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The colored eggs of the birds were considered to be traits that has evolved only amongst birds and evolved independently from their dinosaur ancestors. However, protoporphyrin IX and biliverdin, pigments that are responsible for colored eggs in birds, have been found in the non-avian dinosaur egg recently, suggesting that colored eggs may have originated from non-avian dinosaur ancestors. Eggs of non-avian dinosaur have been analyzed through Raman microspectroscopy and the results showed that egg color pigments were present in most eumaniraptoans. Color bands for protoporphyrin IX and biliverdin were found in the eggs that belong to eumaniraptoans, but not for the eggs that belong to other species. Principal component analysis (PCA) was used to confirm the endogeneity of the pigments. First PCA result separated cluster into sediments and fossils, showing that pigments were absence in sediments. The second PCA result separated unpigmented and pigmented fossils into two different clsuters, suggesting the difference of pigment between eggshell fossils determined the different clustering. The surface map and depth profiles of eggshell in the non-avian dinosaurs showed a similarity between color and pigment pattern of extant birds and non-avian birds. The overall results suggest that birds may have inherited their complex color pattern from their ancestors.

Both PCA results showed similar clustering as the PCA plot that has been derived from the source data. The axis for the both PCA seemed to differ, as the first PCA plot matched that of the original article when it has been rotated around the vertical axis, while the second PCA plot matched that of the original article when it has been rotated around the origin. Both data in the original articles seemed to be not standardized, as the PCA plot deviated from those of original article when the data set was standardized before performing PCA. The explained variance ratio differed as unstandardized explained variance ratio matched the that of the first PCA(PC1: 73.11%, PC2:10.97%) while the standardized explain variance ratio(PC1: 72.39%, PC2: 11.00%) slightly differed. The difference was bigger in the second PCA (Unstandardized, PC1: 57.11%, PC2: 23.84%) (Standardized, PC1: 54.29%, PC2: 18.65%). The overall clustering was same regardless of standardizing for the first PCA, but it differed a bit in the second PCA, as three of unpigmented eggshell showed similar clustering with pigmented eggshells. Overall, the first PCA result is not affected greatly by standardization, while the second PCA result changes when standardization was applied. Based on this result, the author’s first assumption, which assumes sediments did not affect the pigments in the eggshells, is verified, but the second assumption, which assumes that the unpigmented and pigmented eggshells differ in PCA plot, remains ambiguous as majority of pigmented and unpigmented eggshells cluster together in the PCA plot performed with standardized data.