Classifying Plankton Species with Computer Vision and Deep Learning

An ANC Seminar Talk by

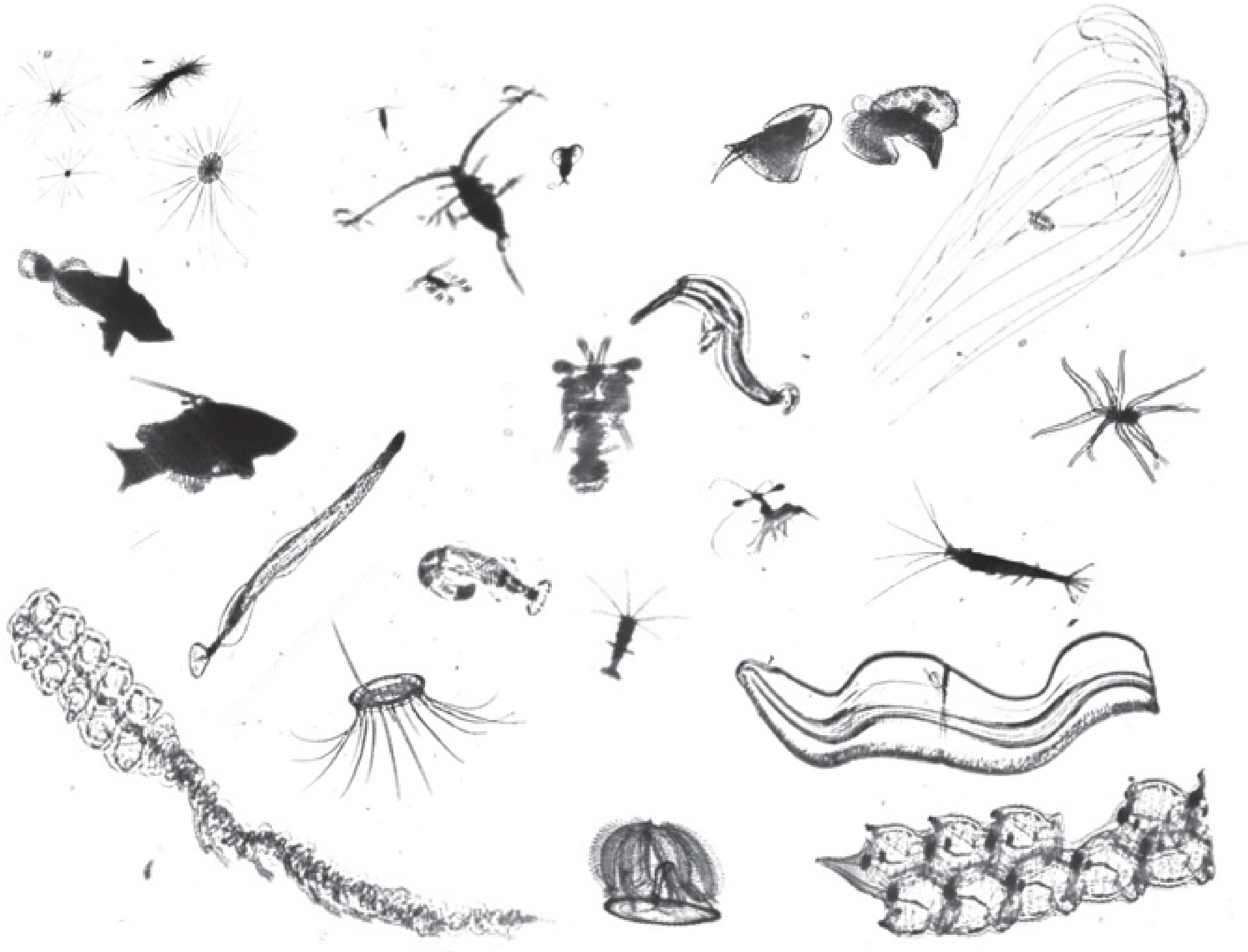
Scott Lowe

24th March, 2015

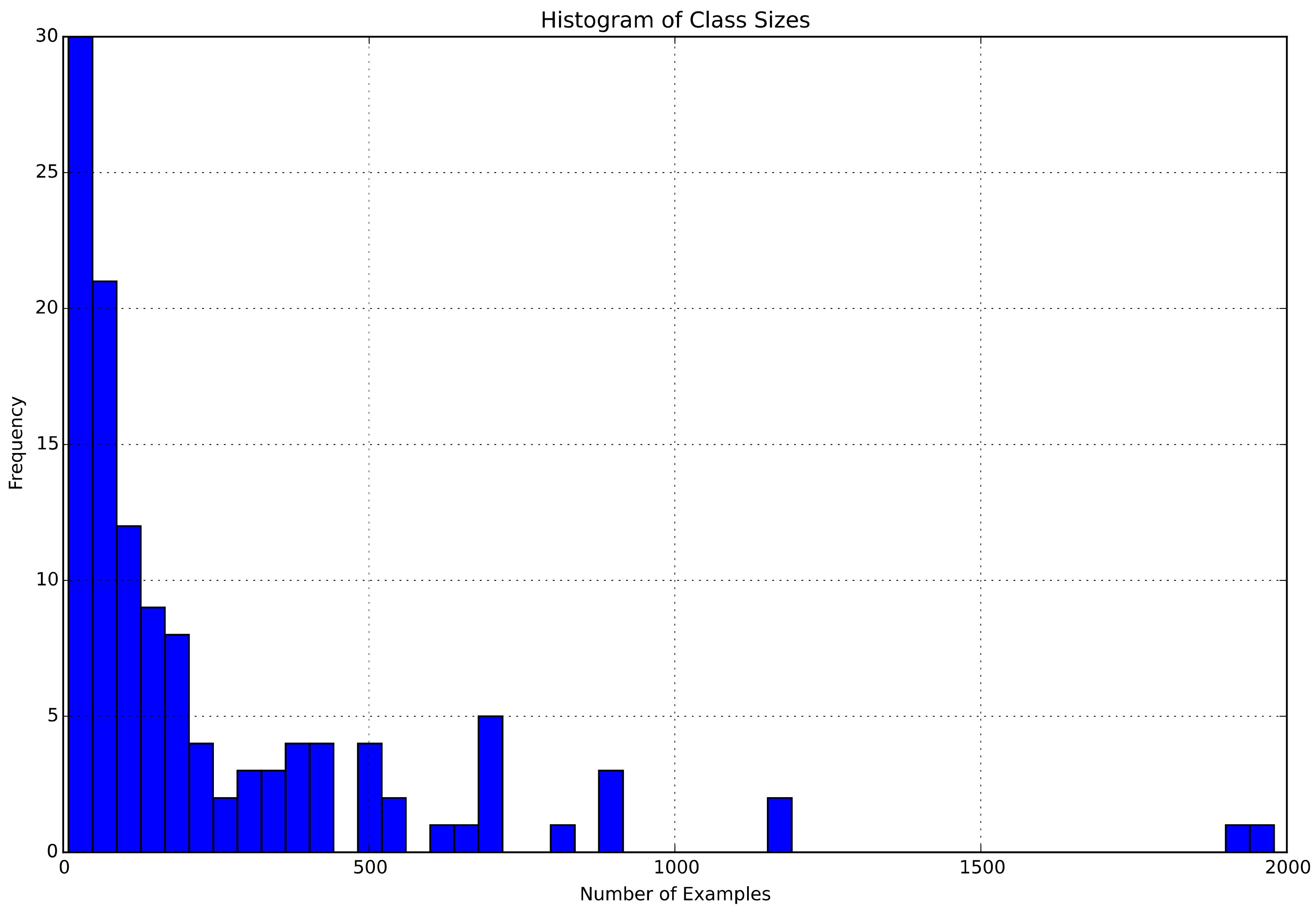
Why am I studying plankton?!

- Kaggle competition, with 1st prize $100,000
- Good way to learn some stuff about Convolutional Neural Networks and Computer Vision
- Fun project
- The team was
  - Matt Graham
  - Gavin Gray
  - Scott Lowe
  - Finlay Maguire
  - Alina Selega
  - Dragos Stanciu

Dataset examples



Distribution of class cardinality



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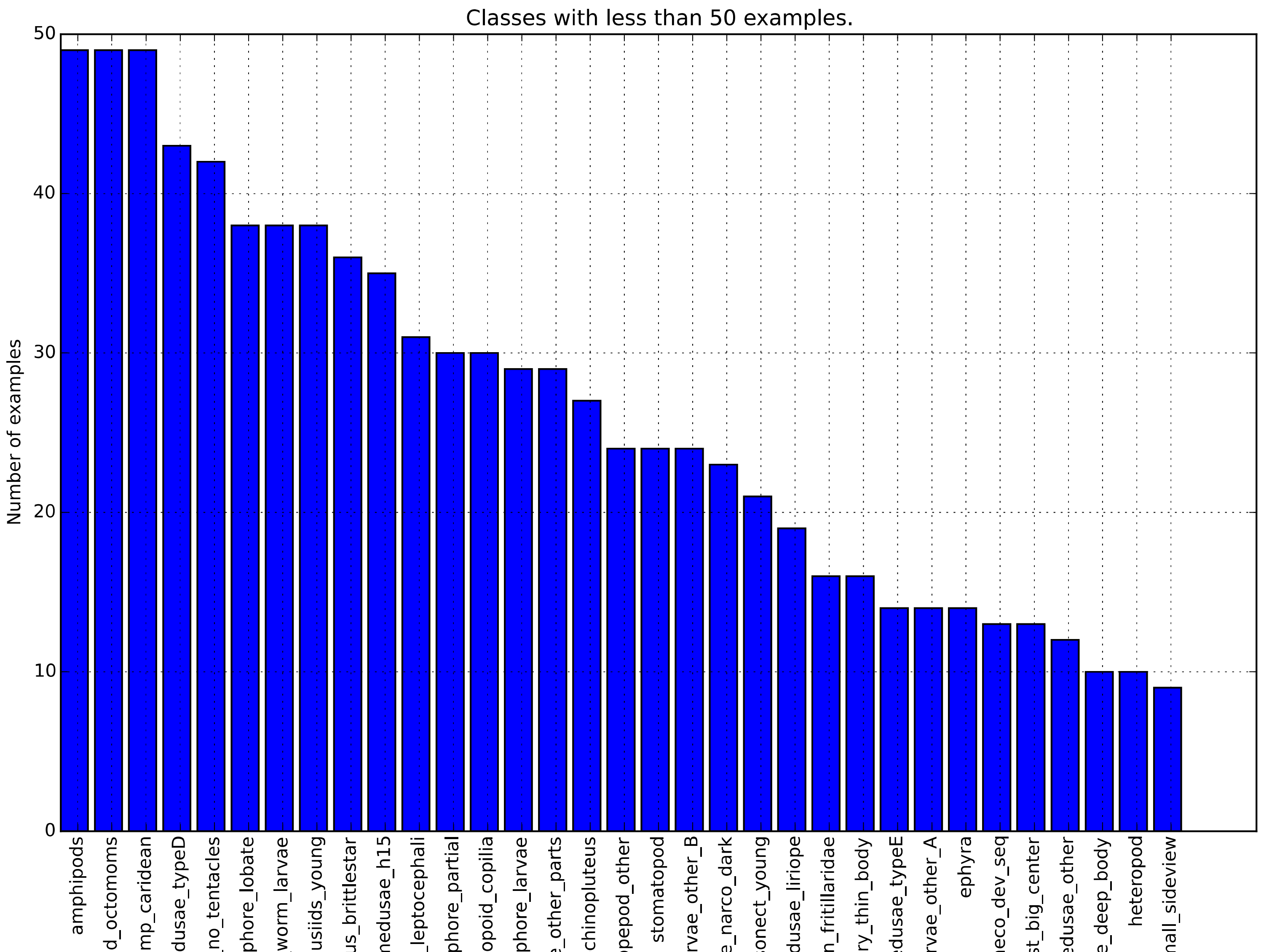
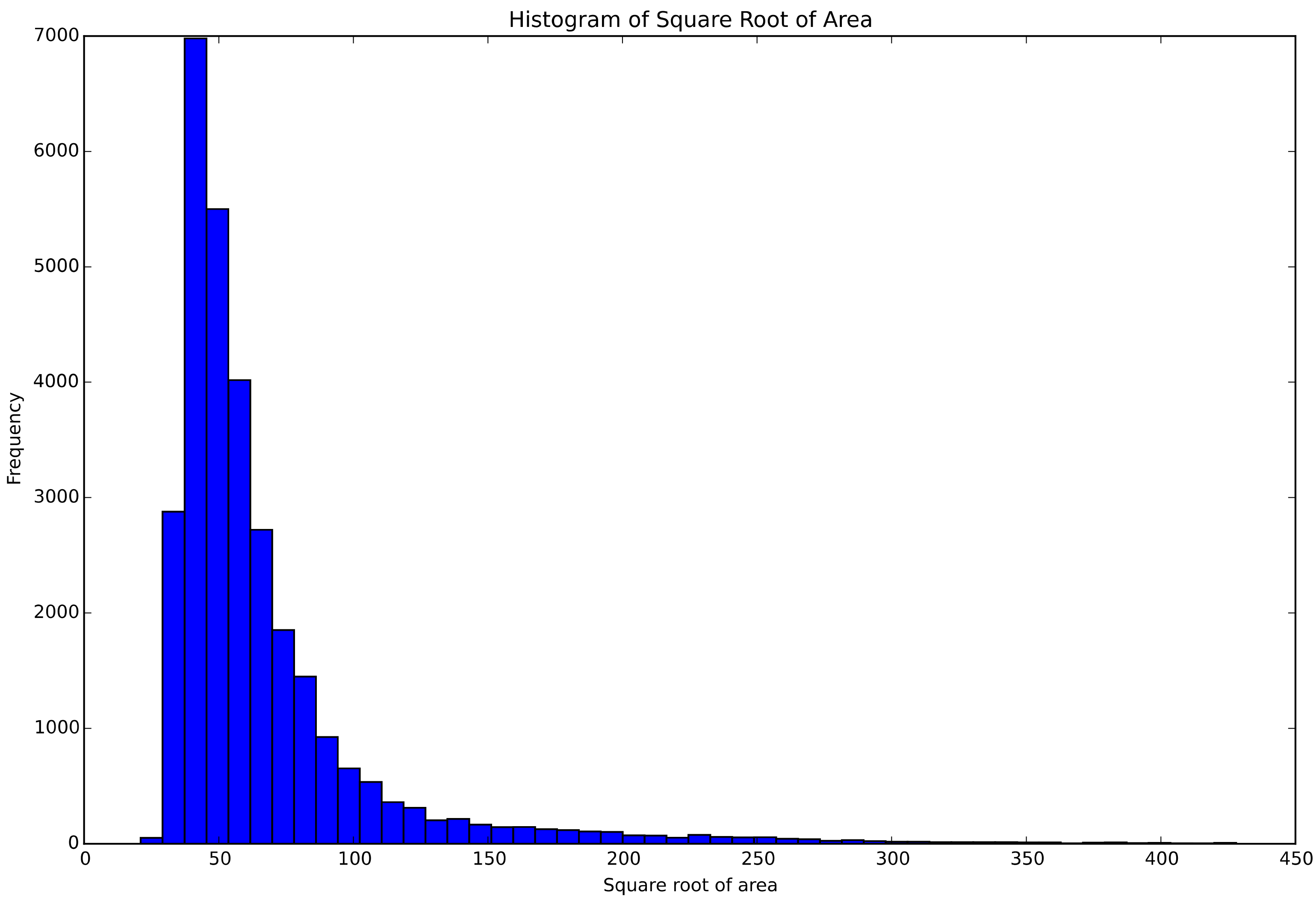
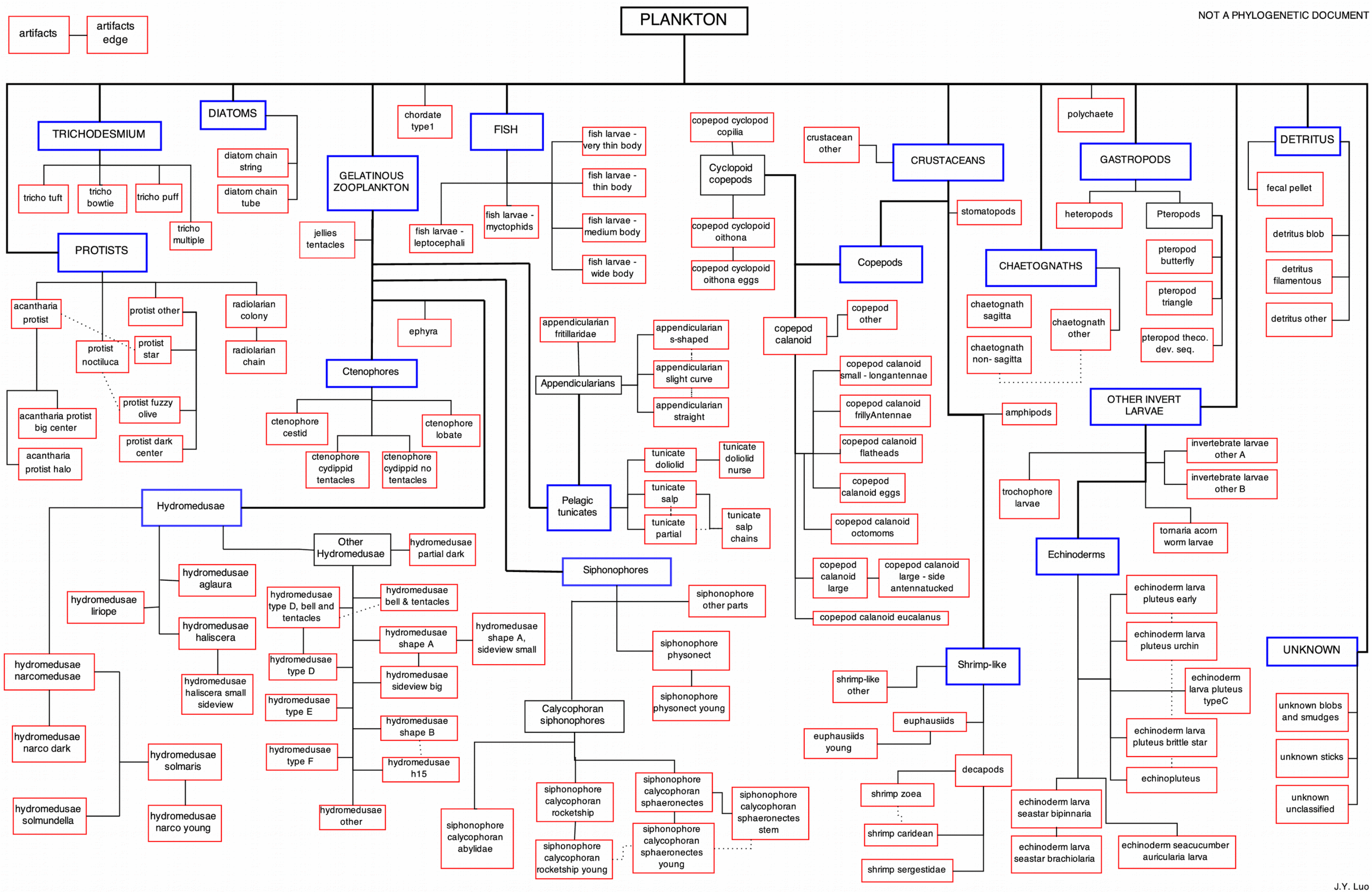


Distribution of image sizes





PLANKTON
NOT A PHYLOGENETIC DOCUMENT
artifacts
artifacts edge
TRICHODESMIUM
tricho tuft
tricho bowtie
tricho puff
tricho multiple
DIATOMS
diatom chain string
diatom chain tube
chordate type1
GELATINOUS ZOOPLANKTON
jellies tentacles
FISH
fish larvae - leptocephali
fish larvae - myctophids
fish larvae - very thin body
fish larvae - thin body
fish larvae - medium body
fish larvae - wide body
copepod cyclopod copilia
Cyclopoid copepods
copepod cyclopoid oithona
copepod cyclopoid oithona eggs
crustacean other
CRUSTACEANS
stomatopods
polychaete
GASTROPODS
heteropods
Pteropods
pteropod butterfly
pteropod triangle
pteropod theco. dev. seq.
DETRITUS
fecal pellet
detritus blob
detritus filamentous
detritus other
PROTISTS
acantharia protist
protist other
radiolarian colony
radiolarian chain
protist noctiluca
protist star
protist fuzzy olive
protist dark center
acantharia protist big center
acantharia protist halo
ephyra
Ctenophores
ctenophore cestid
ctenophore lobate
ctenophore cydippid tentacles
ctenophore cydippid no tentacles
appendicularian fritillaridae
Appendicularians
appendicularian s-shaped
appendicularian slight curve
appendicularian straight
tunicate doliolid
tunicate doliolid nurse
tunicate salp
tunicate salp chains
tunicate partial
Pelagic tunicates
Copepods
copepod other
copepod calanoid
copepod calanoid small - longantennae
copepod calanoid frillyAntennae
copepod calanoid flatheads
copepod calanoid eggs
copepod calanoid octomoms
copepod calanoid large
copepod calanoid large - side antennatucked
copepod calanoid eucalanus
CHAETOGNATHS
chaetognath sagitta
chaetognath non- sagitta
chaetognath other
amphipods
OTHER INVERT LARVAE
invertebrate larvae other A
invertebrate larvae other B
trochophore larvae
tornaria acorn worm larvae
Echinoderms
echinoderm larva pluteus early
echinoderm larva pluteus urchin
echinoderm larva pluteus typeC
echinoderm larva pluteus brittle star
echinopluteus
echinoderm larva seastar bipinnaria
echinoderm larva seastar brachiolaria
echinoderm seacucumber auricularia larva
Hydromedusae
Other Hydromedusae
hydromedusae partial dark
hydromedusae aglaura
hydromedusae liriope
hydromedusae haliscera
hydromedusae haliscera small sideview
hydromedusae narcomedusae
hydromedusae narco dark
hydromedusae solmaris
hydromedusae narco young
hydromedusae solmundella
hydromedusae type D, bell and tentacles
hydromedusae bell & tentacles
hydromedusae type D
hydromedusae shape A
hydromedusae shape A, sideview small
hydromedusae sideview big
hydromedusae type E
hydromedusae shape B
hydromedusae type F
hydromedusae h15
hydromedusae other
Siphonophores
siphonophore other parts
siphonophore physonect
siphonophore physonect young
Calycophoran siphonophores
siphonophore calycophoran abylidae
siphonophore calycophoran rocketship
siphonophore calycophoran rocketship young
siphonophore calycophoran sphaeronectes
siphonophore calycophoran sphaeronectes young
siphonophore calycophoran sphaeronectes stem
Shrimp-like
shrimp-like other
euphausiids
euphausiids young
decapods
shrimp zoea
shrimp caridean
shrimp sergestidae
UNKNOWN
unknown blobs and smudges
unknown sticks
unknown unclassified
J.Y. Luo

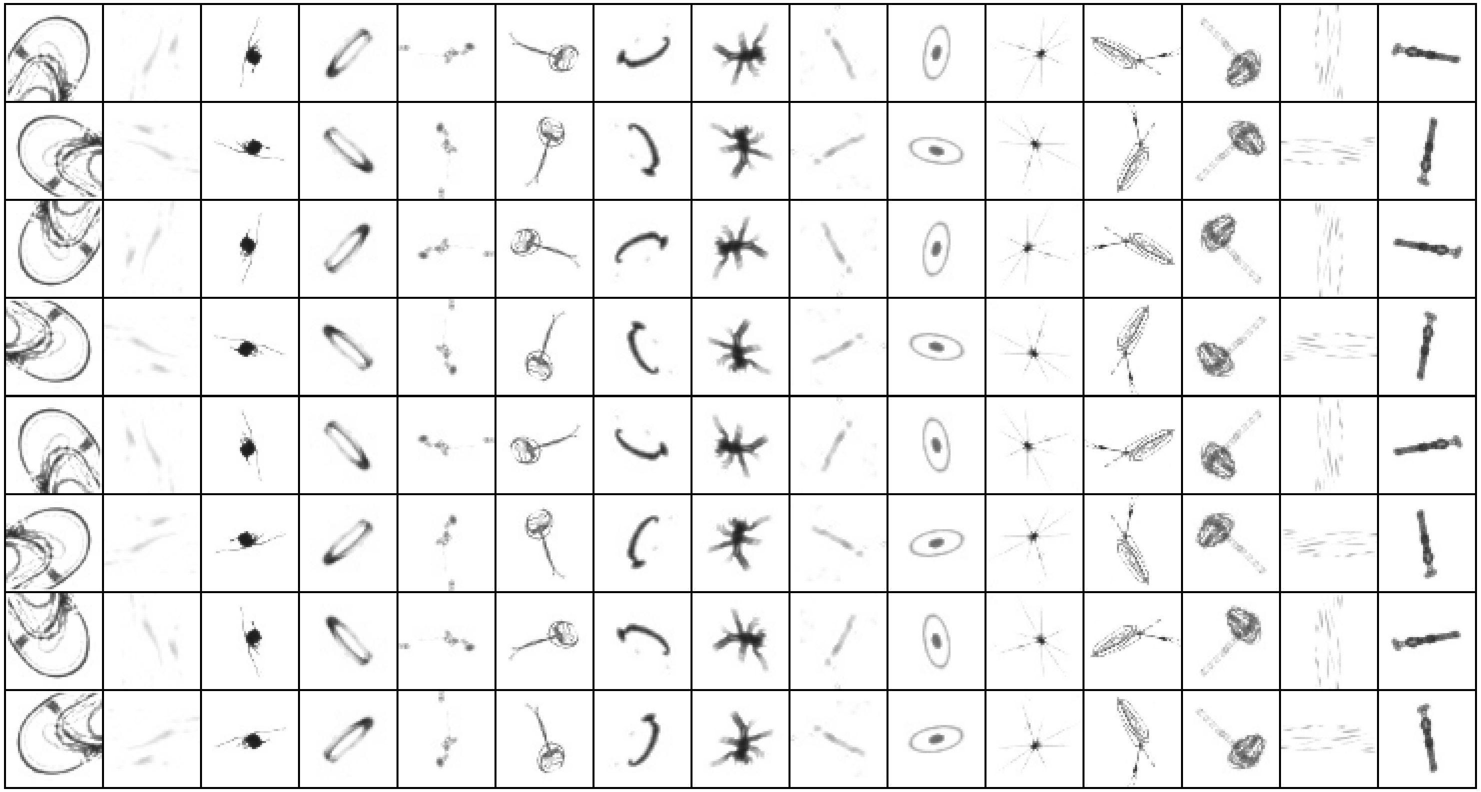
Our approach

- Two general routes for solving image classification problem
  - Convolutional neural networks (“convnets”)
  - Computer vision heuristic techniques
- So combine the two techniques and beat though who use only one!

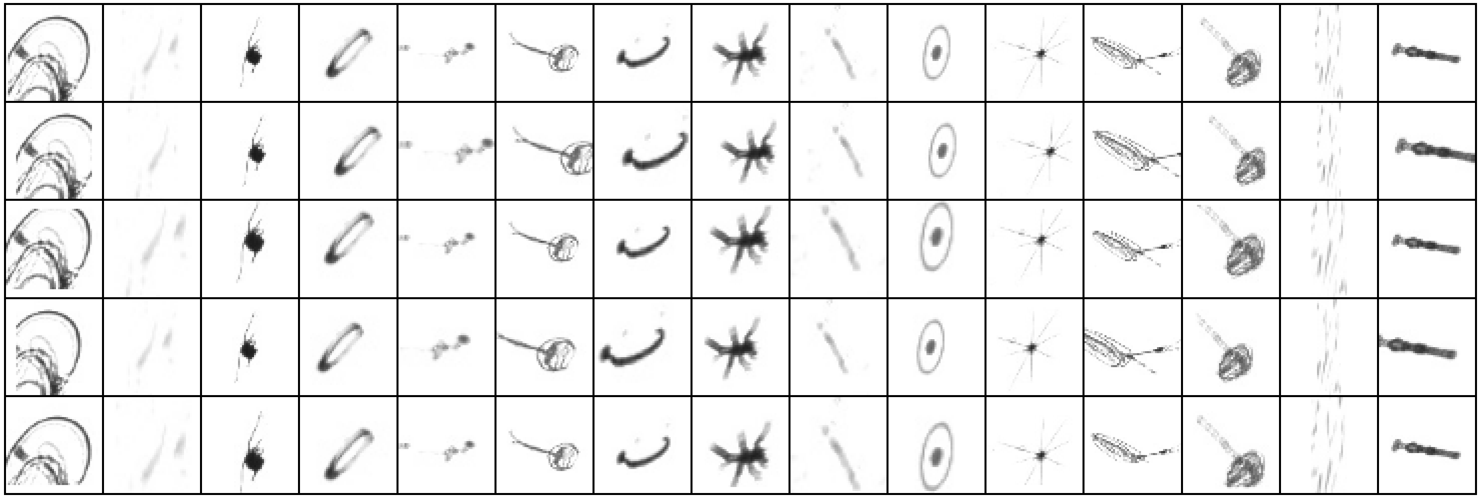
Offline Image Augmentation

- Offline augmentations
  - Rotation: [0,90,180,270] or [0,45,90,...] degrees, etc
  - Reflection: [no, yes]
  - Crop: [none, 20% top, 20% left, bottom, right]
  - Others implemented but not used
- Constrained by lack of CPU RAM

Offline Image Augmentation



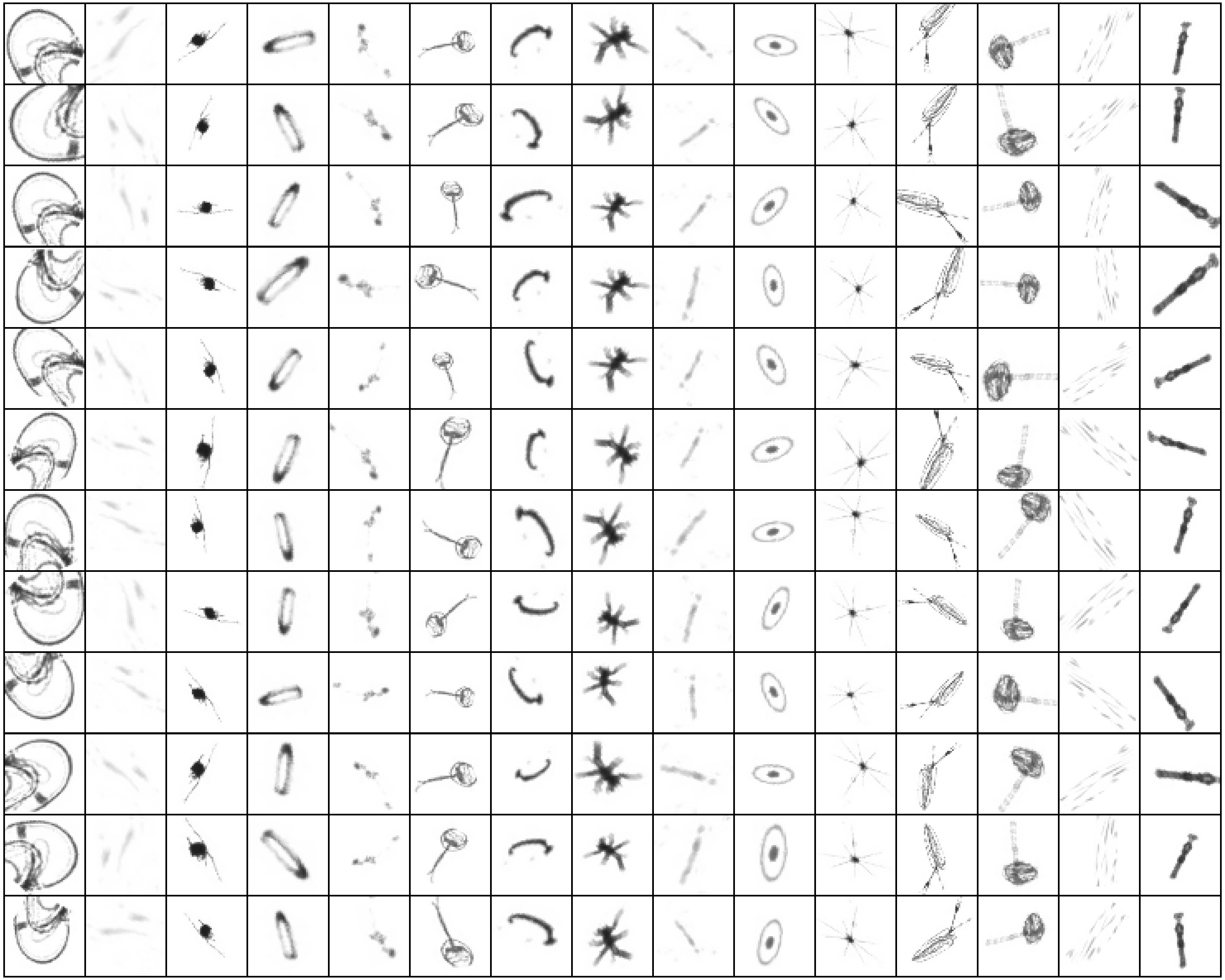
Offline Image Augmentation



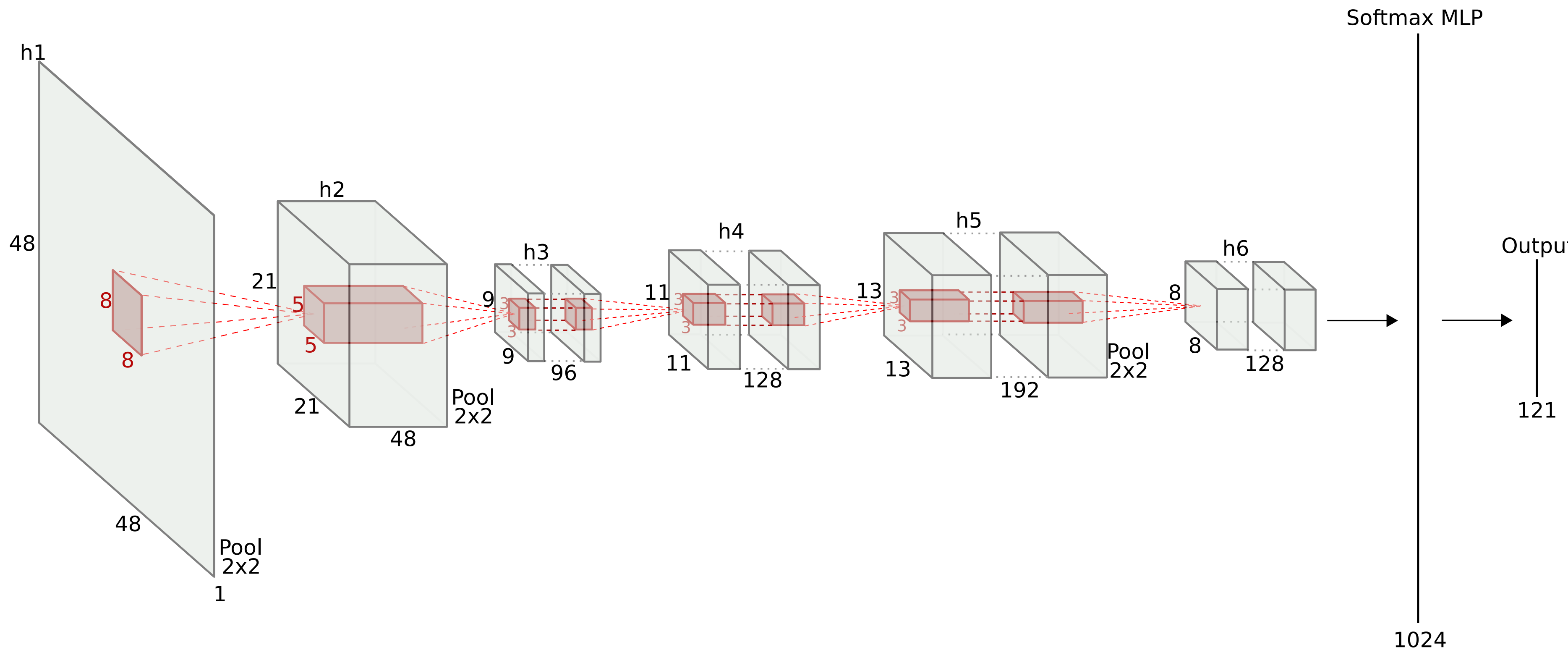
Online Image Augmentation

- Online augmentations
  - Rotation: Uniform across [0,360) degrees
  - Reflection: Bernouli distributed
  - Translation: Gaussian in x and y, N(0%, 5%)
  - Scale: Gaussian N(1.0, 0.1)
  - Stretch: Gaussian in x and y individually, N(0, 0.01)
  - Shear: Gaussian N(0, 5°)
- Augmentations generated for next batch on CPU while training on GPU

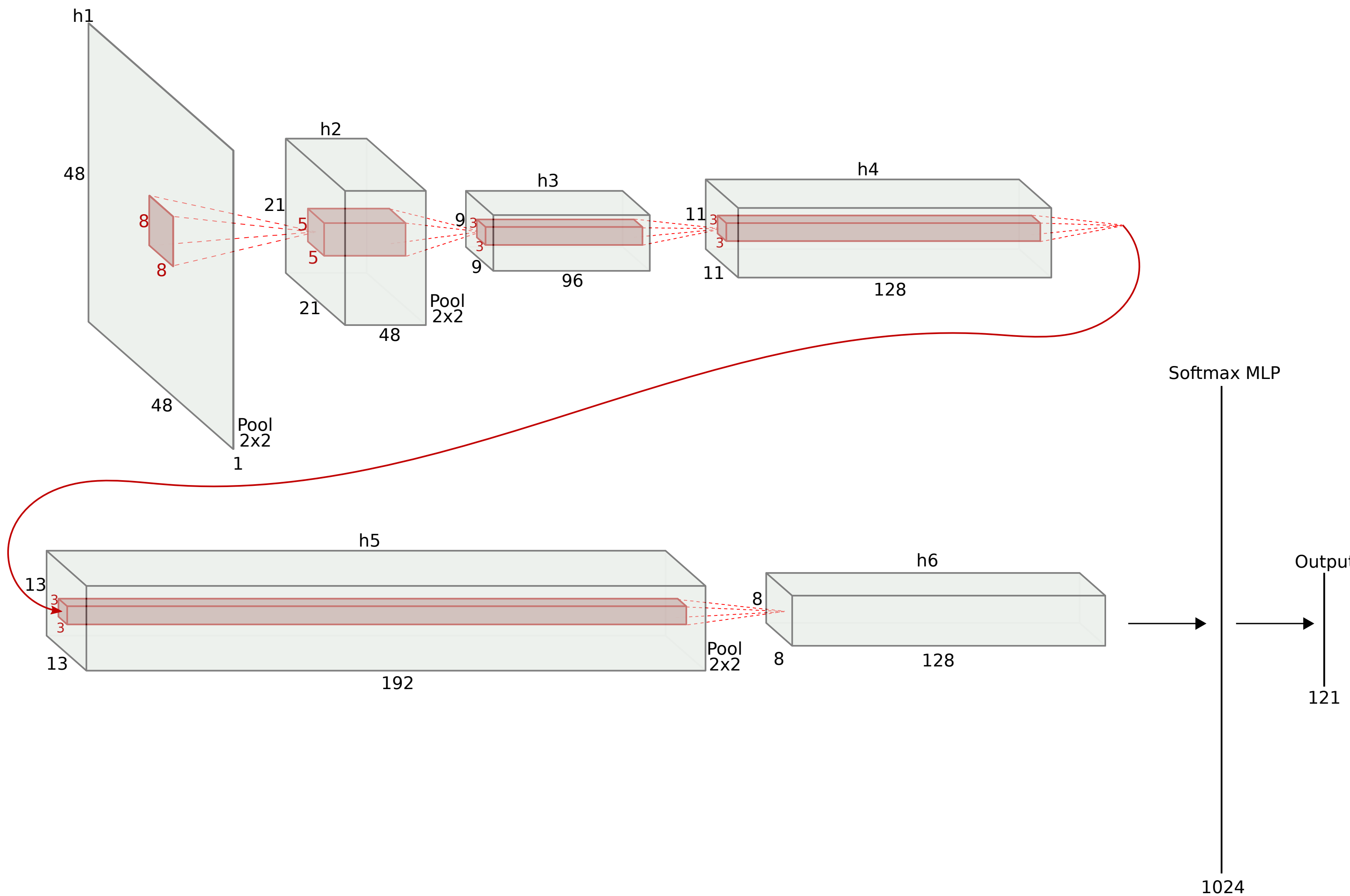
Online Image Augmentation



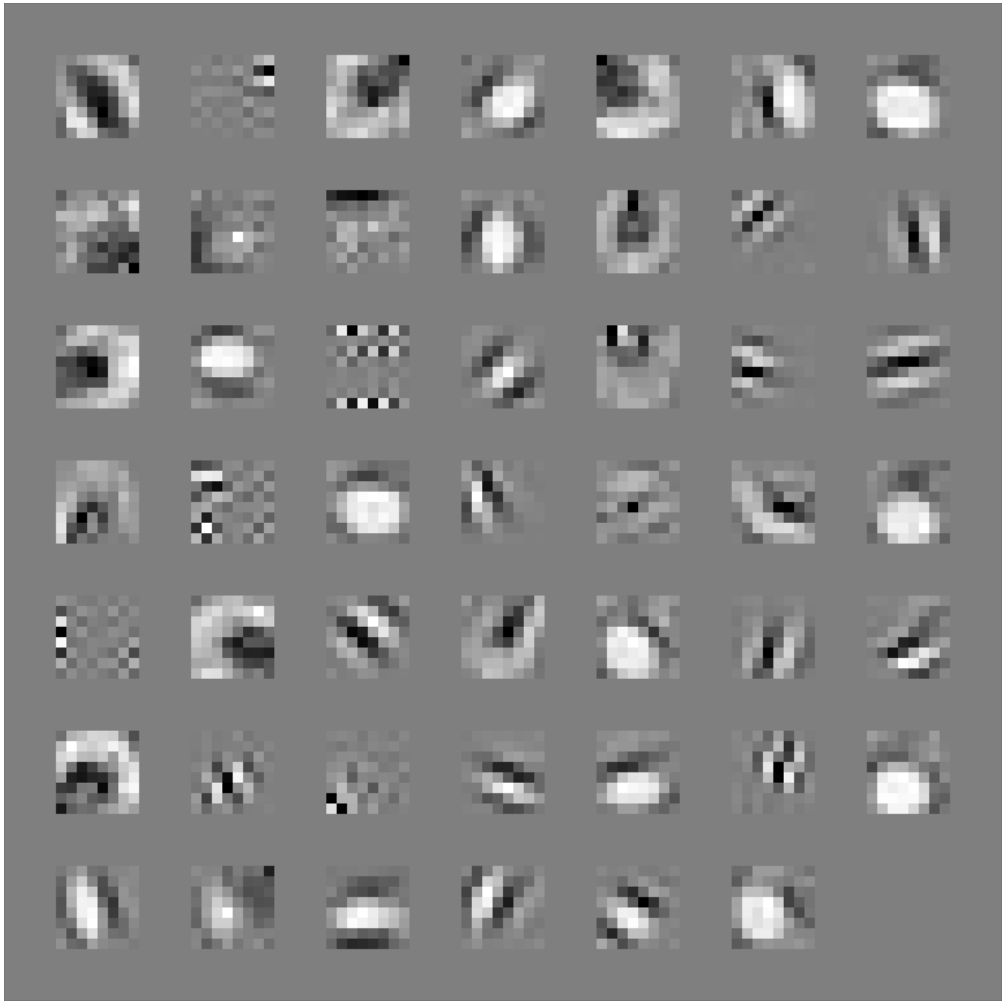
Convnet schema



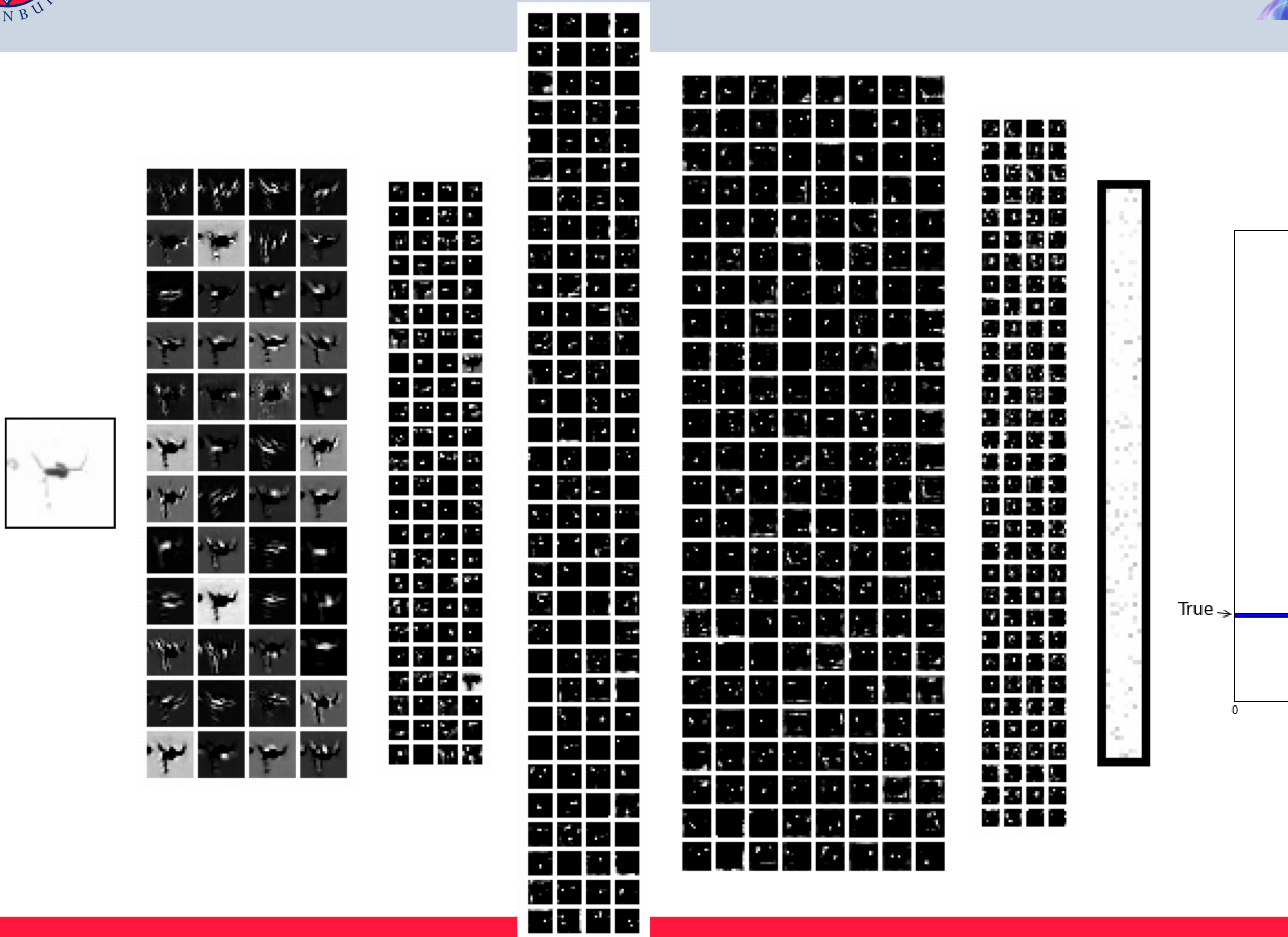
Convnet schema



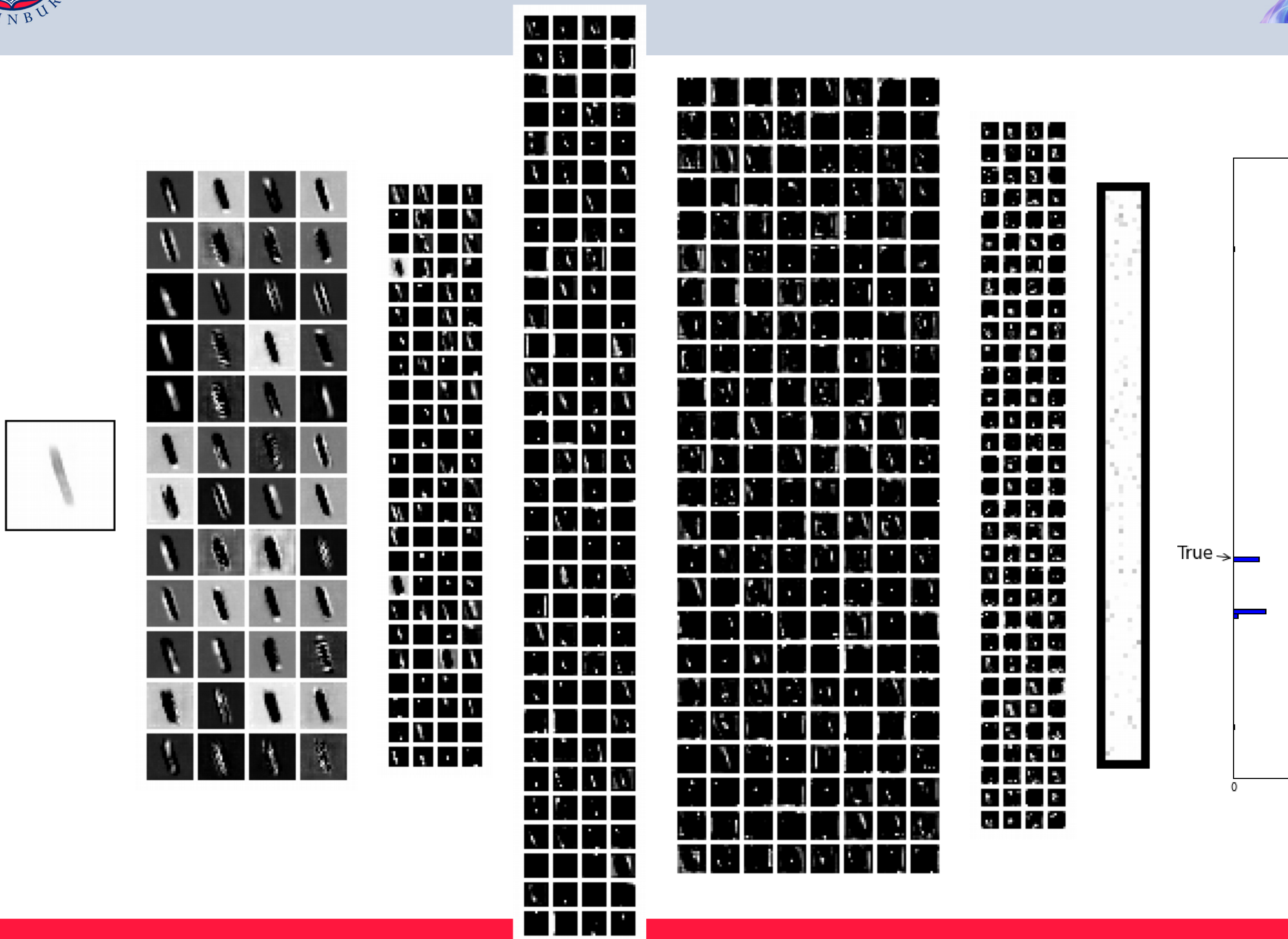
Initial layer kernels



Example stimulus response

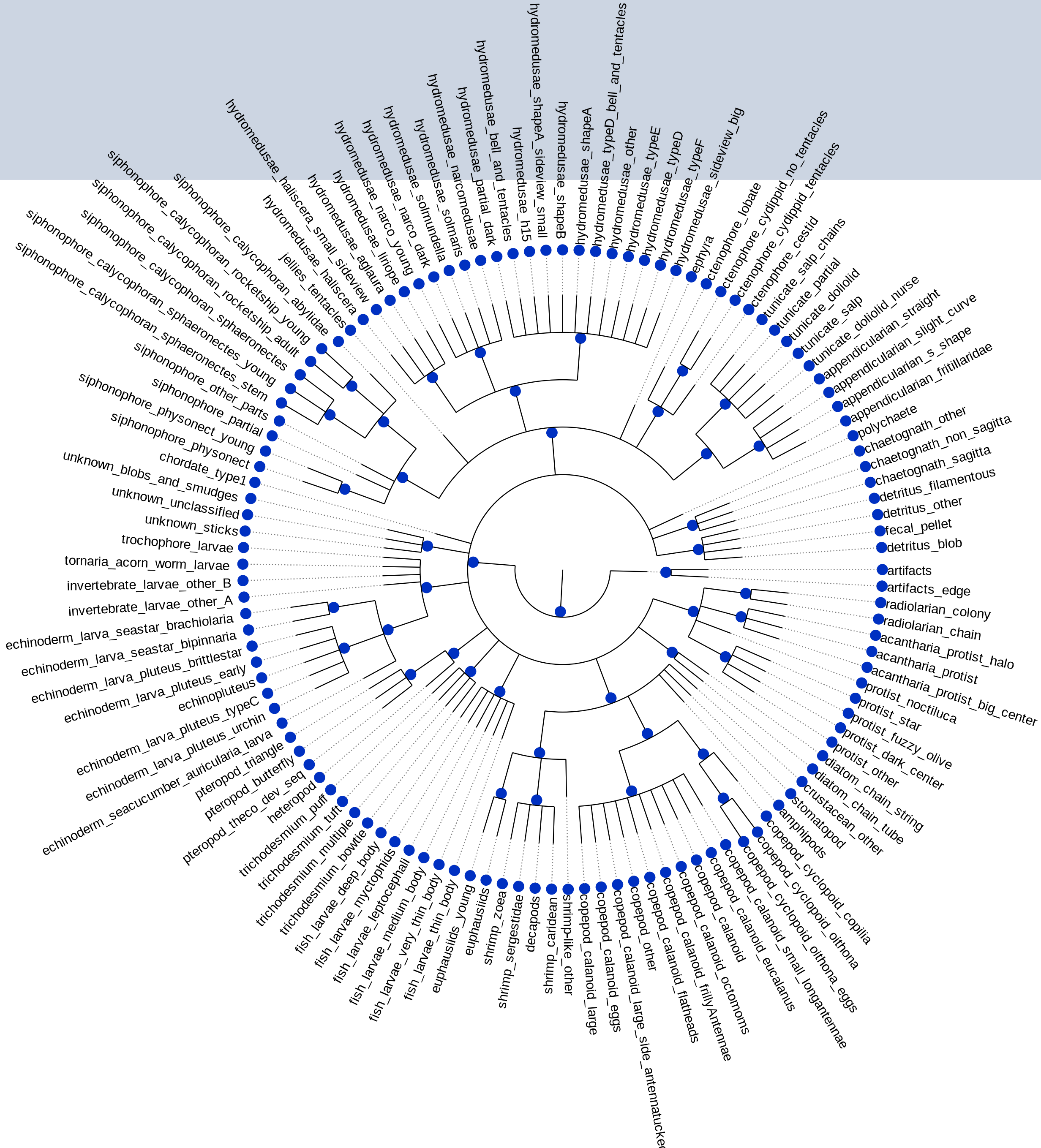


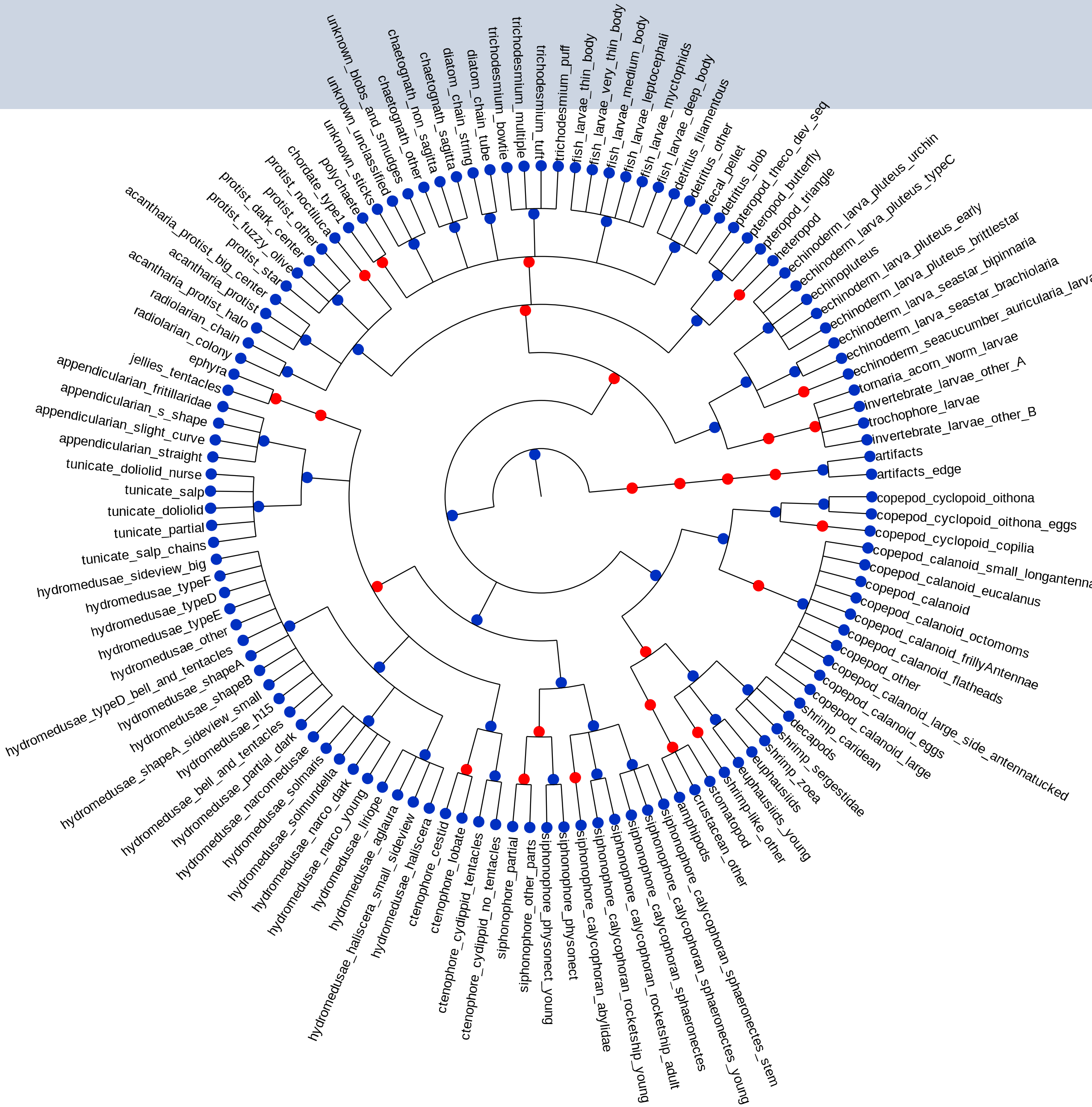
Example stimulus response



Hierarchical Modelling

- We can also tell the network about the class structure
- Increase performance by adding this information to the output targets?


hydromedusae_haliscera_small_sideview
hydromedusae_haliscera
hydromedusae_aglaura
hydromedusae_liriope
hydromedusae_narco_young
hydromedusae_narco_dark
hydromedusae_solmundella
hydromedusae_solmaris
hydromedusae_narcomedusae
hydromedusae_partial_dark
hydromedusae_bell_and_tentacles
hydromedusae_h15
hydromedusae_shapeA_sideview_small
hydromedusae_shapeB
hydromedusae_shapeA
hydromedusae_typeD_bell_and_tentacles
hydromedusae_other
hydromedusae_typeE
hydromedusae_typeD
hydromedusae_typeF
hydromedusae_sideview_big
ephyra
ctenophore_lobate
ctenophore_cydippid_no_tentacles
ctenophore_cydippid_tentacles
ctenophore_cestid
tunicate_salp_chains
tunicate_partial
tunicate_doliolid
tunicate_salp
tunicate_doliolid_nurse
appendicularian_straight
appendicularian_slight_curve
appendicularian_s_shape
appendicularian_fritillaridae
polychaete
chaetognath_other
chaetognath_non_sagitta
chaetognath_sagitta
detritus_filamentous
detritus_other
fecal_pellet
detritus_blob
artifacts
artifacts_edge
radiolarian_colony
radiolarian_chain
acantharia_protist_halo
acantharia_protist
acantharia_protist_big_center
protist_noctiluca
protist_star
protist_fuzzy_olive
protist_dark_center
protist_other
diatom_chain_string
diatom_chain_tube
crustacean_other
stomatopod
amphipods
copepod_cyclopoid_copilia
copepod_cyclopoid_oithona
copepod_cyclopoid_oithona_eggs
copepod_calanoid_small_longantennae
copepod_calanoid_eucalanus
copepod_calanoid_octomoms
copepod_calanoid
copepod_calanoid_frillyAntennae
copepod_calanoid_flatheads
copepod_other
copepod_calanoid_large_side_antennatucked
copepod_calanoid_eggs
copepod_calanoid_large
shrimp-like_other
shrimp_caridean
decapods
shrimp_sergestidae
shrimp_zoea
euphausiids
euphausiids_young
fish_larvae_thin_body
fish_larvae_very_thin_body
fish_larvae_medium_body
fish_larvae_leptocephali
fish_larvae_myctophids
fish_larvae_deep_body
trichodesmium_bowtie
trichodesmium_multiple
trichodesmium_tuft
trichodesmium_puff
heteropod
pteropod_theco_dev_seq
pteropod_butterfly
pteropod_triangle
echinoderm_seacucumber_auricularia_larva
echinoderm_larva_pluteus_urchin
echinoderm_larva_pluteus_typeC
echinopluteus
echinoderm_larva_pluteus_early
echinoderm_larva_pluteus_brittlestar
echinoderm_larva_seastar_bipinnaria
echinoderm_larva_seastar_brachiolaria
invertebrate_larvae_other_A
invertebrate_larvae_other_B
tornaria_acorn_worm_larvae
trochophore_larvae
unknown_sticks
unknown_unclassified
unknown_blobs_and_smudges
chordate_type1
siphonophore_physonect
siphonophore_physonect_young
siphonophore_partial
siphonophore_other_parts
siphonophore_calycophoran_sphaeronectes_stem
siphonophore_calycophoran_sphaeronectes_young
siphonophore_calycophoran_sphaeronectes
siphonophore_calycophoran_rocketship_adult
siphonophore_calycophoran_rocketship_young
siphonophore_calycophoran_abylidae
jellies_tentacles


acantharia_protist_big_center
acantharia_protist
acantharia_protist_halo
radiolarian_chain
radiolarian_colony
ephyra
jellies_tentacles
appendicularian_fritillaridae
appendicularian_s_shape
appendicularian_slight_curve
appendicularian_straight
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tunicate_doliolid
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hydromedusae_typeD
hydromedusae_typeE
hydromedusae_other
hydromedusae_typeD_bell_and_tentacles
hydromedusae_shapeA
hydromedusae_shapeB
hydromedusae_shapeA_sideview_small
hydromedusae_h15
hydromedusae_bell_and_tentacles
hydromedusae_partial_dark
hydromedusae_narcomedusae
hydromedusae_solmaris
hydromedusae_solmundella
hydromedusae_narco_dark
hydromedusae_narco_young
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hydromedusae_haliscera_small_sideview
hydromedusae_haliscera
ctenophore_cestid
ctenophore_lobate
ctenophore_cydippid_tentacles
ctenophore_cydippid_no_tentacles
siphonophore_partial
siphonophore_other_parts
siphonophore_physonect_young
siphonophore_physonect
siphonophore_calycophoran_abylidae
siphonophore_calycophoran_rocketship_young
siphonophore_calycophoran_rocketship_adult
siphonophore_calycophoran_sphaeronectes
siphonophore_calycophoran_sphaeronectes_young
siphonophore_calycophoran_sphaeronectes_stem
amphipods
crustacean_other
stomatopod
shrimp-like_other
euphausiids_young
euphausiids
shrimp_zoea
decapods
shrimp_caridean
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fish_larvae_myctophids
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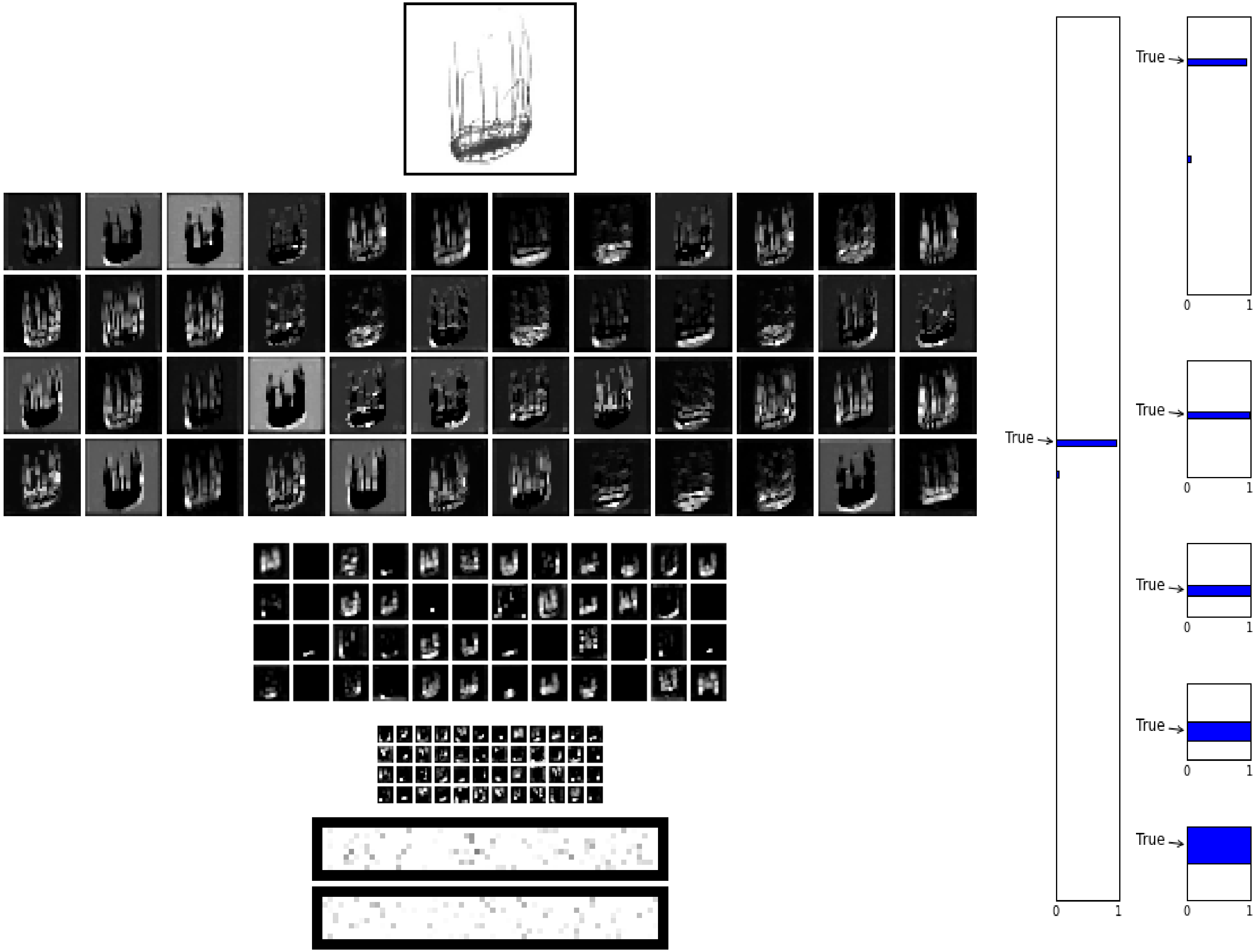
trichodesmium_tuft
trichodesmium_multiple
trichodesmium_bowtie
diatom_chain_tube
diatom_chain_string
chaetognath_sagitta
chaetognath_non_sagitta
chaetognath_other
unknown_blobs_and_smudges
unknown_unclassified
unknown_sticks
polychaete
chordate_type1
protist_noctiluca
protist_other
protist_dark_center
protist_fuzzy_olive
protist_star

Example stimulus response



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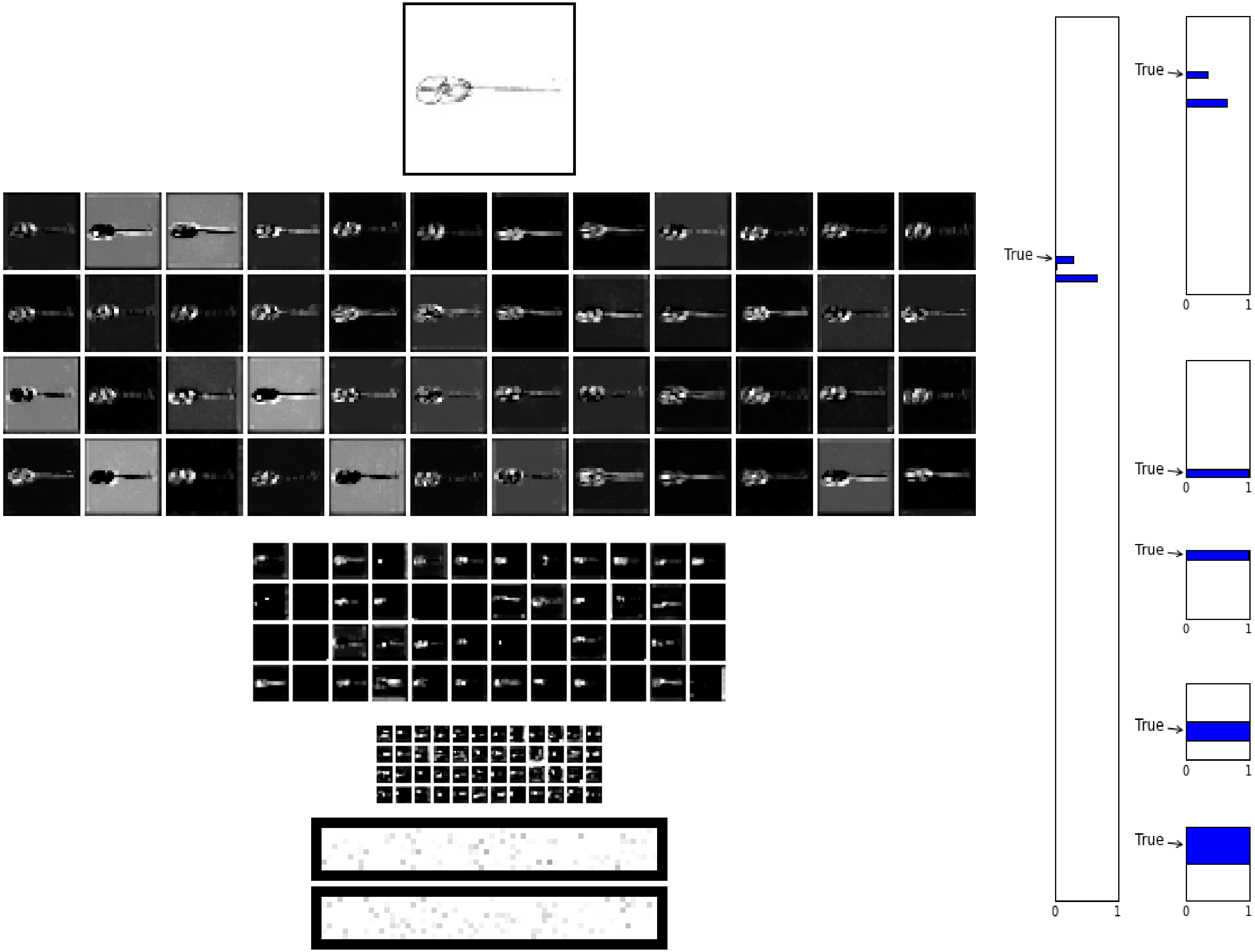


Things which didn't work, but should have: Hierarchical class encoding

- Models trained using the hierarchical structure as the output targets
- Peak performed was similar to models without hierarchical class encoding

Things which didn't work, but should have: Siamese networks

- Resizing images loses detail in large images, and loses the absolute size of the plankton
- Convnets are frequently applied to patches of a larger image
- Why not feed the image through with and without resizing and show both to the network?
- Did not help - performed worse than single resized input

Things which which really underperformed: CV feature-based decoder

- Detected global texture features
  - Haralick features
  - Grey-Level Co-ocurrance Matrix properties
  - Contour moments and Hu moments
  - Grey-level intensity histogram (within contour)
  - Parameter Free Threshold Adjacency Statistics
- Local feature detection and description
  - ORB
  - BRISK (but super slow, so not used)
  - MSER
- Fit classifier with RF, SVM or Logistic Regression (similar performances)
- Performance was better with global than local features
- Constructed a hierarchical model, but got no benefit (for global features)
- All models were worse than the simplest convnets

Things which didn't work, but should have: CV feature integration

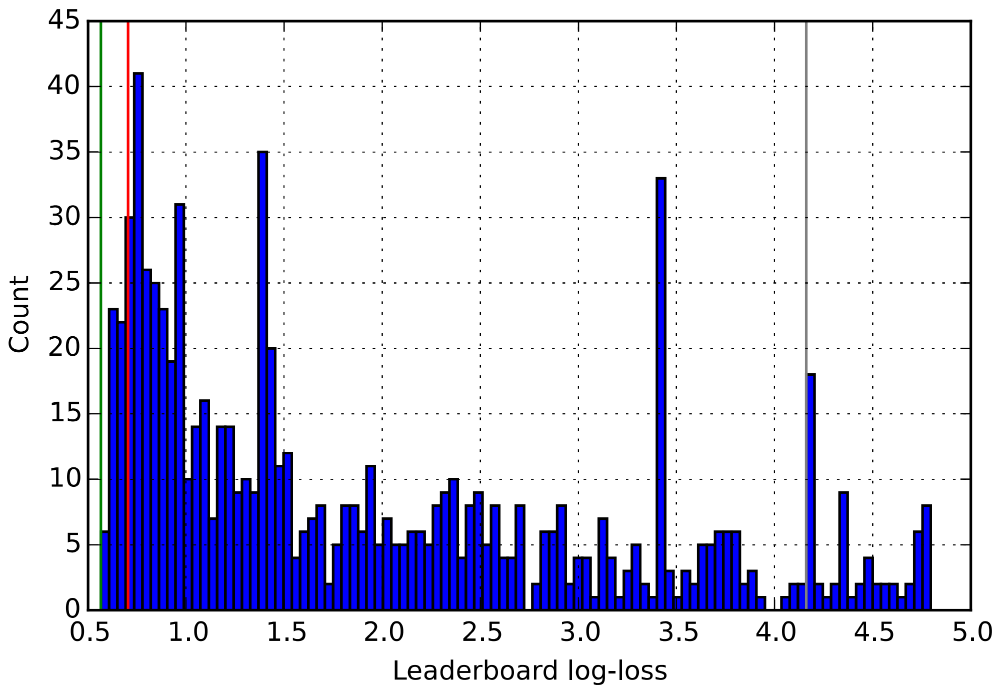
- Tried to integrate offline-augmented CV features with convnet
- Joined CV features into the network after convolutions
- Got worse performance than other models

Final submission

- Average probabilities from lots of augmented versions of test stimulus
- Weighted average of 3 models

Competition Results

- 57^{th} out of 1049 teams (top 5.4%)
- Log-loss 0.704582
  - Winner: 0.565971
  - Uniform distribution: 4.795791
  - Stratified prior: 4.161789



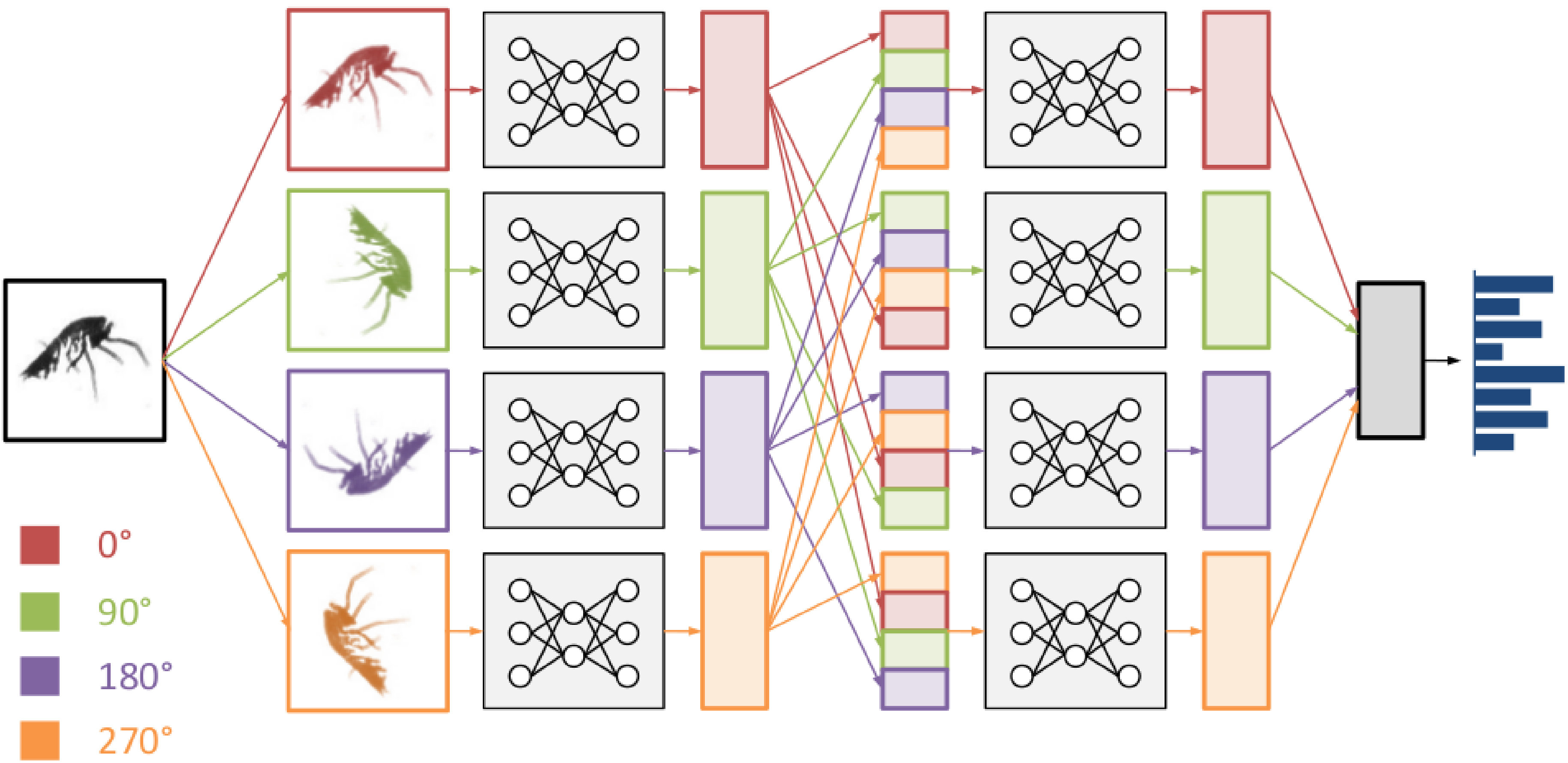
Toolkit

- Git repository for code sharing on Github
- waffle.io for issue tracking
- Unit tests (but only at the beginning...)
- Tests performed on every push using Travis
- Python 2.7
  - Convnets built with Pylearn2 (Theano under the hood) running CUDA
  - skimage, mahotas, OpenCV
  - sklearn
  - HoloViews for plotting

What did the winning team do?

- Everything we did but better
- More convolution layers (10), and smaller convolutions
- Cyclic pooling & maxing across 4 rotations simultaneously
- Leaky rectified linear units

Winning team's Cyclic pooling



Source: Sander Dieleman *et al.*, http://benanne.github.io/2015/03/17/plankton.html

Conclusions

- Unit testing is essential to know your code works the way you think it does
- Running experiments testing only one thing at a time is essential
- Pylearn2 is poorly documented and probably not work using
- Convnets more powerful technique than Computer Vision feature extraction
- Hierarchical modelling did not work for us

Acknowledgements

- The team was
  - Matt Graham
  - Gavin Gray
  - Scott Lowe
  - Finlay Maguire
  - Alina Selega
  - Dragos Stanciu
- Our thanks to Bob Fisher, Amos Storkey and Chris Williams for their helpful advice.

What next?

- Diabetic Retinopathy Detection challenge on Kaggle, could be tackled with a similar approach. Prize is $50,000