# Evolution in 3D: students use 3D-printed moa bones to learn measurement and phylogenetic mapping of evolutionary characters


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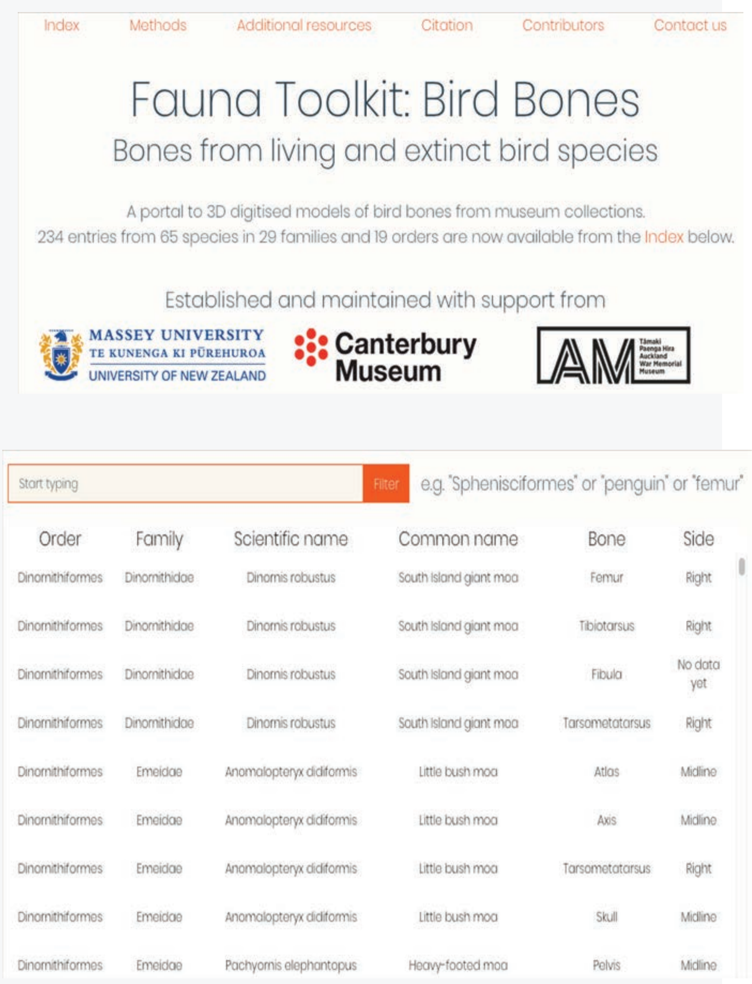
## Abstract

For BIOSCI 109: Ecology and Evolution, we developed a new lab practical exercise that uses 3D-printed classroom sets of the bones of fossil moa, and other birds. The goal is to give students hands-on experience in testing hypotheses in evolutionary biology, focusing on the concepts of specimen, species, character, homology, character mapping, form vs. function, and adaptation.


## Methods:

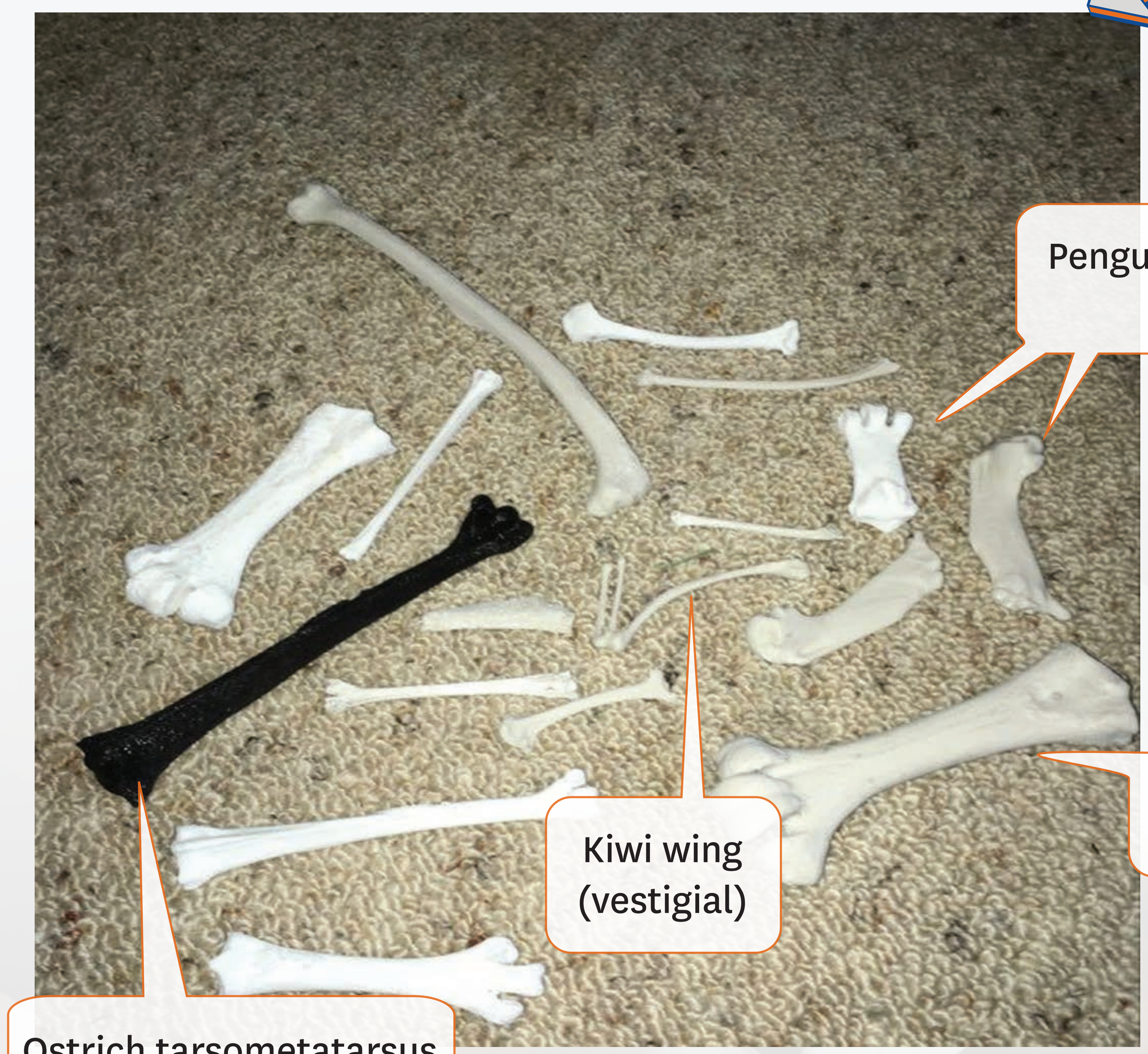
3D scan files were obtained from the FaunalToolkit and Aves3D databases. After training at UoA's MakerSpace, 20 classroom sets of bones were printed on 3D printers (2x Makerbot Replicator+ 3D printers; 1x Ender-3 Pro 3D printer). Bones that were too large (e.g. giant moa) or small (e.g. kiwi wings) for the printers were re-sized, with the scale recorded. Students were introduced to the exercise with an HP5 presentation, and had to (A) identify the bones by type (leg vs. wing), (B) match to species, (C) identify/score discrete characters and map onto a phylogeny, (D) measure predefined quantitative characters with calipers, and (E) graph this data and propose a hypothesized explanation, along with how they would test this hypothesis with new data.

### 1. Museum 3D scans from collections:


https://www.faunatoolkit.com/

### 2. 3D printed bones of moa, kiwi, penguins, etc. (some rescaled)




### 4. Students score characters, measure with calipers, plot data, and propose hypothesis and tests

| Scientific Name | Leg bone | Wing bone(s) | Mass of adult bird (kg) | tarsometatarsus length | width | Humerus length | width | ulna length | width | tmt length/width ratio | hms length/width ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Apteryx mantelli* | tarsometatarsus | humerus, radius, & ulna | 2.8 | 81 | 9.8 | 46 | 2.3 | 21.0 | 1.7 | 8.2 | 20 |
| *Dinornis robustus* | tarsometatarsus | (absent in this species) | 230 | 478 | 69.2 | 0 | 0 | 0 | 0 | 6.9 | N/A |
| *Anomalopteryx didiformis* | tarsometatarsus | (absent in this species) | 30 | 185 | 30.8 | 0 | 0 | 0 | 0 | 6 | N/A |
| *Struthio camelus* | tarsometatarsus | humerus | 157 | 441 | 33.2 | 368 | 19.5 | ? | ? | 13.3 | 18.9 |
| *Ninox albifacies* | tarsometatarsus | humerus & ulna | 0.6 | 71 | 4.1 | 79 | 4.5 | 86.0 | 4.4 | 17.5 | 17.4 |
| *Callaeas wilsoni* | tarsometatarsus | humerus | 0.233 | 61 | 2.8 | 35 | 2.8 | 35.0 | 2.2 | 21.5 | 12.7 |
| *Muriwaimanu tuatahi* | tarsometatarsus | (not available) | 12 | 105 | 32.1 | ? | ? | ? | ? | 3.3 | ? |
| *Pygoscelis antarctica* | (not available) | humerus & ulna | 5 | ? | ? | 72 | 15.3 | 46.0 | 12.9 | ? | 4.7 |
| *Aptenodytes patagonicus* | (not available) | humerus & ulna | 15 | ? | ? | 74 | 16.9 | ? | ? | ? | 4.4 |

| Scientific Name | Max. weight (kg) | tmt length/width ratio |
|---|---|---|
| *Apteryx mantelli* | 2.8 | 8.2 |
| *Dinornis robustus* | 230 | 6.9 |
| *Anomalopteryx didiformis* | 30 | 6.0 |
| *Struthio camelus* | 157 | 13.3 |
| *Ninox albifacies* | 0.6 | 17.5 |
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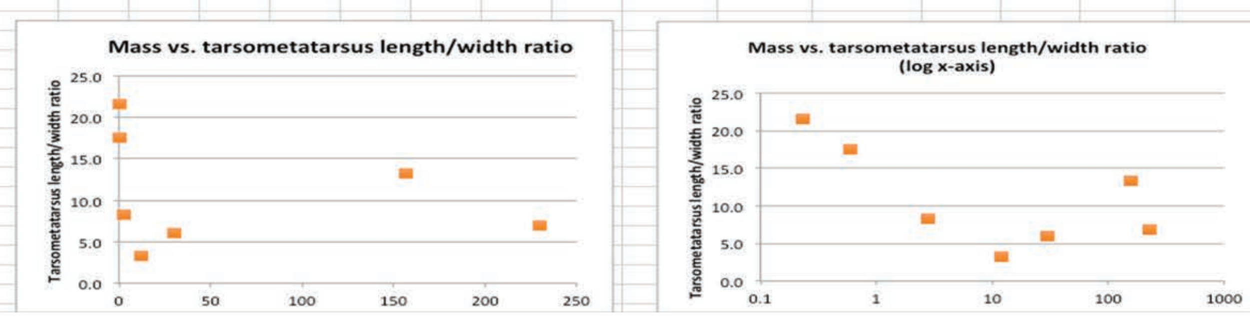
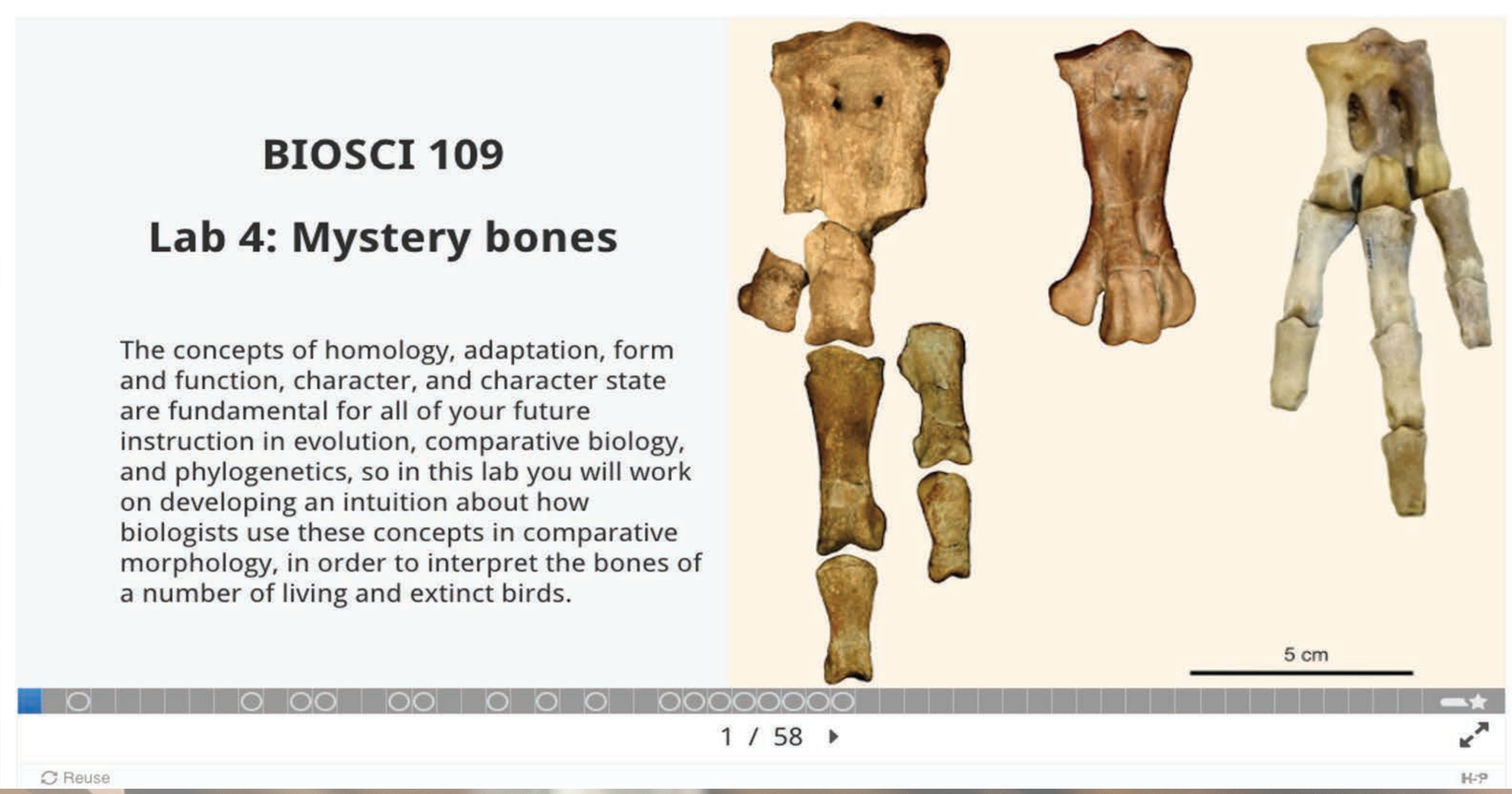
| *Muriwaimanu tuatahi* | 12 | 3.3 |
| *Pygoscelis antarctica* | 5 | ? |
| *Aptenodytes patagonicus* | 15 | ? |




### 3. H5P exercise for BIOSCI 109




## Conclusion:

3D-printing can revolutionise introductory evolution teaching because rare fossil specimens that are usually only seen in museums or textbooks can, as 3D-printed specimens, be handled, measured, and discussed by students.


## Acknowledgements:

3D scan .OBJ files courtesy of: Daniel Thomas, Massey University (https://www.faunatoolkit.com/ )

Kiwi leg/wing scans from Aves3D courtesy of: Leon Claessens, Scott Edwards, Abby Drake (https://www.aves3d.org/ )

U. Auckland MakerSpace 3D printers & training: Sean Kelly, https://www.cie.auckland.ac.nz/unleash-space/

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