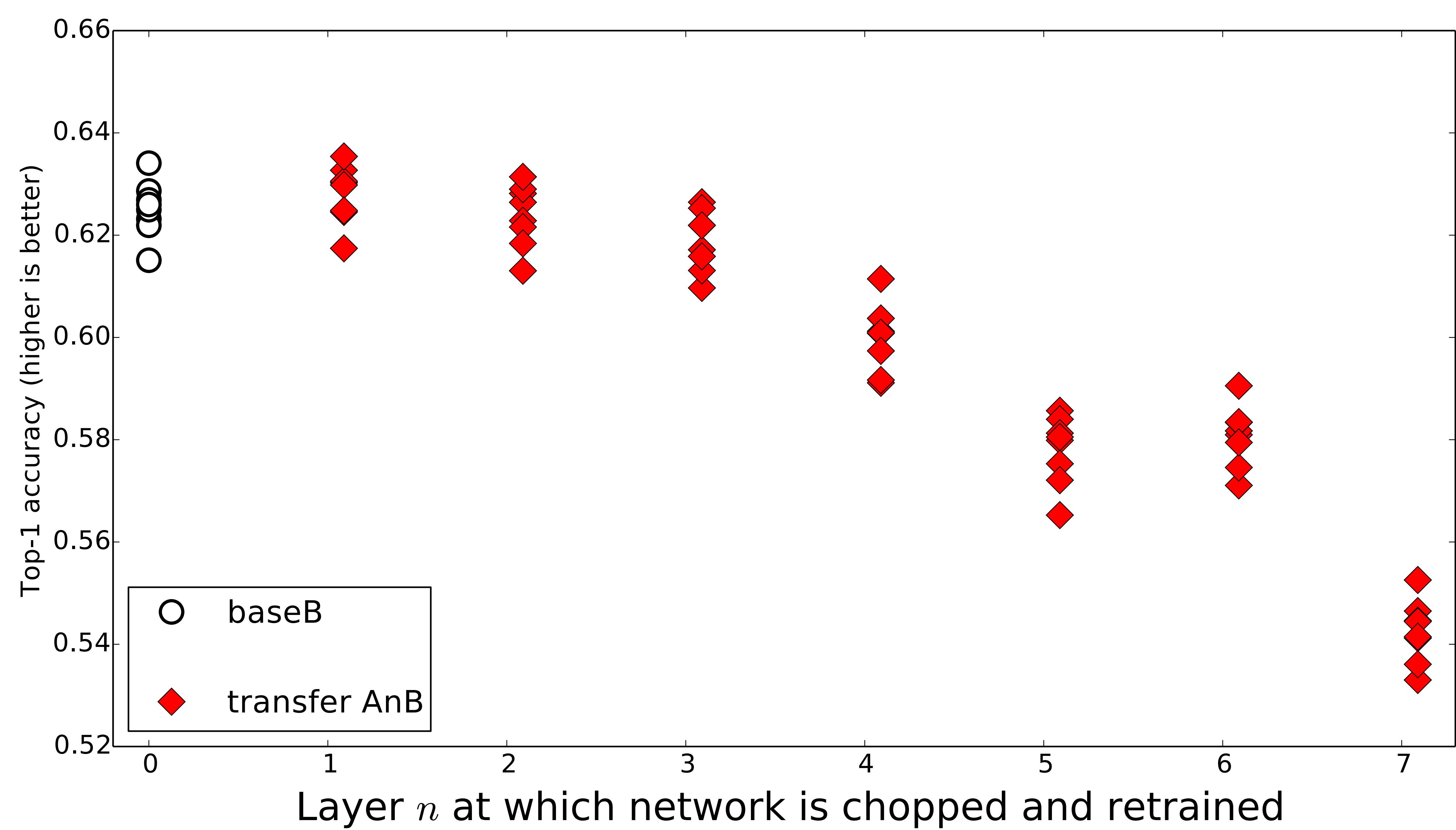


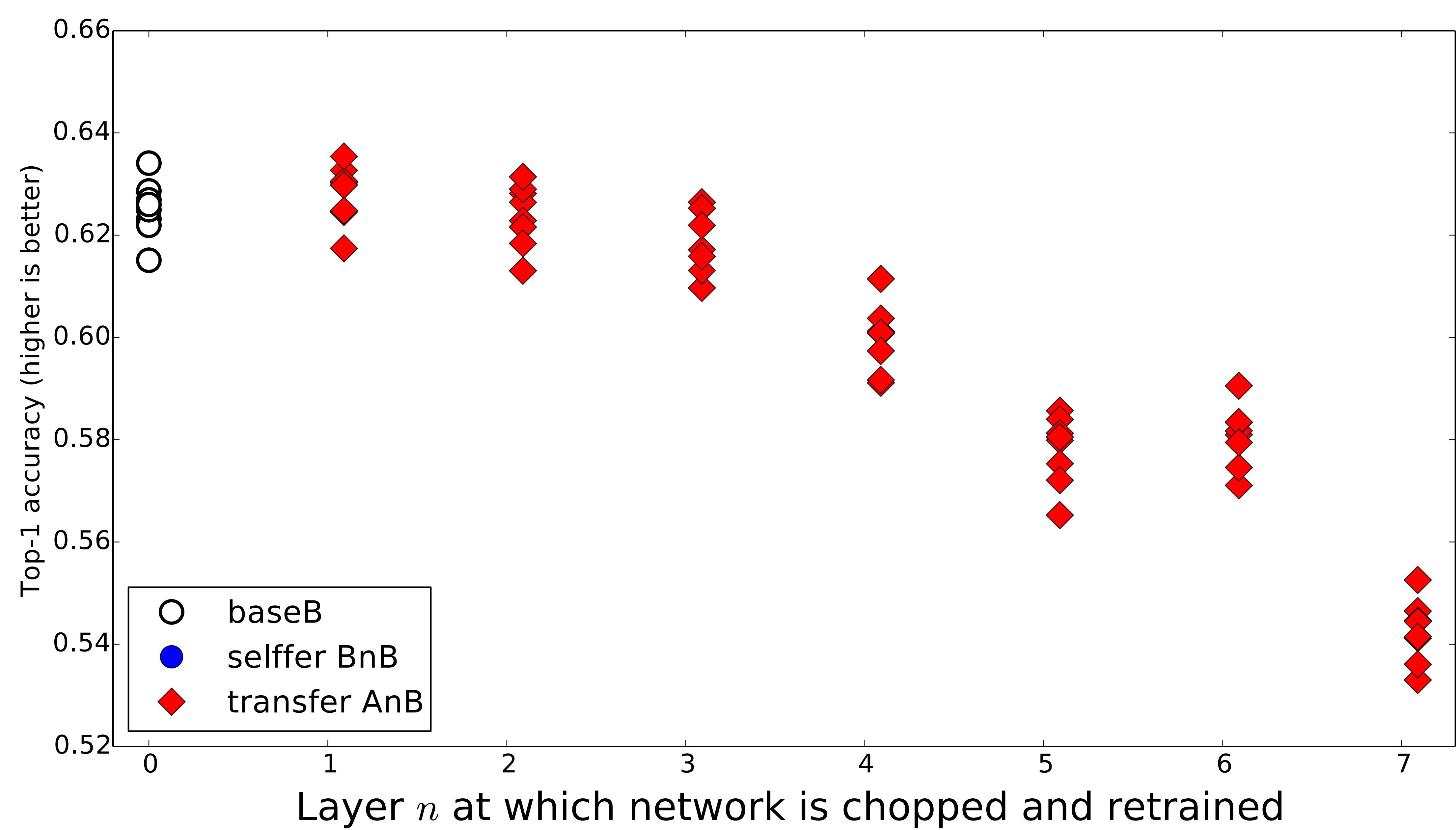
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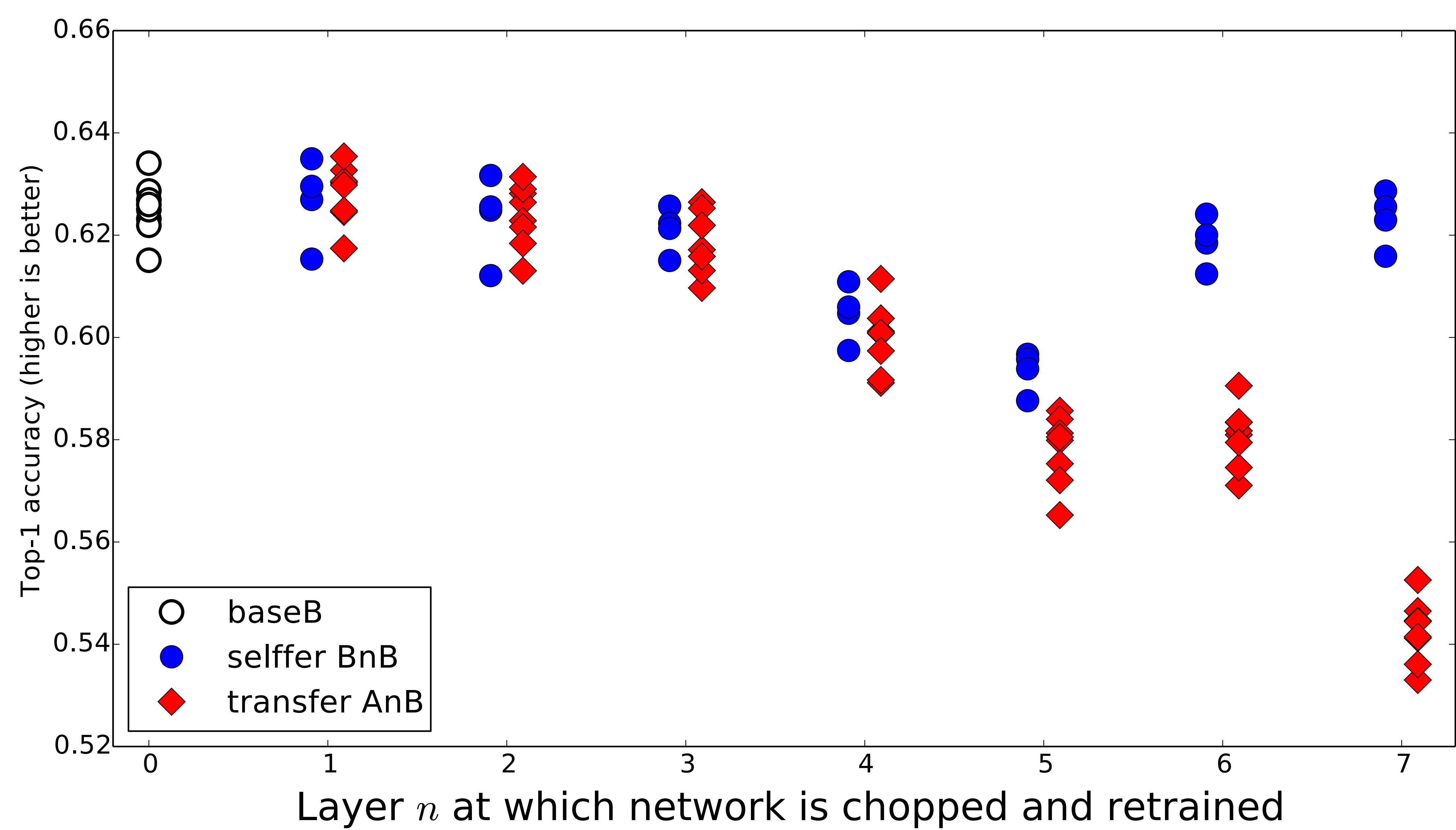


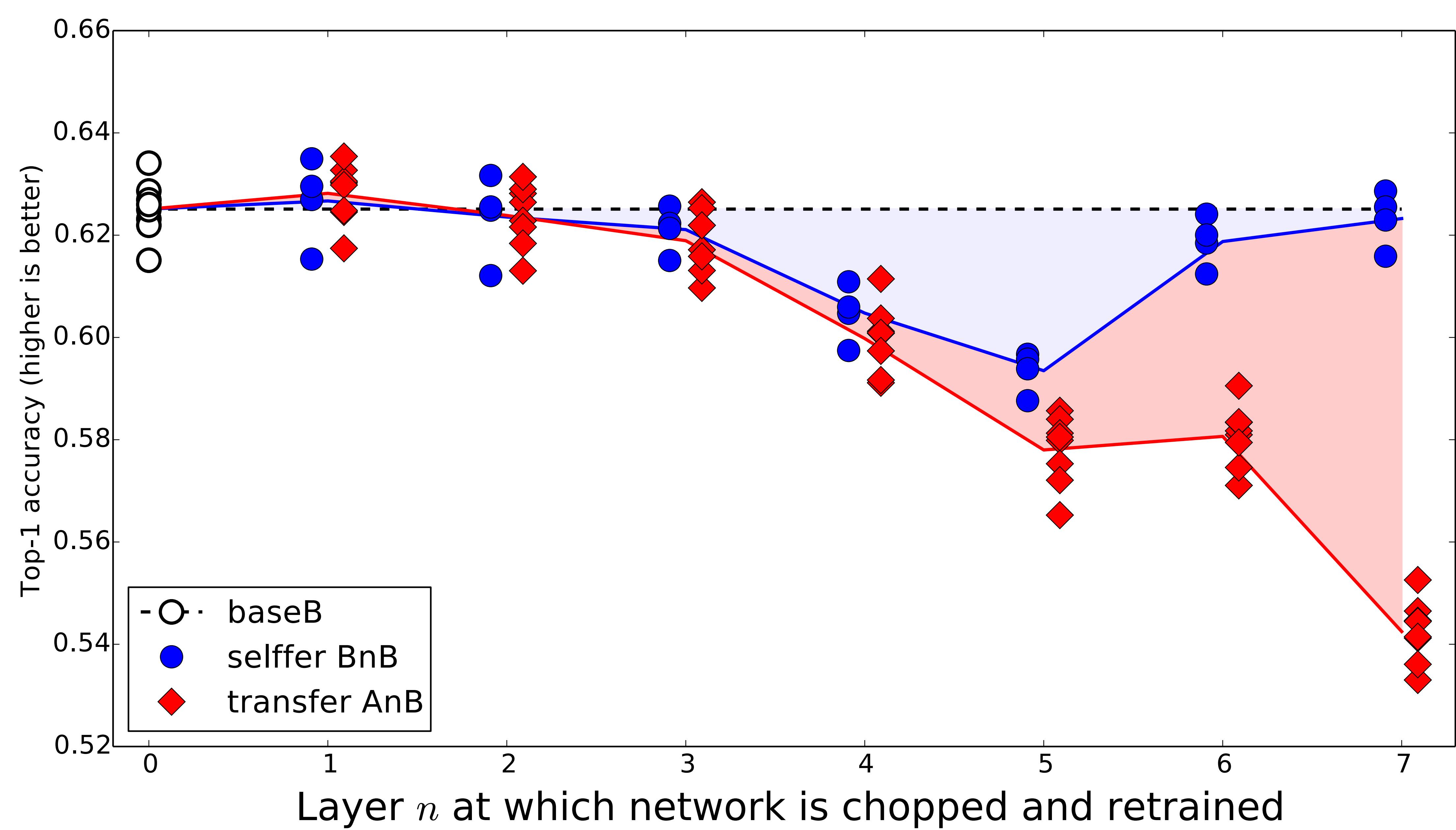
B Labels

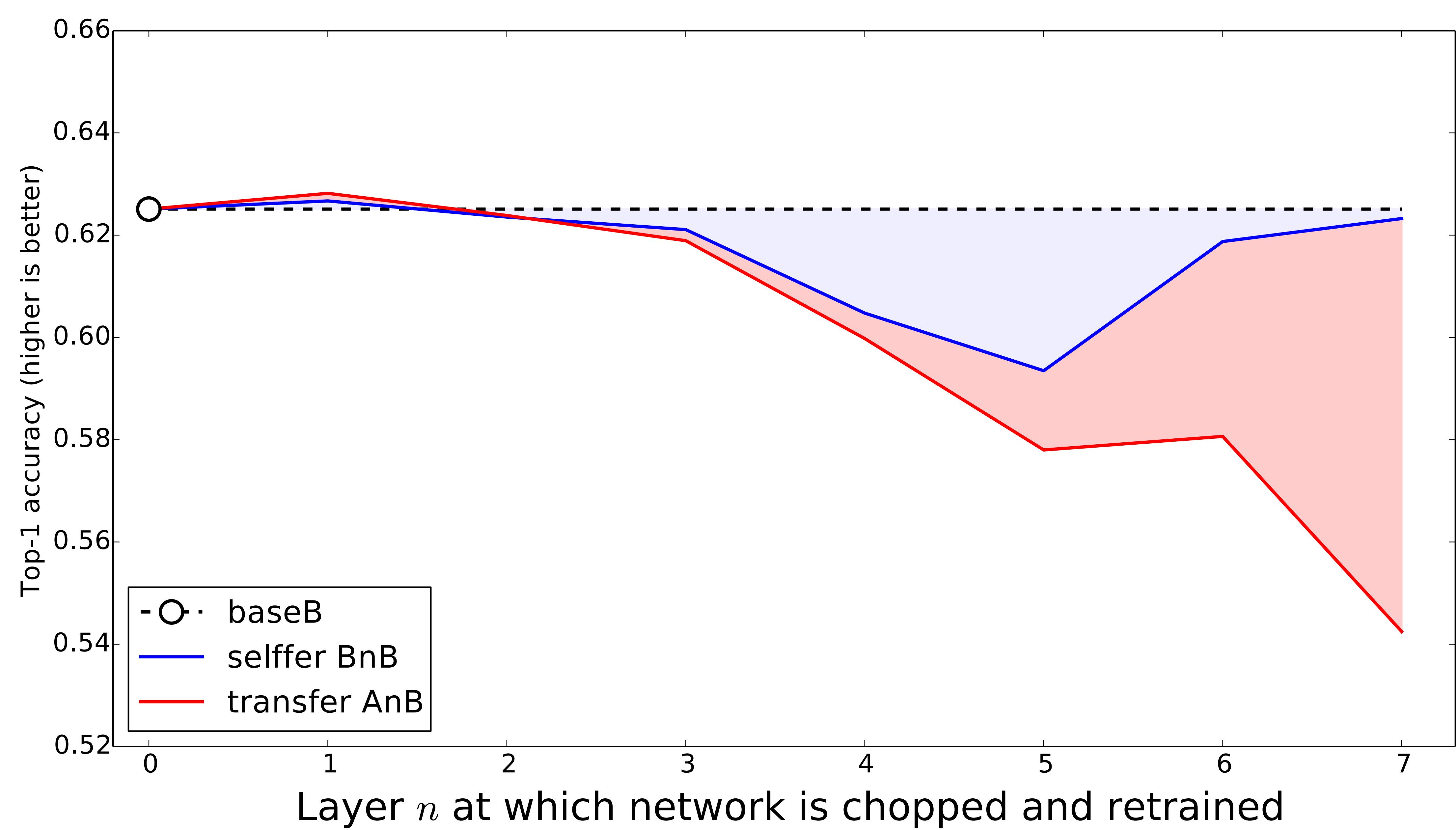




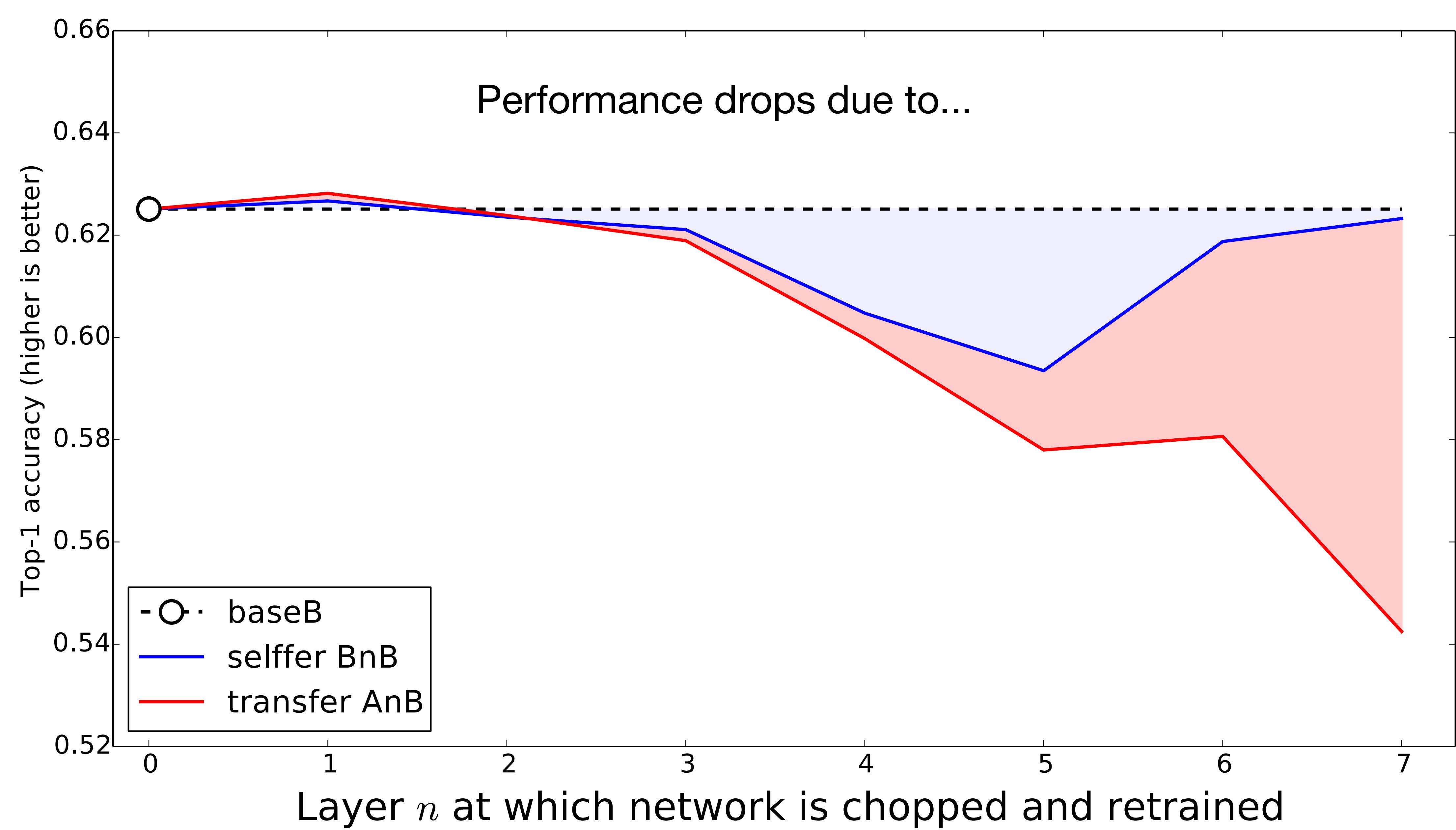




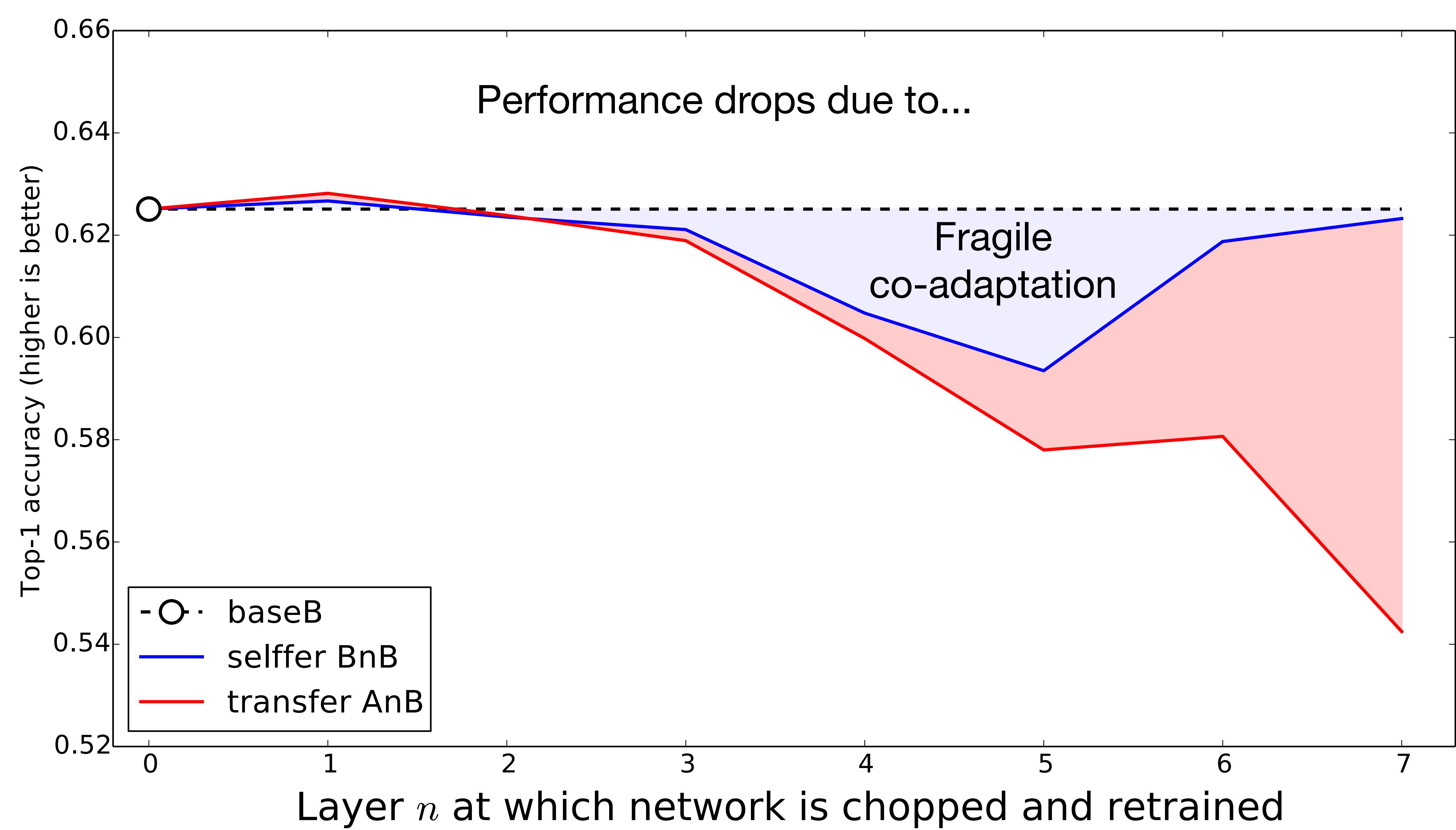


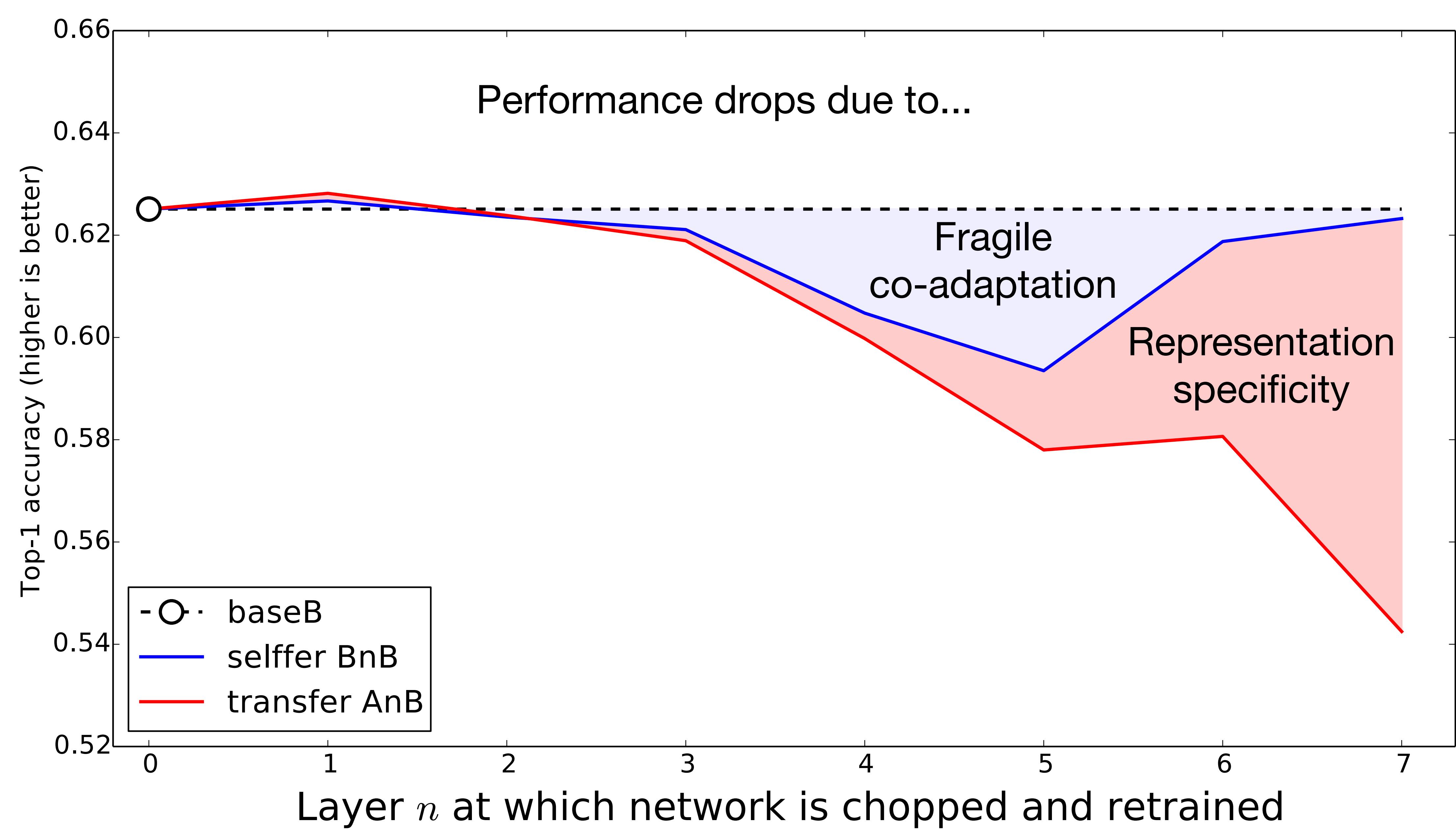


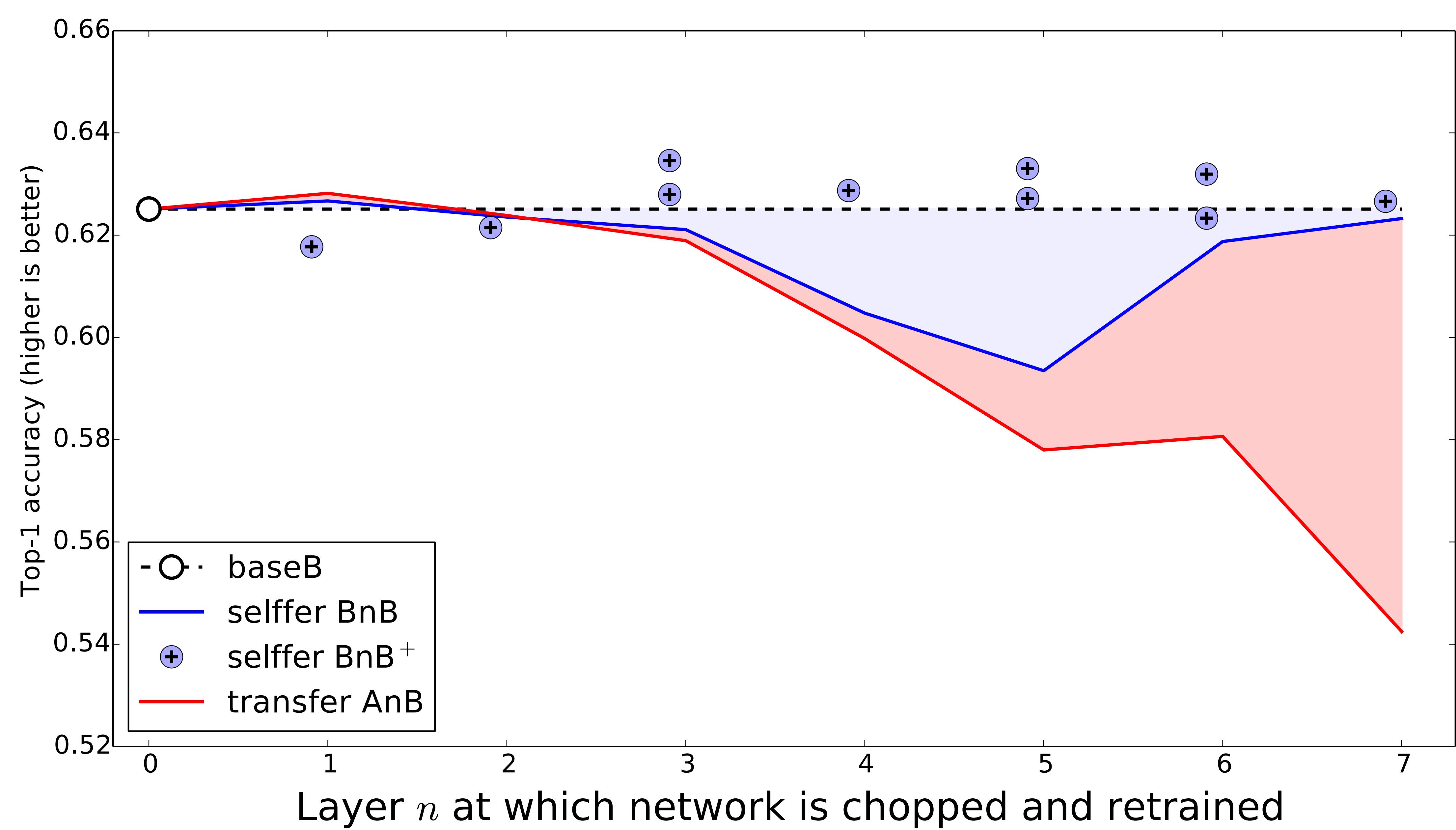
Performance drops due to...

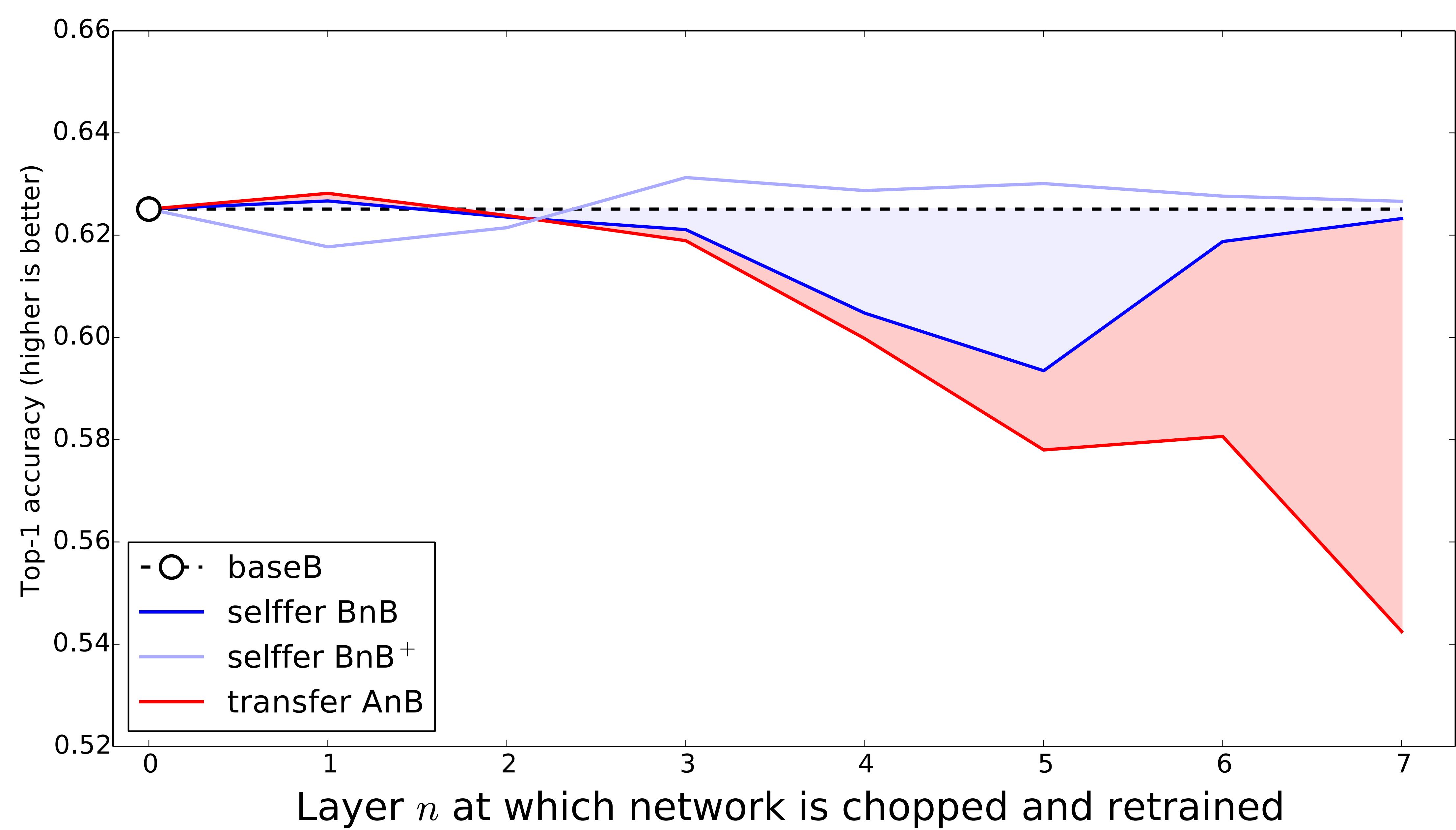


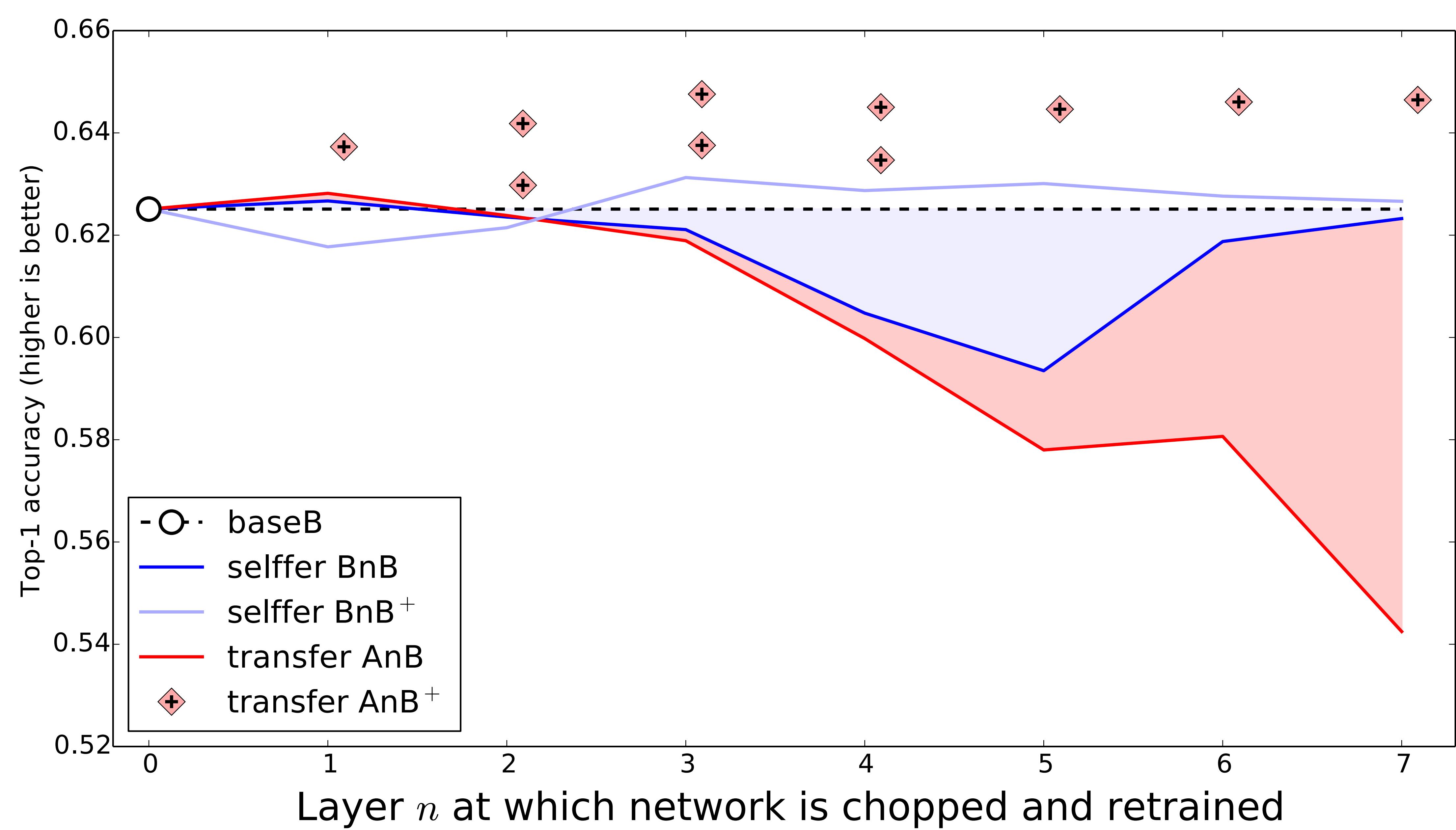
Performance drops due to...

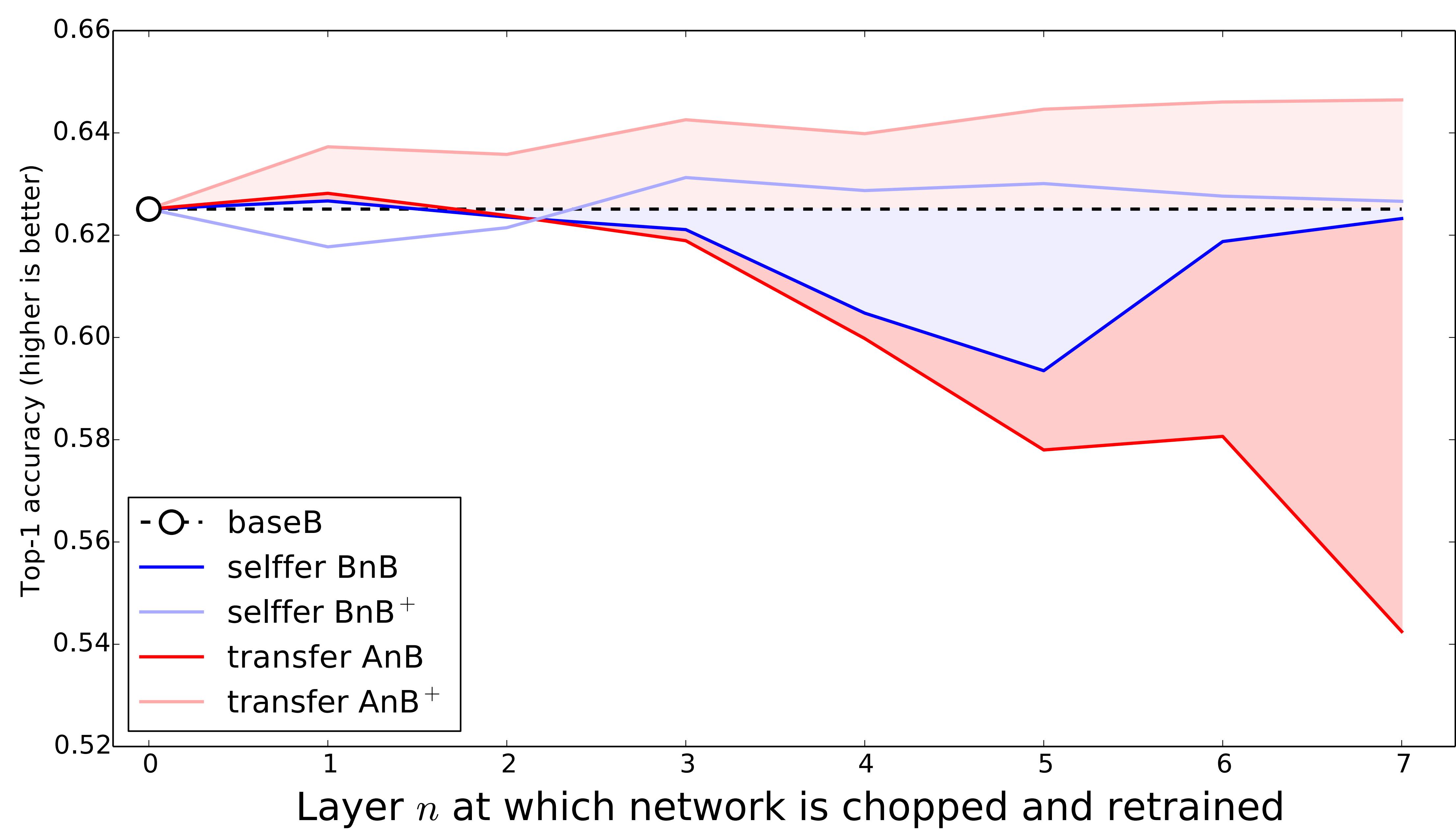


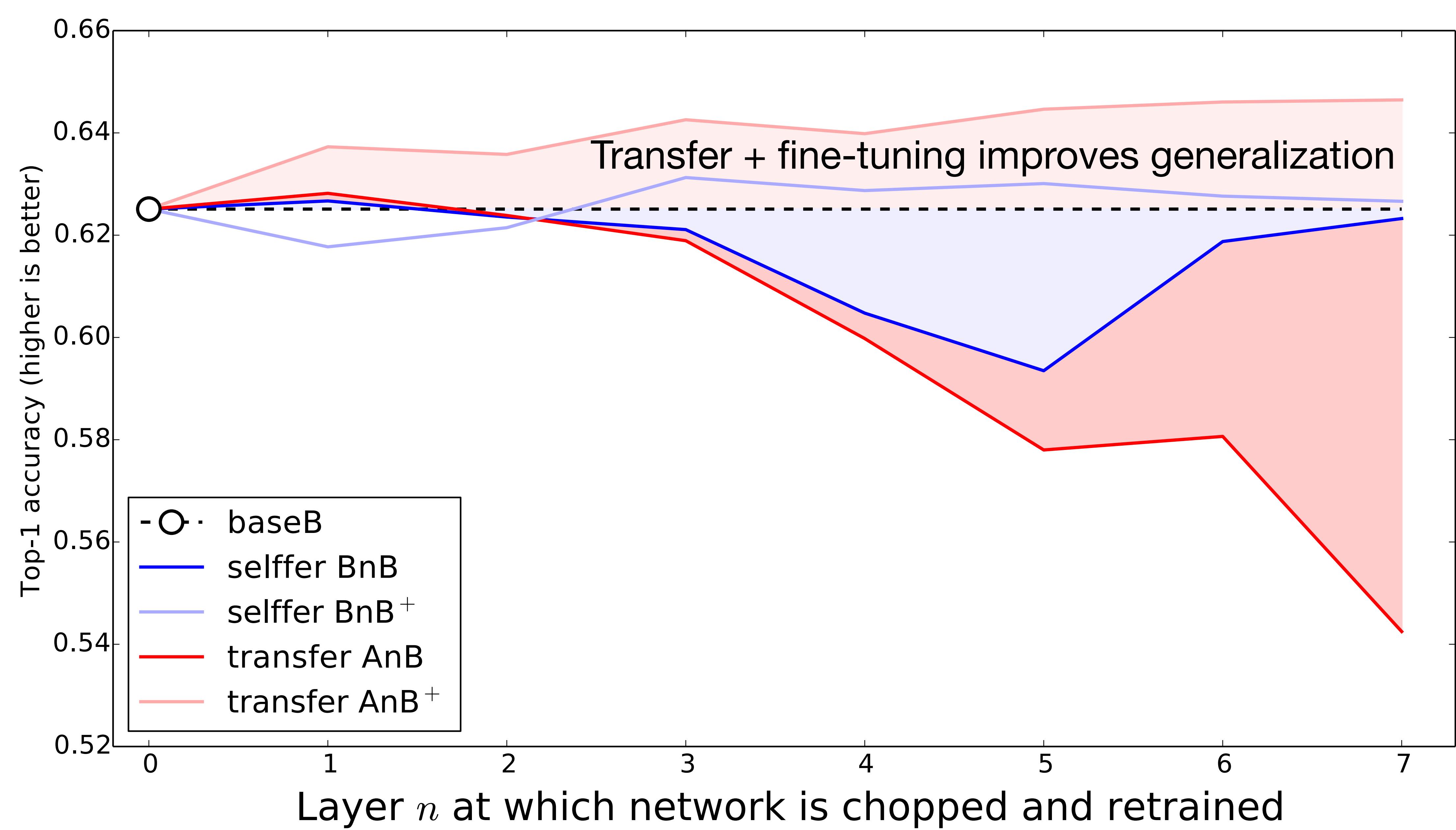












ImageNet has many related categories...

Dataset A: random

gecko

fire truck

baseball

panther

rabbit

gorilla

Dataset B: random

garbage truck

toucan

radiator

binoculars

lion

bookshop

ImageNet has many related categories...

Dataset A: man-made

garbage truck

fire truck

radiator

baseball

binoculars

bookshop

Dataset B: natural

gorilla

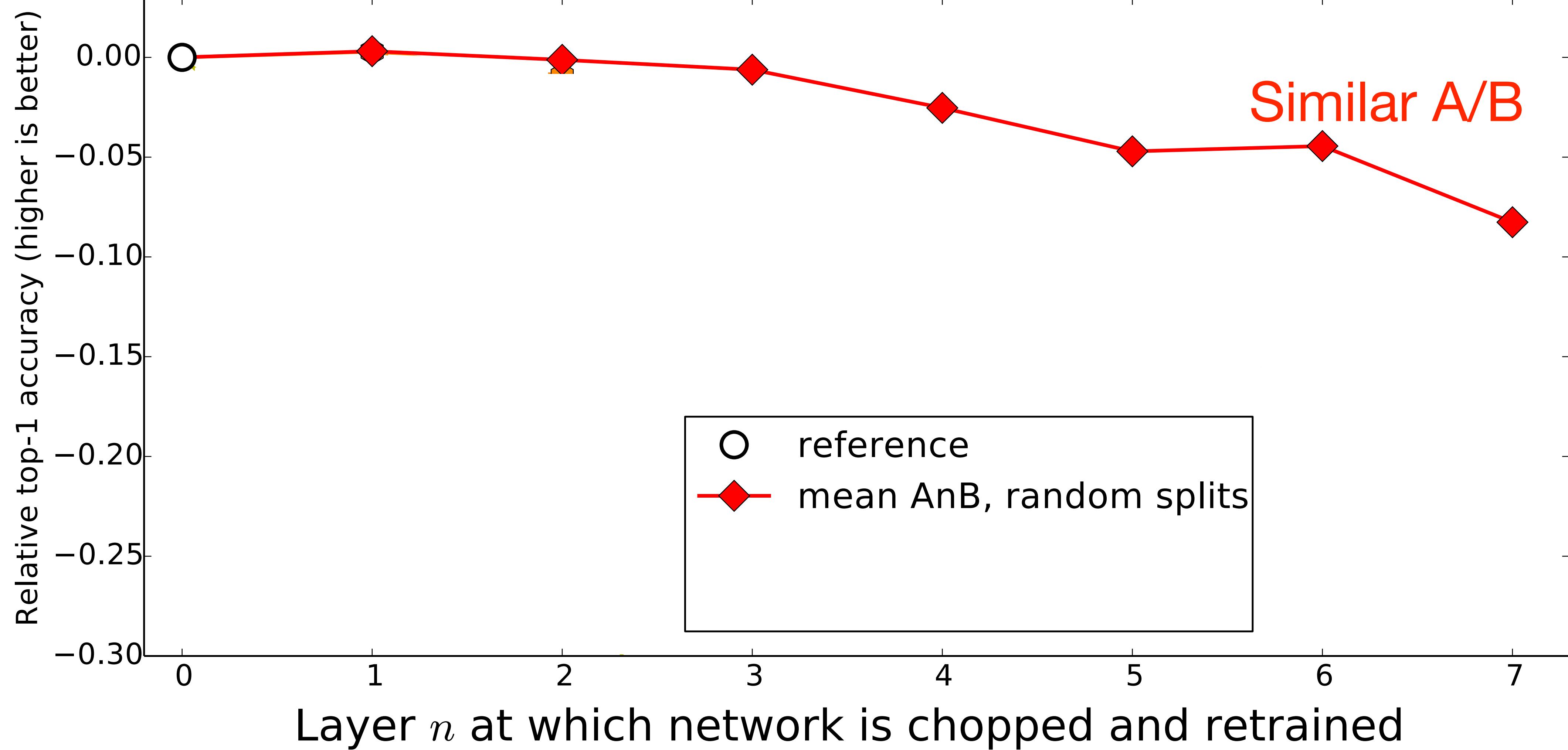
gecko

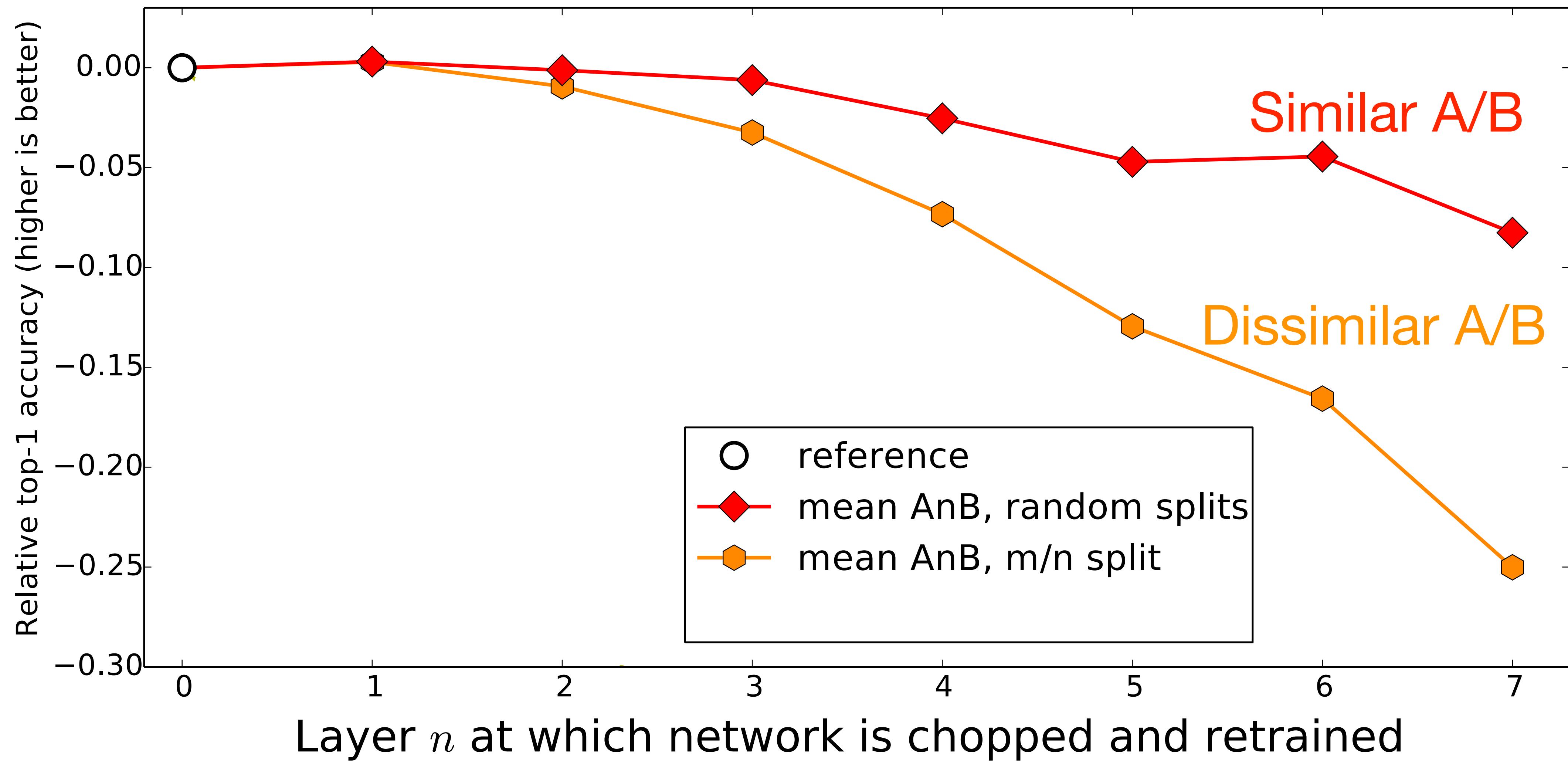
toucan

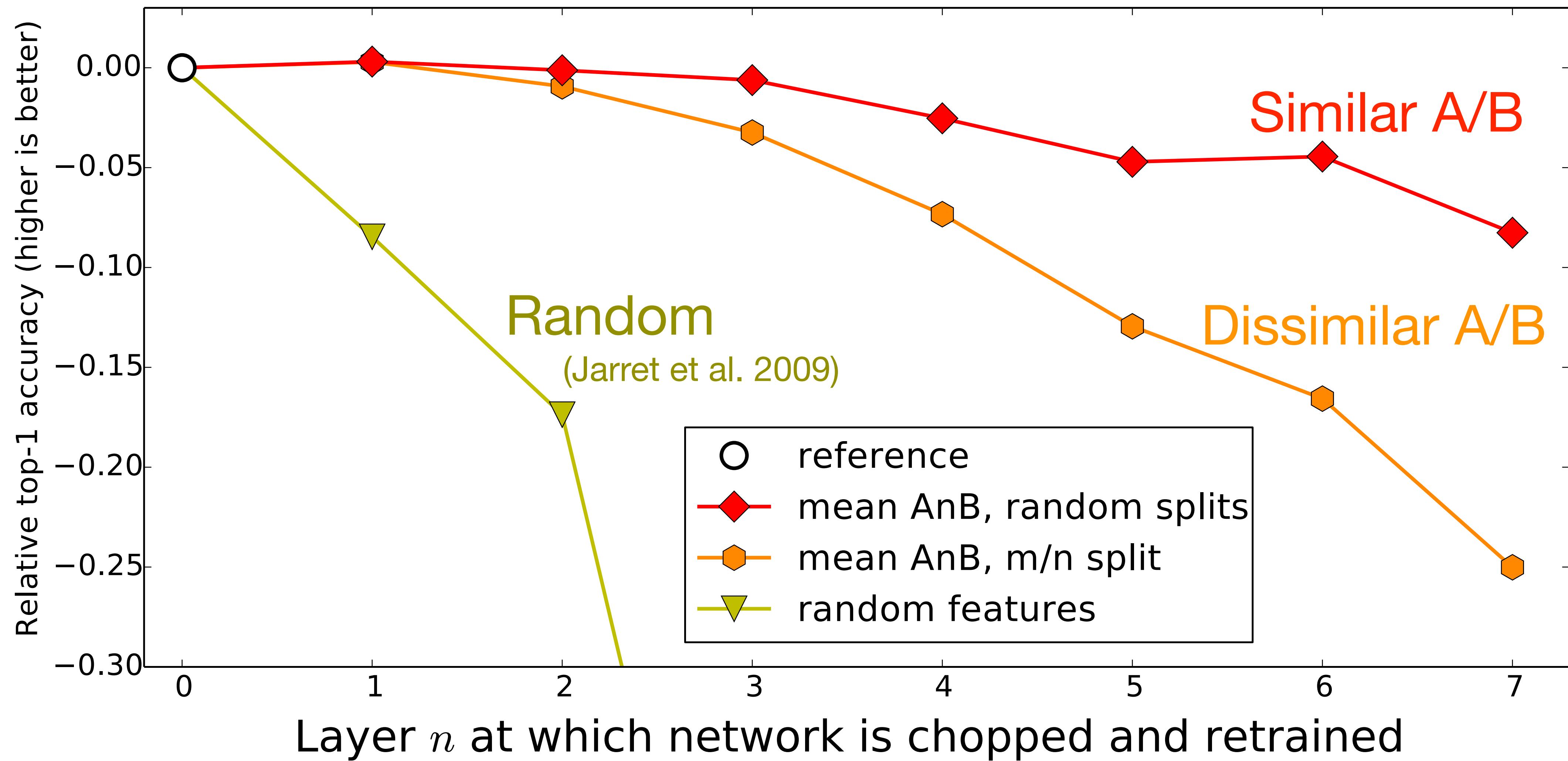
rabbit

panther

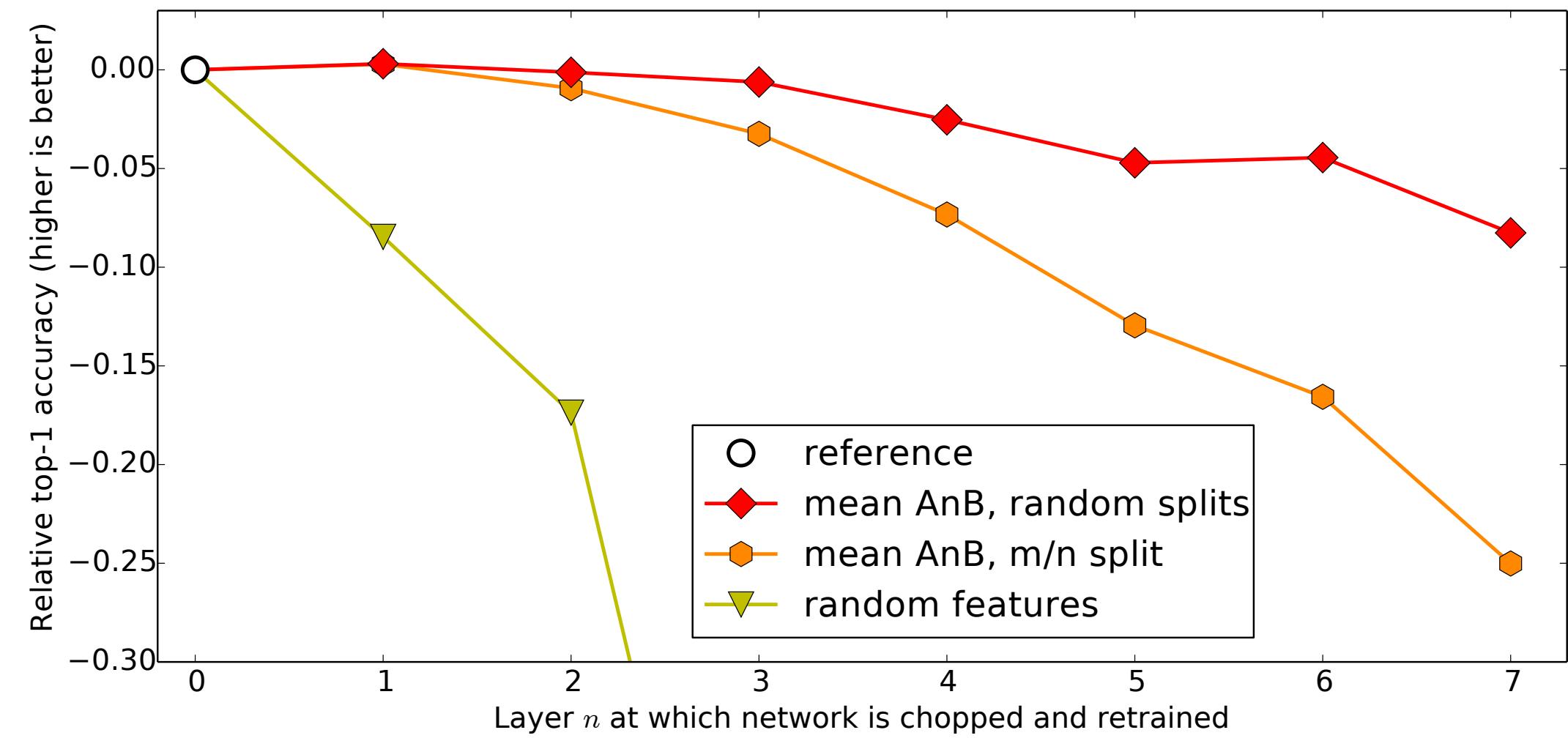
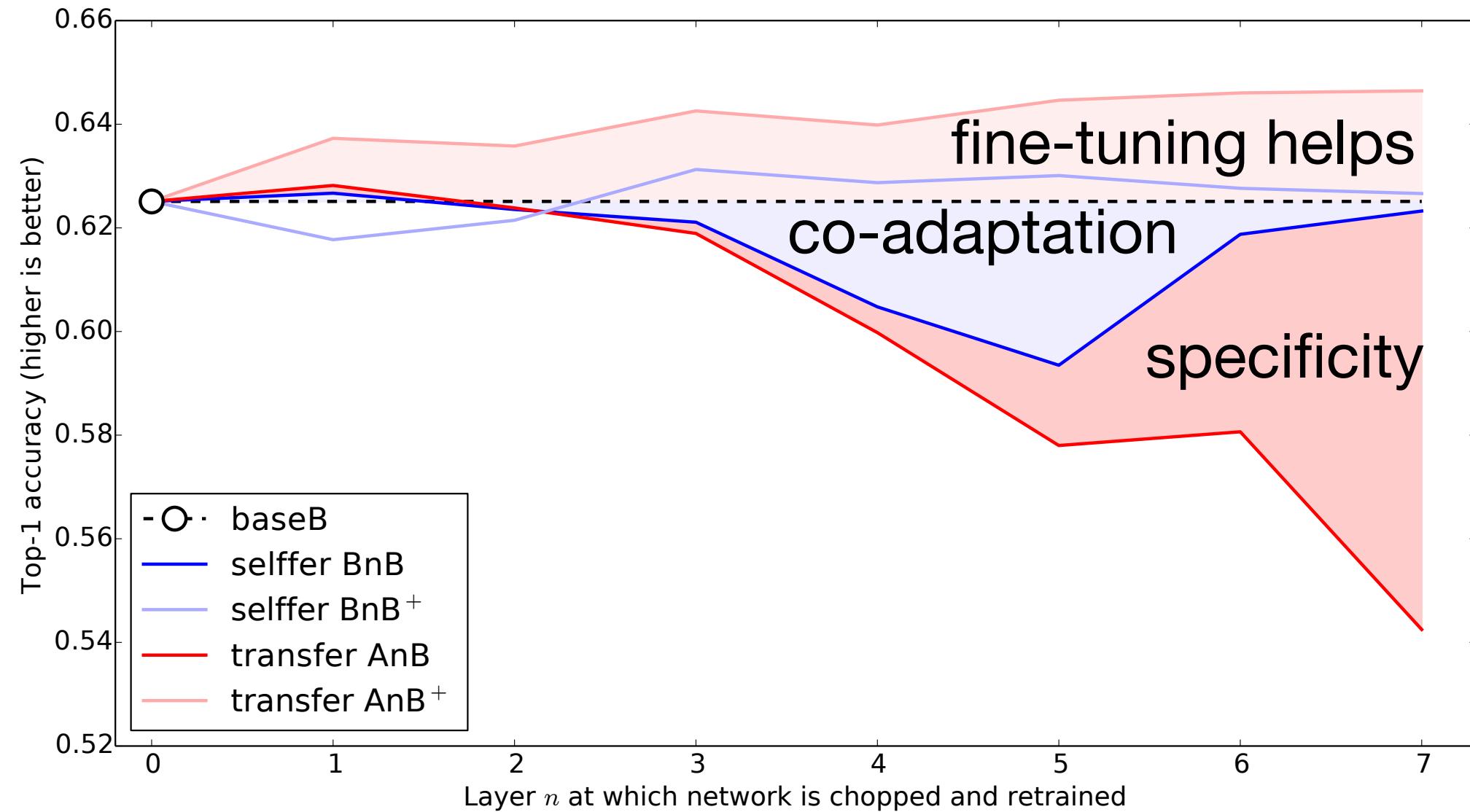
lion



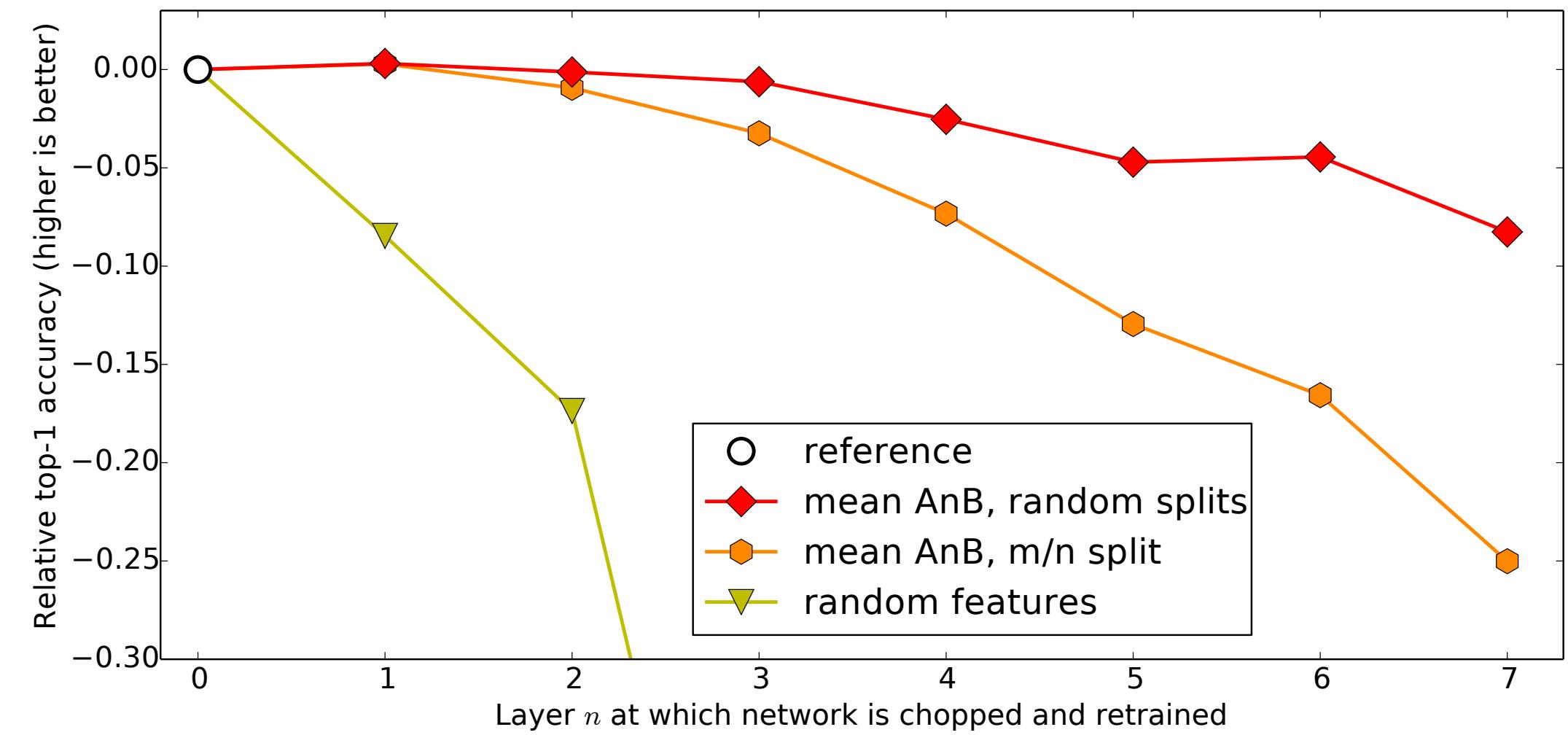
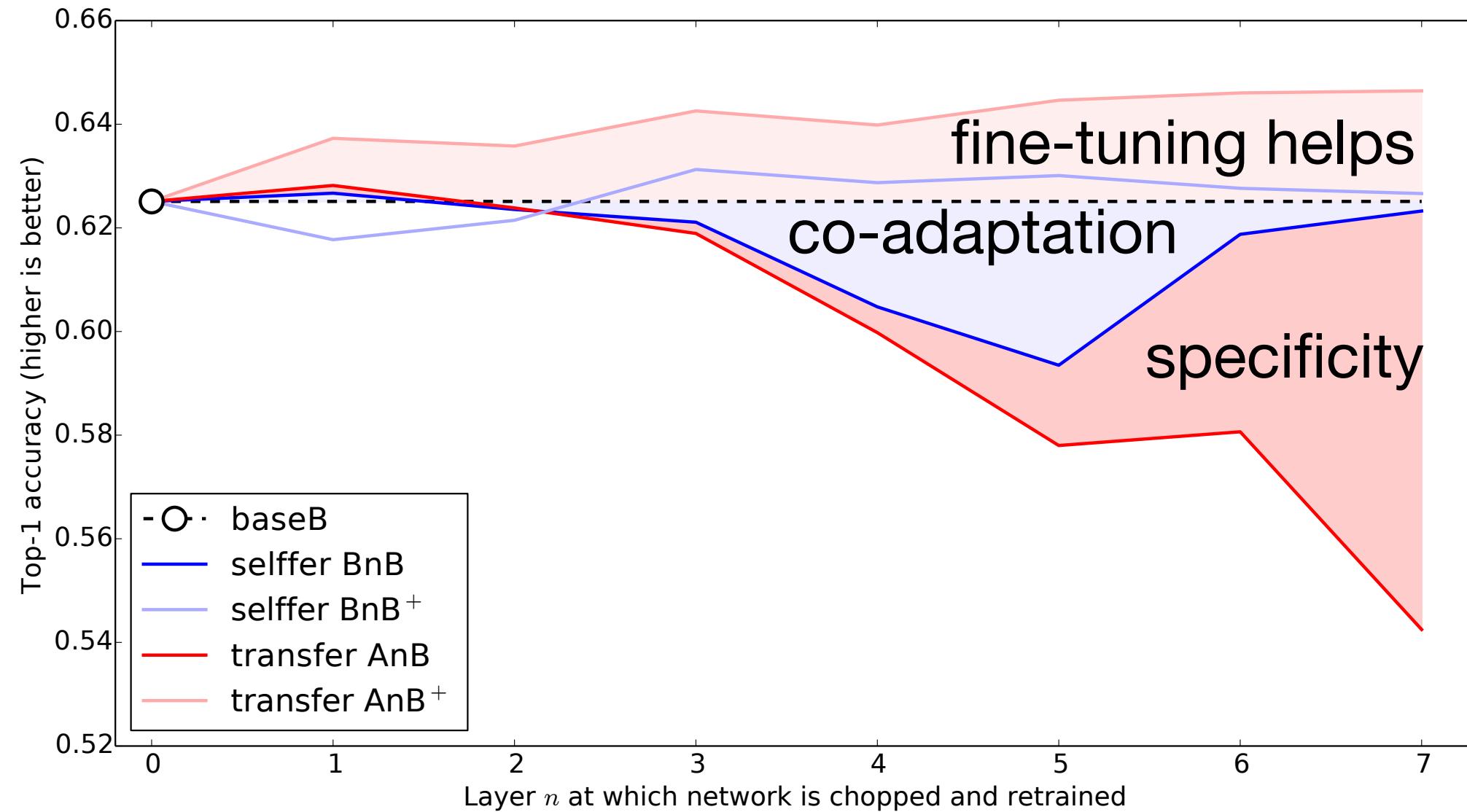




Conclusions

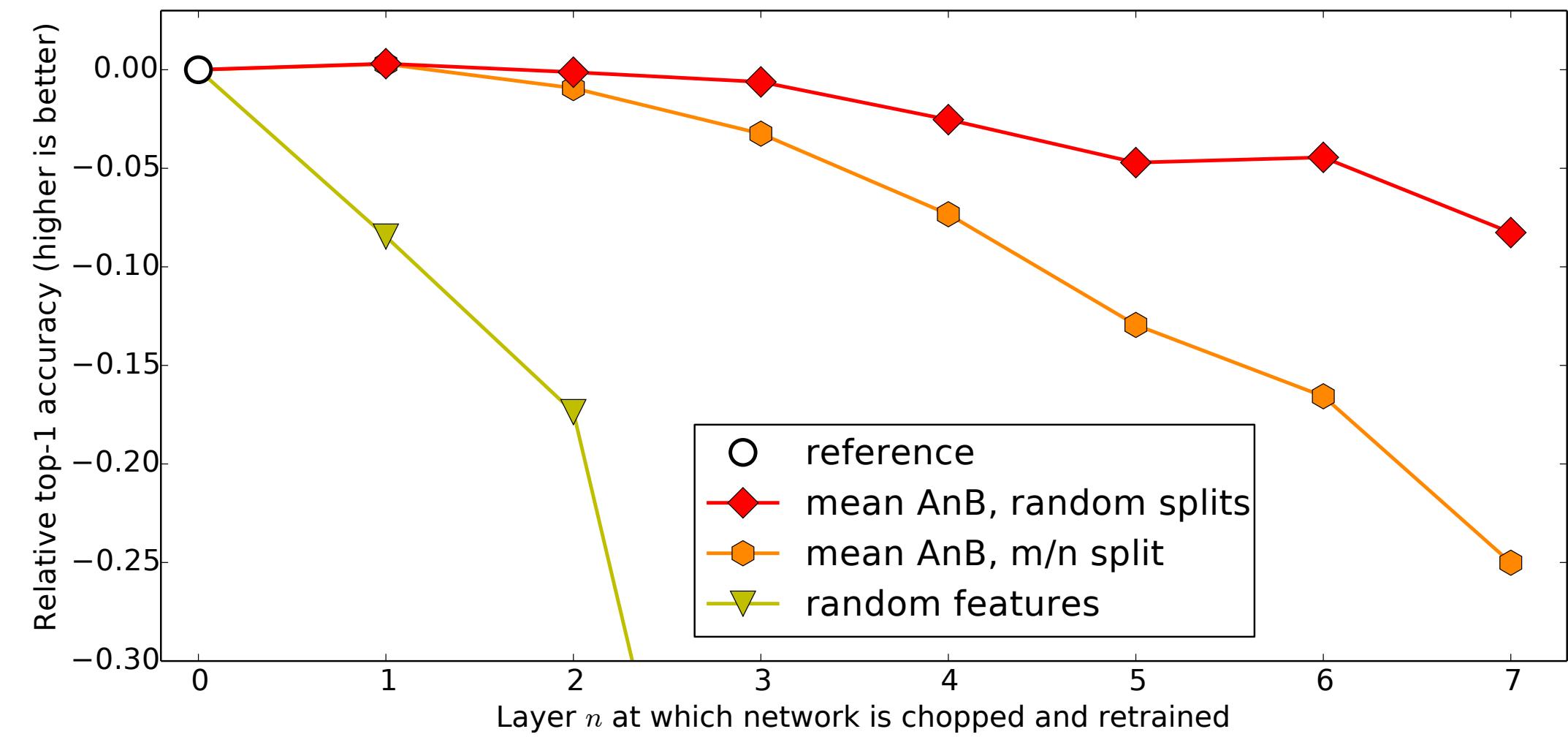
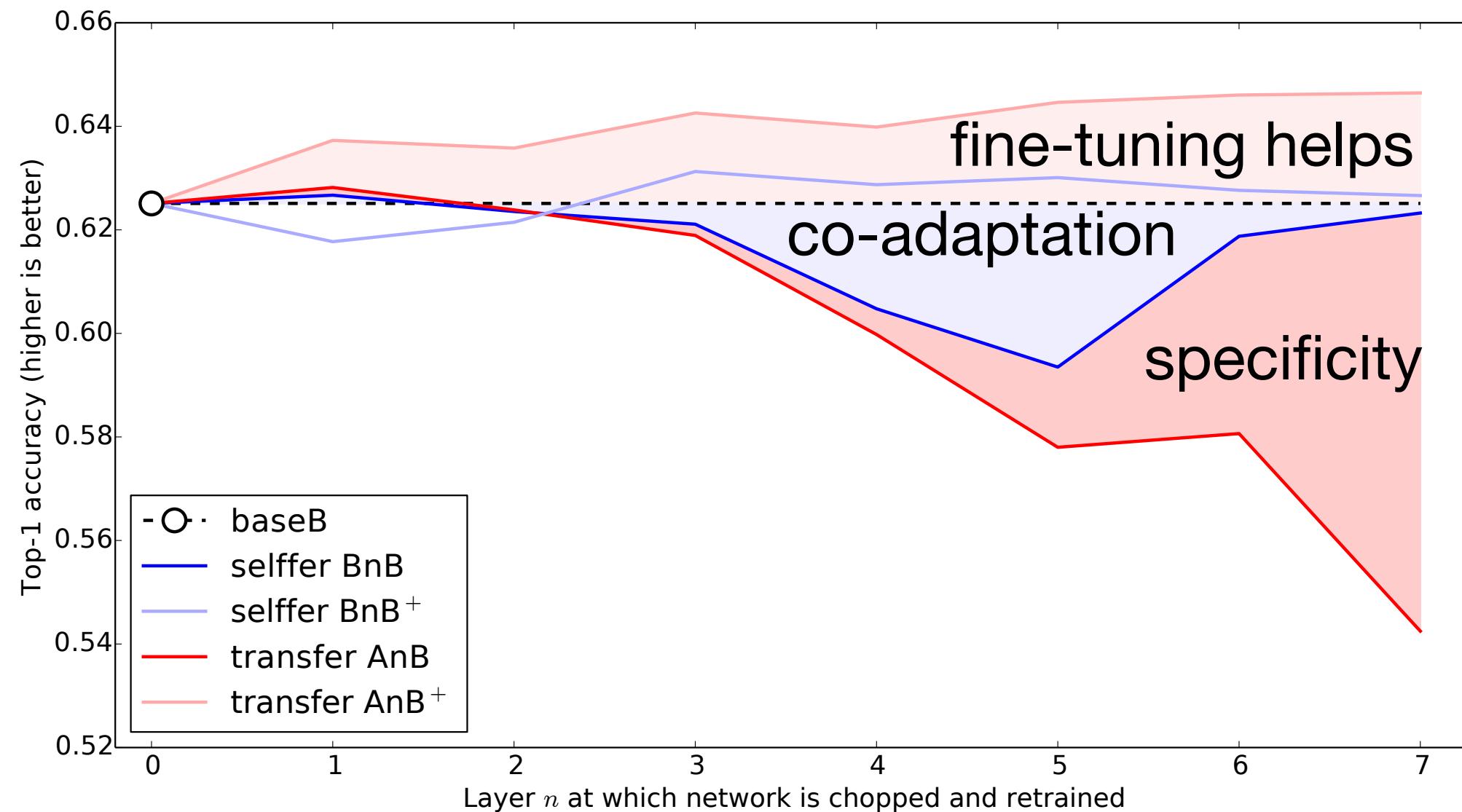


Conclusions



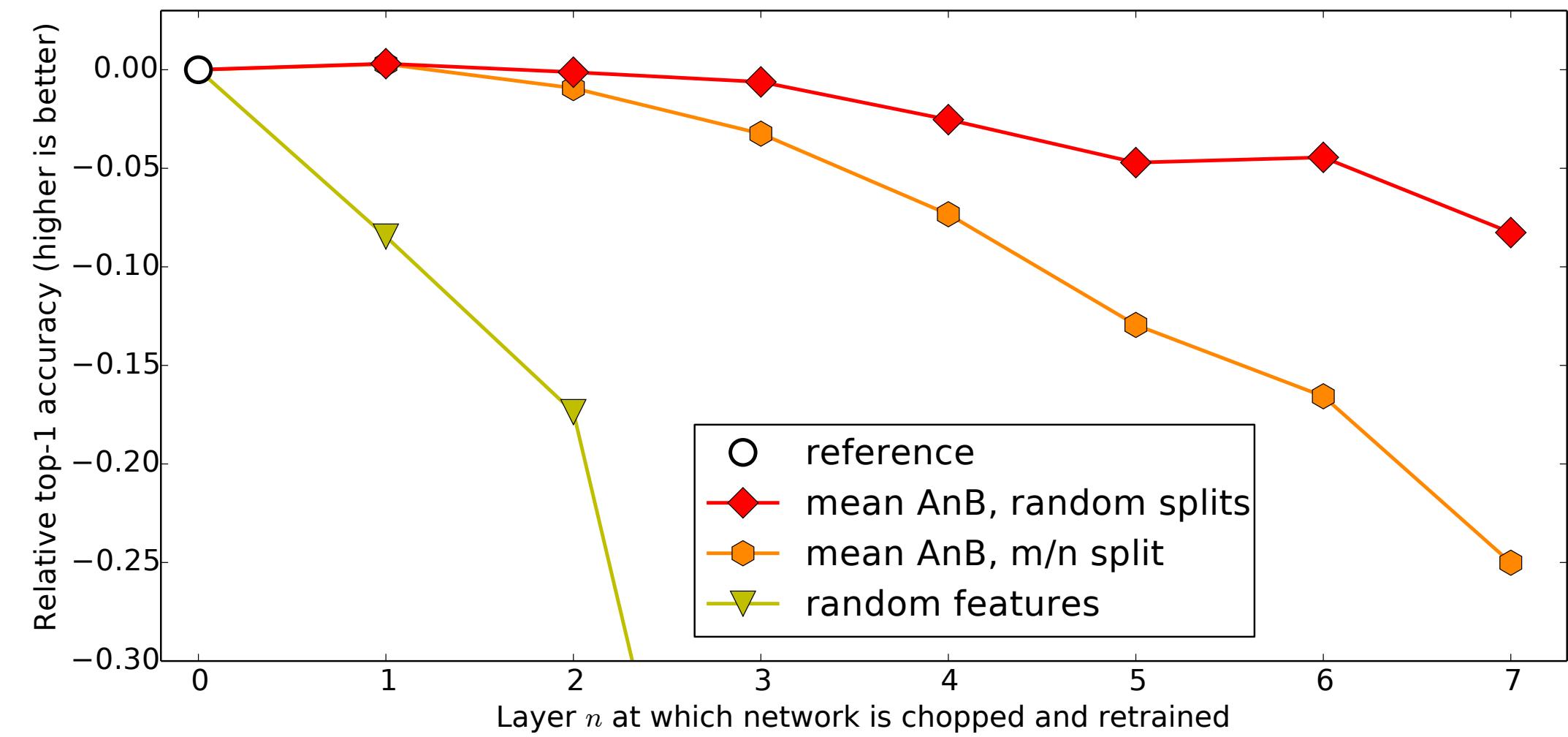
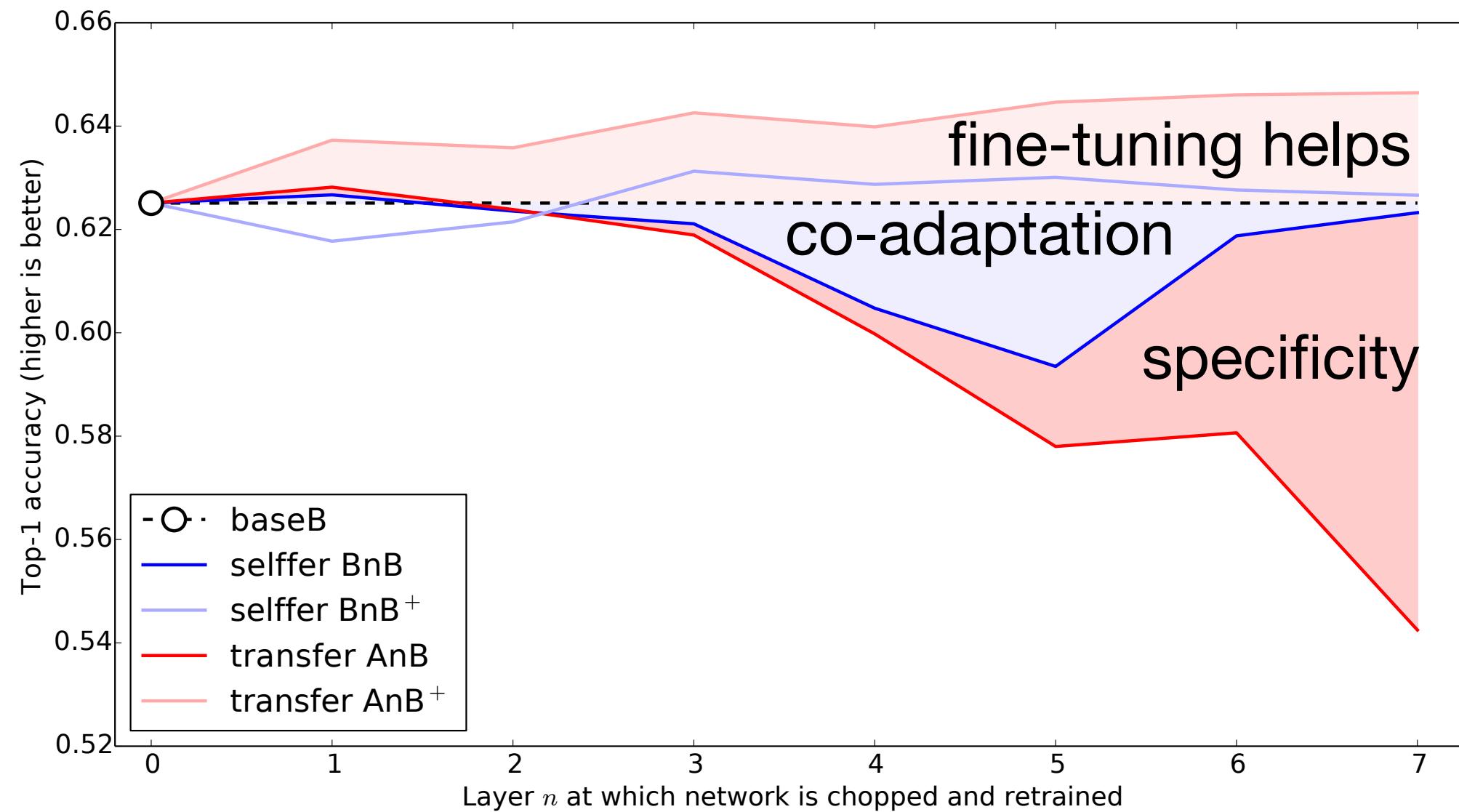
- Measure *general to specific* transition layer by layer

Conclusions



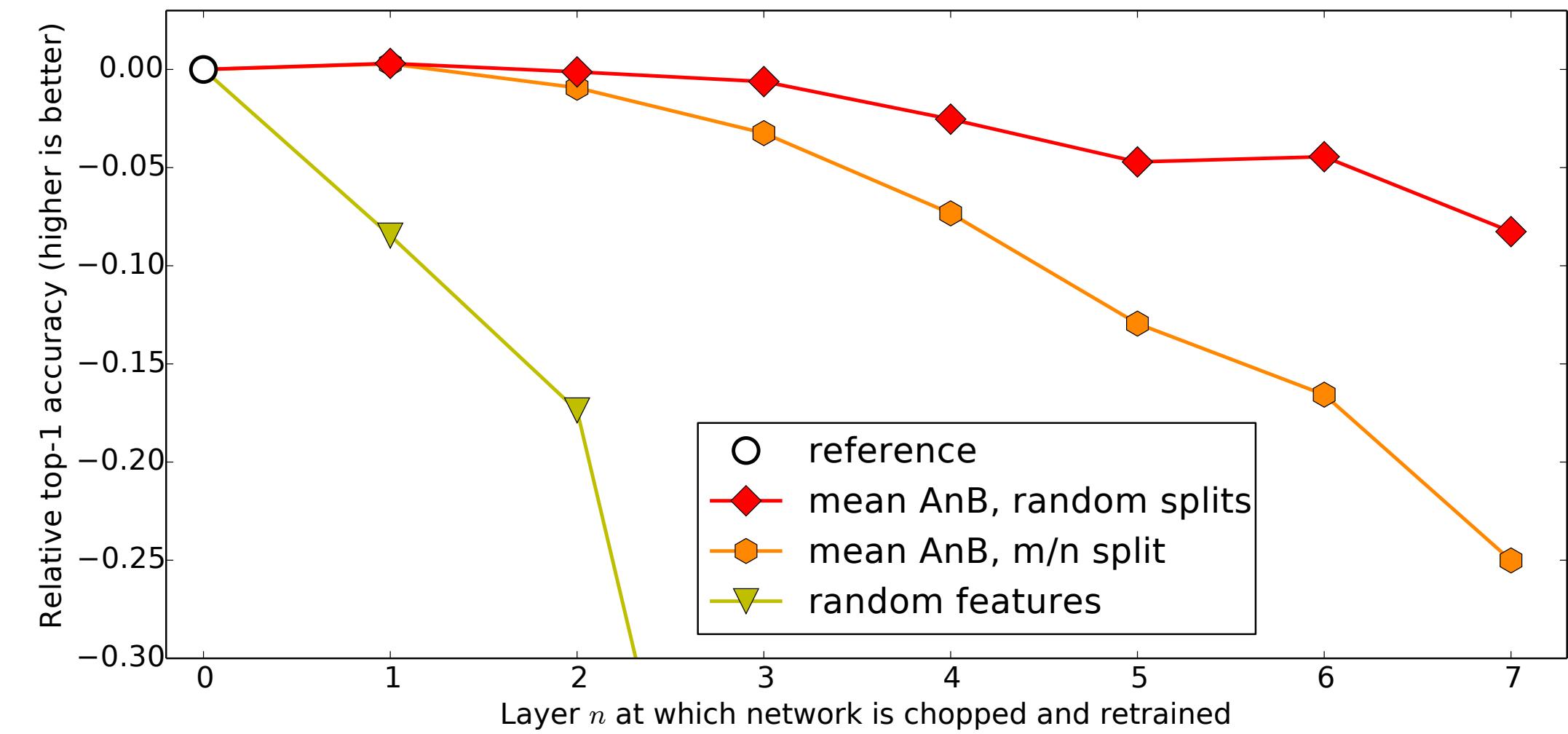
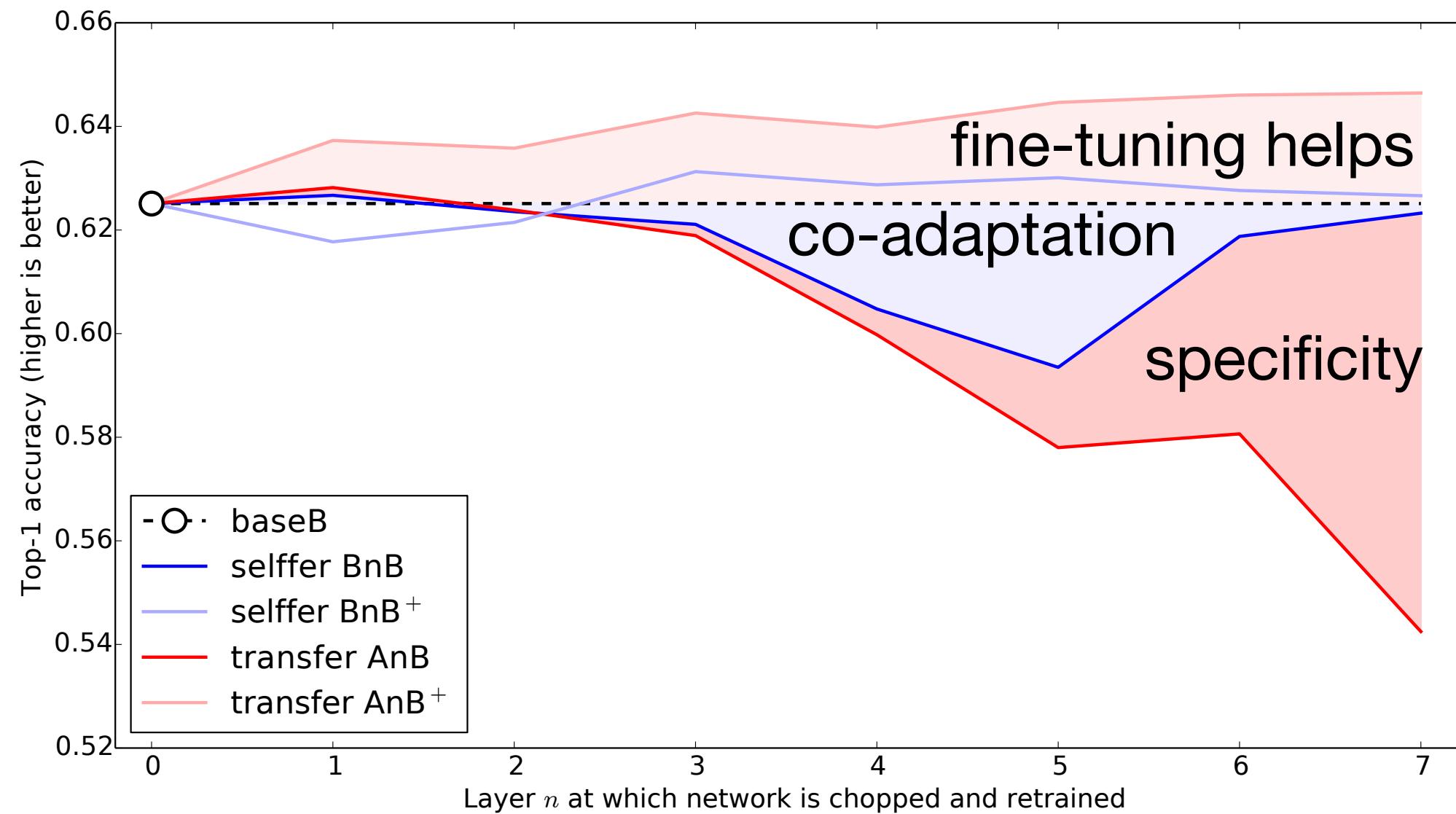
- Measure *general* to *specific* transition layer by layer
- Transferability governed by:

Conclusions



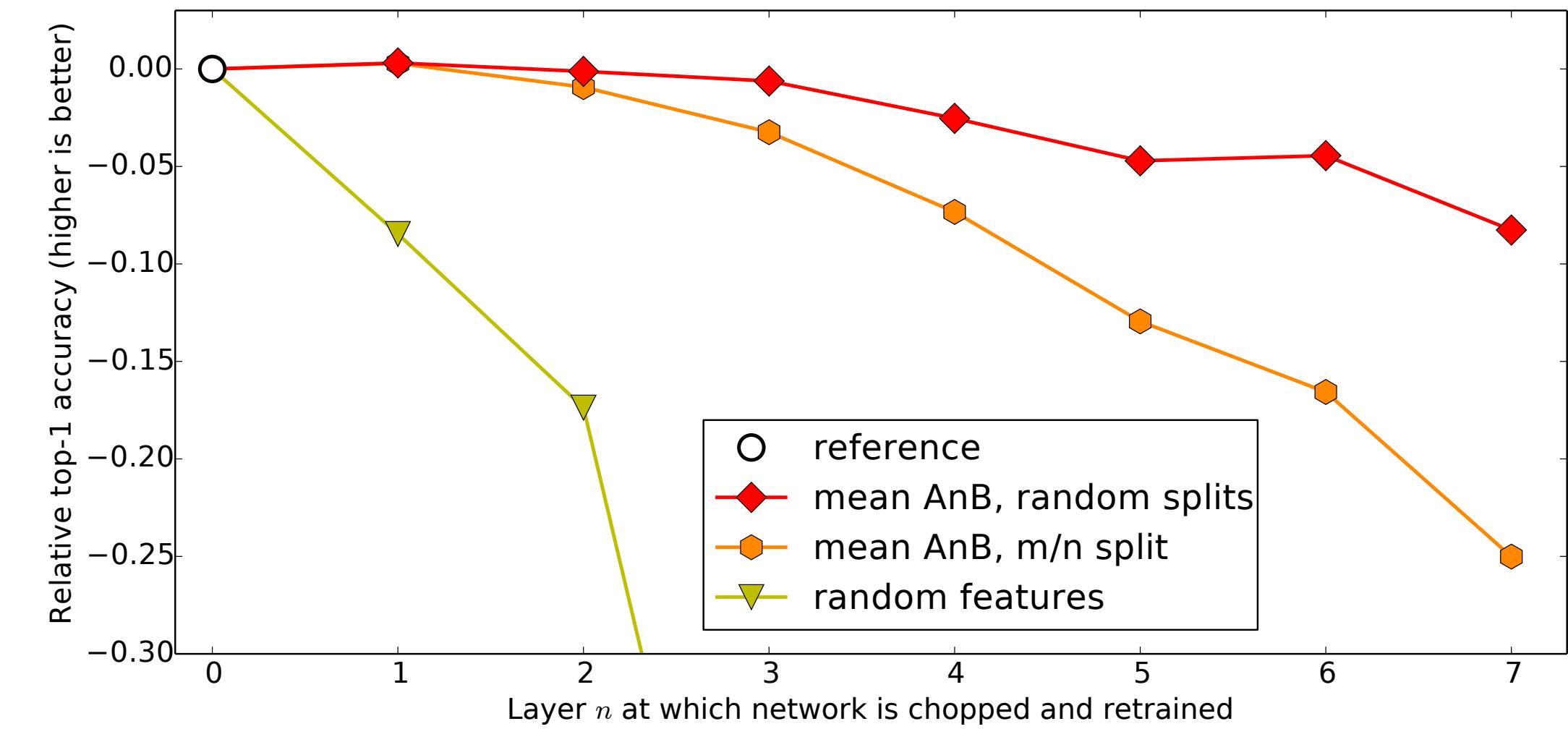
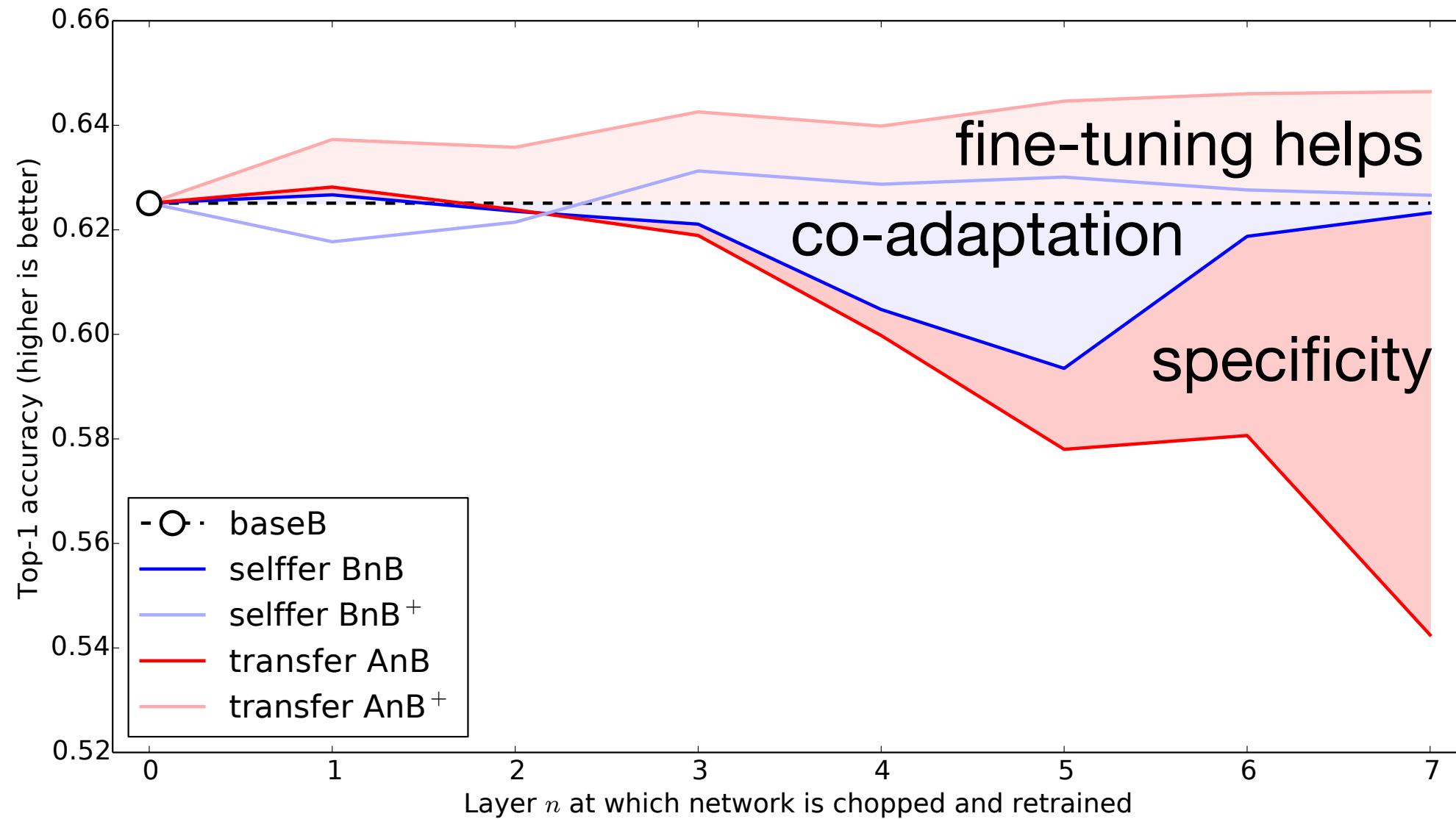
- Measure *general* to *specific* transition layer by layer
- Transferability governed by:
 - lost co-adaptations

Conclusions



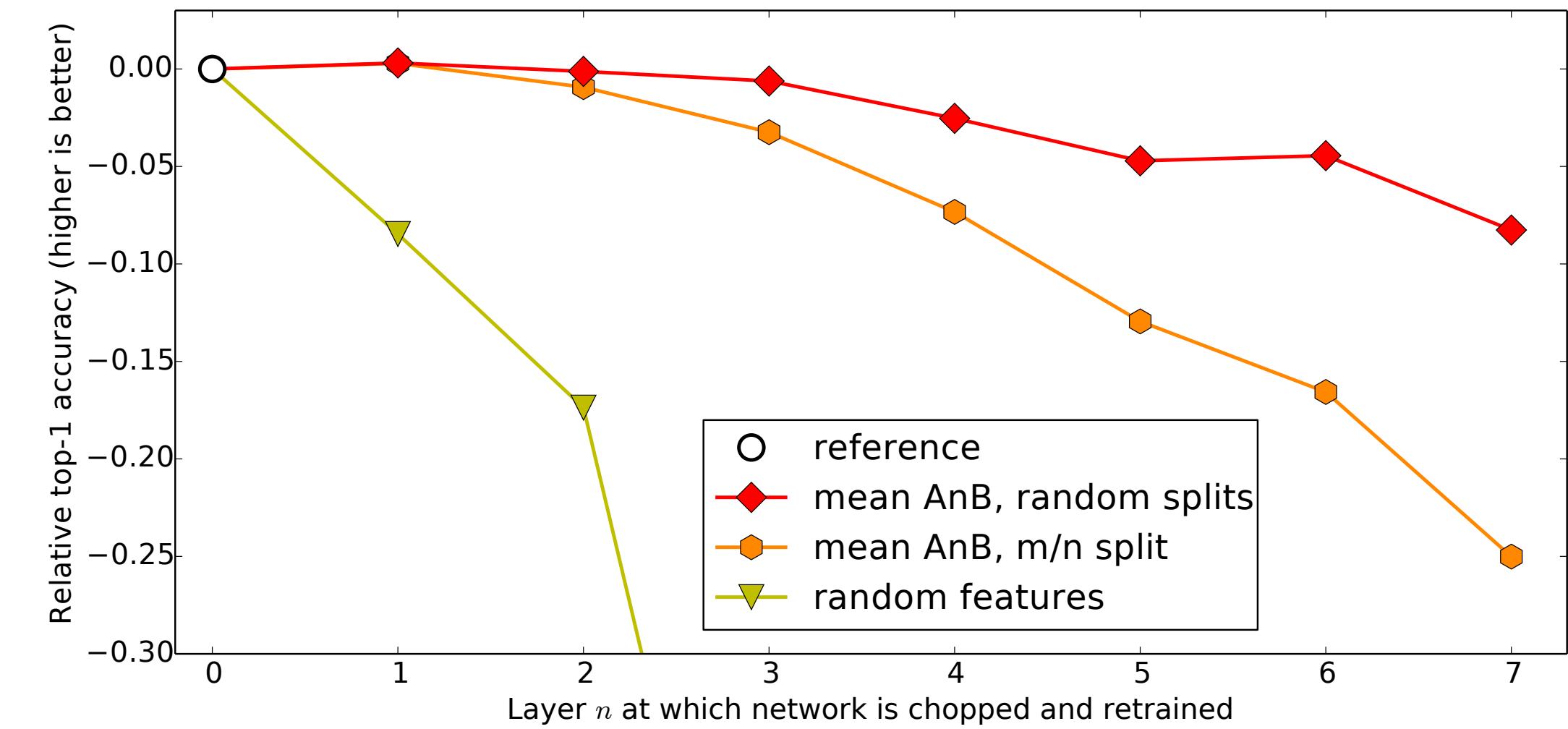
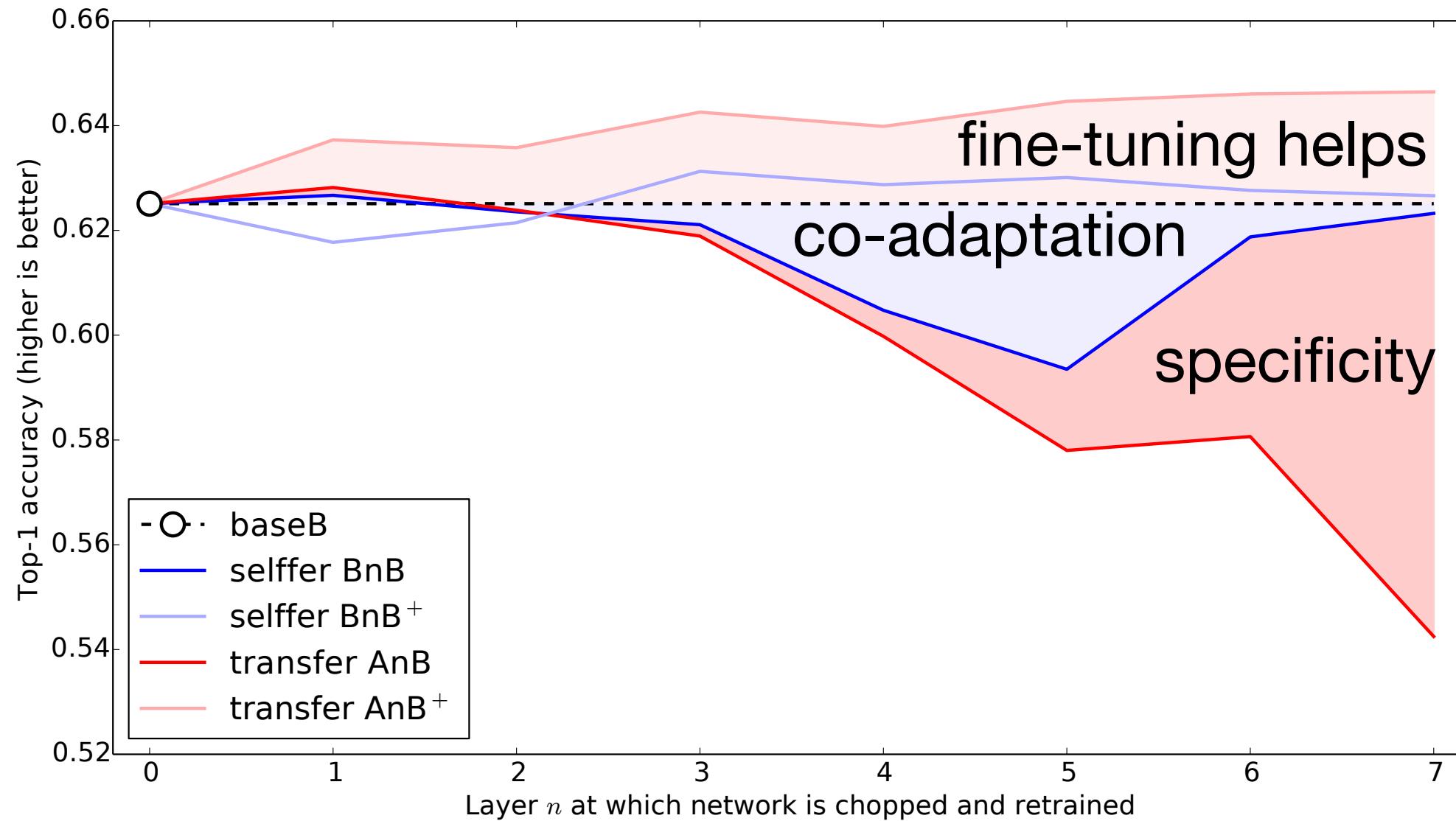
- Measure *general* to *specific* transition layer by layer
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 - lost co-adaptations
 - specificity

Conclusions



- Measure *general* to *specific* transition layer by layer
- Transferability governed by:
 - lost co-adaptations
 - specificity
 - difference between base and target dataset

Conclusions



- Measure *general* to *specific* transition layer by layer
- Transferability governed by:
 - lost co-adaptations
 - specificity
 - difference between base and target dataset
- Fine-tuning helps even on large target dataset

Additional reading on transfer learning

<http://cs231n.github.io/transfer-learning/>

Transfer learning tutorial in PyTorch:

https://pytorch.org/tutorials/beginner/transfer_learning_tutorial.html

Transfer learning for real problems:

“Dermatologist-level classification of skin cancer
with deep neural networks”, Nature Medicine (2017)

https://web.stanford.edu/group/blau/pdfs/Esteva_Thrun_2017.pdf