ERYTHROCYTE MEASUREMENTS IN BIRDS

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Gulliver (1840, 1846, 1875) appears to have been the earliest to make an extensive study of the size of red cells in vertebrates, including birds. Cleland and Johnston (1912) measured the erythrocytes in 90 species of birds distributed among 30 families. Bartsch, Ball, Rosenzweig, and Salman (1937) reported measurements in 50 North American birds. However, only two of their species were studied by us. Lucas and Jamroz (1961) described the various blood cell types in the fowl but they give no cell measurements for species other than *Gallus domesticus*.

Measurements of red cell size give some idea of the surface area offered for exchange of gases with the plasma. The least diameter of elliptical erythrocytes is a gauge of minimal capillary diameter for a particular species. Erythrocyte size appears to be related to the general metabolic activity of the species. For these reasons such information is valuable in a comparative study.

While collecting specimens for adrenal and other studies we were frequently presented with the opportunity to make fresh blood smears from the animals. Material so obtained was used as a basis for this study. Our tropical material came from Panamá while the remainder was from the United States, mostly Ohio and Florida.

Methods

Blood smears were made immediately after the death of the animals. These were dried promptly and stored until prepared for study in the laboratory. Staining was carried out under controlled conditions. Five drops of standard Wright's stain were allowed to remain on the slide for one minute before addition of a pH 6.5 buffer. The slide was allowed to stand for five minutes at room temperature and then washed with distilled water for 30 seconds and allowed to dry.

Ten cells on each slide, selected for excellence of staining and internal cytology, were measured by means of a calibrated eyepiece used in conjunction with an oil-immersion objective. In this way 10 measurements of maximum cell width and length as well as nuclear width and length were made. The ratios of cytosome length to width and nucleus length to width have been calculated. This is a measure of cell and nuclear deviation from a spherical shape. The surface area of the cell is an important parameter, but was not calculated because cell thickness in these air-dried specimens could not be determined.

Results

In this survey, 124 species distributed among 46 families are included (Table 1). When measurements are of only one individual of a species, the standard error of the values for the different cells is shown, while when three or more individual specimens of a species are measured the standard error is based on the averages of the individuals involved.

TABLE 1

ERYTHROCYTE MEASUREMENTS IN BIRDS

Family and species	Cytosome			Nucleus		
	Length (μ)	Width (μ)	Ratio L/W	Length (μ)	Width (μ)	Ratio L/W
Tinamidae						
Crypturellus soui	13.5 ± 0.24	7.6 ± 0.26	1.87	5.2 ± 0.19	2.3 ± 0.11	2.26
" "	13.9 ± 0.19	7.5 ± 0.12	1.85	4.4 ± 0.10	2.5 ± 0.06	1.76
Podicipedidae						
Podiceps dominicus	12.7 ± 0.80	8.2 ± 0.80	1.60	5.1 ± 0.50		
" "	13.7 ± 0.80	8.0 ± 0.30	1.71	5.7 ± 0.80	2.8 ± 0.30	2.03
Podilymbus podiceps	14.6 ± 0.26	8.2 ± 0.11	1.87	5.2 ± 0.12	2.2 ± 0.02	2.36
Pelecanidae						
Pelecanus occidentalis (10)	14.2 ± 0.20	7.8 ± 0.09	1.75	5.9 ± 0.12	2.9 ± 0.065	2.03
Phalacrocoracidae						
Phalacrocorax auritus (6)	13.6 ± 0.17	7.6 ± 0.17	1.75	5.2 ± 0.11	2.6 ± 0.08	2.00
Anhingidae						
Anhinga anhinga	15.1 ± 0.52	8.6 ± 0.30	1.54	6.5 ± 0.37	3.0 ± 0.30	2.17
" "	15.7 ± 0.19	10.5 ± 0.33	1.57	5.4 ± 0.19		
Ardeidae						
Ardea herodias	14.3 ± 0.92	7.4 ± 0.68	2.00	5.8 ± 0.56	3.0 ± 0.34	1.93
Butorides virescens	13.0 ± 0.22	8.3 ± 0.15	1.62	6.0 ± 0.16	2.9 ± 0.17	2.07
Florida caerulea	12.8 ± 0.64	7.3 ± 0.49	1.85	6.1 ± 0.33	3.0 ± 0.15	2.03
Casmerodius albus (3)	15.0 ± 0.39	7.9 ± 0.30	1.87	6.7 ± 0.33	3.3 ± 0.23	2.03
Tigrisoma lineatum	15.8 ± 0.37	10.2 ± 0.17	1.58	7.0 ± 0.22	2.9 ± 0.19	2.41
Leucophoyx thula	13.1 ± 0.38	7.7 ± 0.16	1.70	5.2 ± 0.12	2.6 ± 0.03	2.00
Cathartidae						
Sarcoramphus papa	14.6 ± 0.34	8.5 ± 0.40	1.79	6.7 ± 0.34	3.3 ± 0.14	2.03
" "	14.0 ± 0.87	7.6 ± 0.43	1.84	6.2 ± 0.33	3.0 ± 0.17	2.06
Coragyps atratus (5)	14.0 ± 0.20	7.7 ± 0.11	1.81	6.3 ± 0.20	2.6 ± 0.17	2.42
Cathartes aura (3)	14.0 ± 0.32	7.5 ± 0.13	1.87	6.0 ± 0.18	2.4 ± 0.07	2.50
Accipitridae						
Accipiter cooperii	14.3 ± 0.27	8.1 ± 0.13	1.77	6.2 ± 0.14	2.4 ± 0.11	2.58
Buteo platypterus	13.4 ± 0.51	7.6 ± 0.34	1.77	6.2 ± 0.31	3.0 ± 0.32	2.07
" "	13.7 ± 0.46	7.8 ± 0.13	1.76	5.5 ± 0.21	2.4 ± 0.17	2.29
Falconidae						
Falco sparverius	11.8 ± 0.18	7.3 ± 0.17	1.62	5.8 ± 0.13	2.1 ± 0.04	2.76
Caracara cheriway	14.1 ± 0.05	8.7 ± 0.16	1.62	6.4 ± 0.13	2.7 ± 0.11	2.37
Cracidae						
Chamaepetes unicolor	13.6 ± 0.52	7.6 ± 0.42	1.84	6.1 ± 0.53	2.7 ± 0.22	2.26
" "	14.1 ± 0.75	7.4 ± 0.35	1.91	6.9 ± 0.65	2.9 ± 0.21	2.38
Phasianidae						
Odontophorus guttatus	11.9 ± 0.46	6.8 ± 0.28	1.75	5.2 ± 0.41	2.3 ± 0.21	2.26
Rallidae						
Rallus elegans	14.5 ± 0.32	7.7 ± 0.17	1.89	5.7 ± 0.13	2.9 ± 0.12	1.97
Aramides cajanea	12.9 ± 0.78	7.2 ± 0.50	1.79	5.5 ± 0.40	3.3 ± 0.37	1.67
Laterallus albigularis	12.3 ± 0.60	7.3 ± 0.39	1.68	5.3 ± 0.43	3.2 ± 0.20	1.65
" "	13.2 ± 0.21	7.1 ± 0.10	1.86	5.1 ± 0.09	3.0 ± 0.07	1.70
Porphyrula martinica	14.2 ± 0.49	7.8 ± 0.24	1.82	6.7 ± 0.53	2.9 ± 0.21	2.31
Fulica americana	11.4 ± 0.26	7.5 ± 0.22	1.51	4.2 ± 0.06	2.3 ± 0.07	1.83
Heliornithidae						
Heliornis fulica	12.6 ± 0.15	7.5 ± 0.14	1.68	5.5 ± 0.21	3.0 ± 0.11	1.83
Jacanidae						
Jacana spinosa	13.7 ± 0.79	7.5 ± 0.52	1.83	5.9 ± 0.64	3.7 ± 0.33	1.59
Charadriidae						
Charadrius wilsonia (6)	12.8 ± 0.27	7.3 ± 0.13	1.76	5.8 ± 0.11	2.4 ± 0.05	2.41
Recurvirostridae						
Himantopus mexicanus	12.8 ± 0.16	6.9 ± 0.18	1.85	5.8 ± 0.20	2.5 ± 0.99	2.32
Columbidae						
Columba albilinea	12.1 ± 0.56	7.7 ± 0.29	1.67	5.8 ± 0.39	2.7 ± 0.31	2.15
" "	13.4 ± 0.67	7.5 ± 0.21	1.78	6.4 ± 0.13	2.7 ± 0.12	2.37
Columbigallina minuta	12.3 ± 0.87	7.4 ± 0.40	1.66	5.9 ± 0.43	2.5 ± 0.13	2.36
Columbigallina talpacoti	11.6 ± 0.28	7.0 ± 0.30	1.66	6.4 ± 0.31	2.4 ± 0.27	2.67
Geotrygon chiriquensis	12.0 ± 0.59	6.9 ± 0.32	1.72	5.6 ± 0.38	2.8 ± 0.28	2.00
" "	13.2 ± 0.48	7.7 ± 0.43	1.71	6.4 ± 0.38	3.3 ± 0.24	1.94
Psittacidae						
Pyrrhura hoffmanni	13.2 ± 0.23	7.2 ± 0.18	1.83	6.1 ± 0.06	2.3 ± 0.04	2.65
Brotogeris jugularis	12.1 ± 0.57	7.7 ± 0.18	1.75	6.0 ± 0.32	2.9 ± 0.25	2.07
Pionus senilis	13.0 ± 0.47	7.6 ± 0.25	1.72	5.8 ± 0.32	2.3 ± 0.04	2.52
Amazona autumnalis	13.6 ± 0.74	7.7 ± 0.01	1.77	6.2 ± 0.54	3.0 ± 0.56	2.07

TABLE 1—*Continued*

Family and species	*Cytosome*			*Nucleus*		
	Length (μ)	*Width* (μ)	*Ratio L/W*	*Length* (μ)	*Width* (μ)	*Ratio L/W*
Cuculidae						
Piaya cayana	13.7 ± 0.19	7.9 ± 0.13	1.73	6.2 ± 0.13	2.9 ± 0.09	2.14
Crotophaga major	12.0 ± 0.64	8.1 ± 0.84	1.48	5.5 ± 0.35	3.4 ± 0.34	1.62
Crotophaga ani (4)	12.9 ± 0.22	6.9 ± 0.26	1.87	5.8 ± 0.28	2.9 ± 0.29	2.00
Strigidae						
Otus choliba	12.6 ± 0.96	7.5 ± 0.33	1.68	6.0 ± 0.33	3.1 ± 0.12	1.94
" "	13.9 ± 0.35	7.4 ± 0.15	1.88	5.4 ± 0.25	2.9 ± 0.03	1.86
Strix varia	13.8 ± 0.24	7.3 ± 0.23	1.82	5.6 ± 0.20	2.7 ± 0.14	2.07
" "	13.5 ± 0.28	7.8 ± 0.16	1.73	5.7 ± 0.11	2.2 ± 0.04	2.59
Rhinoptynx clamator (4)	13.7 ± 0.22	7.7 ± 0.29	1.80	5.9 ± 0.18	3.0 ± 0.21	1.96
Speotyto cunicularia	14.1 ± 0.11	7.8 ± 0.25	1.81	6.3 ± 0.32	2.7 ± 0.12	2.33
Nyctibiidae						
Nyctibius griseus	14.4 ± 0.77	8.2 ± 0.52	1.77	6.3 ± 0.30	3.4 ± 0.34	1.85
" "	13.2 ± 0.56	7.7 ± 0.47	1.71	6.4 ± 0.31	3.3 ± 0.22	1.94
Caprimulgidae						
Nyctidromus albicollis (3)	13.6 ± 0.53	8.3 ± 0.56	1.64	6.3 ± 0.23	3.3 ± 0.80	1.91
Trochilidae						
Glaucis hirsuta	12.2 ± 0.43	6.9 ± 0.37	1.77	6.2 ± 0.37	2.8 ± 0.20	2.21
Phaethornis guy	11.5 ± 0.26	6.3 ± 0.10	1.77	4.5 ± 0.23	2.1 ± 0.04	2.14
" "	12.0 ± 0.14	7.0 ± 0.20	1.71	5.2 ± 0.19	2.1 ± 0.04	2.47
Campylopterus hemileucurus	11.1 ± 0.37	5.6 ± 0.35	1.98	5.0 ± 0.19	1.8 ± 0.25	2.77
Anthracothorax nigricollis	10.7 ± 0.12	6.4 ± 0.13	1.67	5.2 ± 0.10	2.6 ± 0.02	2.00
Thalurania furcata	11.3 ± 0.34	6.4 ± 0.21	1.77	5.5 ± 0.41	2.1 ± 0.13	2.68
Damophila julie	10.9 ± 0.38	6.1 ± 0.36	1.79	5.2 ± 0.17	2.6 ± 0.10	2.00
Amazilia edward	11.4 ± 0.21	6.0 ± 0.02	1.90	5.7 ± 0.08	2.0 ± 0.04	2.85
Amazilia tzacatl	11.5 ± 0.23	6.3 ± 0.13	1.85	5.6 ± 0.21	2.6 ± 0.22	2.15
" "	10.9 ± 0.11	6.5 ± 0.21	1.68	5.7 ± 0.08	2.5 ± 0.03	2.28
Heliodoxa jacula	12.3 ± 0.17	6.3 ± 0.12	1.95	6.0 ± 0.05	2.1 ± 0.05	2.85
Selasphorus scintilla	10.7 ± 0.85	6.1 ± 0.46	1.75	5.7 ± 0.26	2.5 ± 0.11	2.28
Trogonidae						
Pharomachrus mocino	12.2 ± 0.57	7.0 ± 0.47	1.74	5.8 ± 0.34	2.7 ± 0.17	2.15
Trogon massena (3)	13.6 ± 0.39	7.6 ± 0.05	1.79	6.3 ± 0.14	2.6 ± 0.35	2.42
Trogon collaris	13.8 ± 0.97	7.8 ± 0.25	1.76	7.0 ± 0.53	2.7 ± 0.19	2.59
" "	13.3 ± 0.87	7.6 ± 0.54	1.76	6.6 ± 0.30	3.0 ± 0.42	2.20
Alcedinidae						
Chloroceryle amazona	14.0 ± 0.47	7.6 ± 0.26	1.79	6.8 ± 0.36	3.1 ± 0.11	2.19
" "	13.8 ± 0.27	7.9 ± 0.29	1.74	6.1 ± 0.21	2.7 ± 0.21	2.26
Chloroceryle aenea	12.6 ± 0.56	6.7 ± 0.31	1.88	6.5 ± 0.50	2.9 ± 0.26	2.24
Bucconidae						
Notharchus macrorhynchos	13.1 ± 0.13	7.6 ± 0.08	1.72	6.2 ± 0.10	2.9 ± 0.08	2.17
Ramphastidae						
Aulacorhynchus prasinus (3)	12.8 ± 0.65	8.0 ± 0.12	1.60	7.2 ± 0.18	2.9 ± 0.18	2.48
Pteroglossus torquatus (5)	13.9 ± 0.25	8.0 ± 0.15	1.73	6.6 ± 0.20	2.7 ± 0.17	2.44
Ramphastos swainsoni	13.3 ± 0.28	7.7 ± 0.35	1.73	5.8 ± 0.30	2.3 ± 0.20	2.52
Picidae						
Dryocopus lineatus	14.3 ± 0.55	7.6 ± 0.23	1.88	6.4 ± 0.39	3.1 ± 0.24	2.06
Melanerpes formicivorus	12.9 ± 0.73	7.1 ± 0.48	1.89	6.4 ± 0.28	2.8 ± 0.15	2.28
" "	11.9 ± 0.89	6.0 ± 0.44	1.98	6.4 ± 0.34	2.8 ± 0.35	2.28
Centurus rubricapillus (6)	13.7 ± 0.37	7.3 ± 0.15	1.88	6.1 ± 0.15	2.4 ± 0.10	2.54
Centurus chrysauchen	11.7 ± 0.11	6.8 ± 0.29	1.80	5.0 ± 0.17	2.1 ± 0.04	2.38
" "	13.0 ± 0.19	7.0 ± 0.16	1.84			
Phloeoceastes guatemalensis (3)	13.8 ± 0.29	7.15 ± 0.33	1.84	6.0 ± 0.29	2.5 ± 0.27	2.40
Dendrocolaptidae						
Dendrocincla homochroa	11.8 ± 0.49	6.7 ± 0.36	1.76	5.4 ± 0.32	2.3 ± 0.29	2.35
Sittasomus griseicapillus	12.0 ± 0.15	6.4 ± 0.12	1.87	5.4 ± 0.13	2.0 ± 0.02	2.70
Xiphorhynchus guttatus	12.0 ± 0.61	7.1 ± 0.41	1.70	5.6 ± 0.29	2.7 ± 0.13	2.07
" "	12.5 ± 0.62	7.4 ± 0.43	1.69	6.4 ± 0.50	2.8 ± 0.20	2.29
Xiphorhynchus erythropygius	12.2 ± 0.52	6.4 ± 0.36	1.91	5.7 ± 0.44	2.4 ± 0.27	2.37
Lepidocolaptes affinis	11.2 ± 0.80	6.6 ± 0.55	1.70	6.0 ± 0.34	2.6 ± 0.13	2.31
Furnariidae						
Synallaxis brachyura	11.1 ± 0.49	6.1 ± 0.39	1.82	5.6 ± 0.42	2.1 ± 0.21	2.67
Anabacerthia striaticollis	11.9 ± 0.17	6.1 ± 0.01	1.95	5.4 ± 0.15	2.1 ± 0.05	2.57
Formicariidae						
Taraba major	13.5 ± 0.33	7.5 ± 0.30	1.80	6.2 ± 0.38	2.7 ± 0.08	2.30
" "	13.7 ± 0.67	7.6 ± 0.26	1.80	7.0 ± 0.55	2.9 ± 0.25	2.41
Pipridae						
Corapipo leucorrhoa	11.1 ± 0.16	6.1 ± 0.10	1.82	5.1 ± 0.11	2.3 ± 0.07	2.22
Manacus vitellinus	12.6 ± 0.26	7.1 ± 0.58	1.67	6.2 ± 0.48	3.0 ± 0.30	2.07
" "	11.3 ± 0.29	6.2 ± 0.42	1.82	5.6 ± 0.26	2.7 ± 0.20	2.07

TABLE 1—*Continued*

Family and species	*Cytosome* Length (μ)	Width (μ)	Ratio L/W	*Nucleus* Length (μ)	Width (μ)	Ratio L/W
Cotingidae						
Cotinga ridgwayi	12.2 ± 0.27	6.6 ± 0.30	1.80	6.2 ± 0.21	2.2 ± 0.19	2.82
" "	12.1 ± 0.26	6.8 ± 0.08	1.78	6.2 ± 0.19	2.0 ± 0.05	3.10
Attila spadiceus	12.3 ± 0.67	6.6 ± 0.42	1.86	5.7 ± 0.30	1.9 ± 0.24	3.00
Tityra semifasciata	11.7 ± 0.63	6.8 ± 0.38	1.72	5.6 ± 0.40	2.7 ± 0.22	2.17
Tyrannidae						
Myiozetetes cayenensis	10.7 ± 0.12	6.3 ± 0.10	1.81	5.2 ± 0.82	2.5 ± 0.06	2.08
Contopus virens (3)	11.9 ± 0.11	6.8 ± 0.05	1.75	6.0 ± 0.30	2.5 ± 0.20	2.40
Empidonax flaviventris	12.2 ± 0.50	5.6 ± 0.29	2.06	6.0 ± 0.33	2.1 ± 0.30	2.86
" "	11.8 ± 0.46	6.2 ± 0.37	1.90	5.4 ± 0.25	2.1 ± 0.13	2.57
Mitrephanes phaeocercus	11.1 ± 0.44	6.4 ± 0.28	1.73	5.6 ± 0.35	2.1 ± 0.13	2.67
Todirostrum cinereum	11.9 ± 0.90	6.4 ± 0.29	1.86	5.7 ± 0.47	2.3 ± 0.21	2.48
Lophotriccus pileatus	11.5 ± 0.14	6.4 ± 0.20	1.79	4.7 ± 0.10	2.2 ± 0.04	2.14
Hirundinidae						
Progne chalybea (3)	12.7 ± 0.70	7.1 ± 0.08	1.79	5.5 ± 0.38	2.7 ± 0.21	2.04
Stelgidopteryx ruficollis (3)	12.2 ± 0.27	6.6 ± 0.25	1.90	5.9 ± 0.11	2.1 ± 0.09	2.81
Pygochelidon cyanoleuca (3)	11.7 ± 0.19	6.4 ± 0.16	1.80	5.4 ± 0.15	2.1 ± 0.09	2.57
Corvidae						
Cyanocitta cristata	13.7 ± 0.14	7.8 ± 0.92	1.77	5.8 ± 0.12	2.6 ± 0.06	2.23
Troglodytidae						
Thryothorus modestus	10.8 ± 0.20	6.5 ± 0.07	1.66	5.6 ± 0.10	2.6 ± 0.02	2.15
Thryothorus fascioventris	12.1 ± 0.56	6.9 ± 0.48	1.75	5.5 ± 0.33	2.9 ± 0.23	1.90
Troglodytes musculus	10.9 ± 0.23	6.7 ± 0.22	1.72	5.5 ± 0.28	2.2 ± 0.10	2.50
" "	11.3 ± 0.22	6.2 ± 0.17	1.82	5.2 ± 0.17	2.1 ± 0.06	2.48
Turdidae						
Turdus grayi	12.1 ± 0.08	6.7 ± 0.15	1.81	5.4 ± 0.11	2.0 ± 0.06	2.70
Turdus plebejus	11.8 ± 0.60	7.3 ± 0.46	1.62	5.5 ± 0.29	2.8 ± 0.25	1.97
Bombycillidae						
Bombycilla cedrorum (4)	12.2 ± 0.26	6.3 ± 0.13	1.93	5.7 ± 0.22	2.3 ± 0.07	2.48
Cyclarhidae						
Cyclarhis gujanensis	11.8 ± 0.71	6.6 ± 0.67	1.79	5.9 ± 0.20	2.6 ± 0.19	2.27
"Coerebidae"						
Dacnis cayana	12.5 ± 0.43	7.4 ± 0.31	1.69	6.2 ± 0.26	3.2 ± 0.19	1.94
Dacnis venusta	11.2 ± 0.18	6.0 ± 0.06	1.87	4.8 ± 0.13	2.1 ± 0.04	2.29
Parulidae						
Mniotilta varia	11.2 ± 0.17	6.1 ± 0.10	1.84	4.9 ± 0.16	2.3 ± 0.05	2.13
Vermivora gutturalis	11.1 ± 0.50	7.2 ± 0.52	1.82	5.6 ± 0.42	2.9 ± 0.25	1.93
Dendroica pensylvanica	11.7 ± 0.34	6.5 ± 0.32	1.80	5.9 ± 0.24	2.2 ± 0.11	2.68
Geothlypis chiriquensis	11.9 ± 0.18	5.9 ± 0.06	2.02	5.3 ± 0.16	2.0 ± 0.03	2.65
Wilsonia pusilla	11.6 ± 0.40	5.9 ± 0.25	2.06	5.7 ± 0.40	2.5 ± 0.24	2.28
" "	11.8 ± 0.14	5.6 ± 0.15	2.11	5.5 ± 0.12	2.0 ± 0.03	2.75
Myioborus miniatus	11.6 ± 0.15	6.1 ± 0.07	1.90	5.1 ± 0.14	2.3 ± 0.07	2.22
Basileuterus rufifrons	11.5 ± 0.33	6.0 ± 0.36	1.91	5.6 ± 0.28	2.6 ± 0.66	2.15
Icteridae						
Zarhynchus wagleri	10.6 ± 0.39	7.1 ± 0.19	1.65	5.0 ± 0.12	2.1 ± 0.05	2.38
" "	11.4 ± 0.24	6.2 ± 0.21	1.84	4.8 ± 0.15	2.2 ± 0.07	2.18
Amblycercus holosericeus	11.6 ± 0.57	6.5 ± 0.27	1.77	5.7 ± 0.47	3.0 ± 0.23	1.90
Icterus mesomelas	13.1 ± 0.54	6.9 ± 0.45	1.90	5.7 ± 0.36	2.8 ± 0.20	2.04
Icterus galbula (3)	12.0 ± 0.30	6.3 ± 0.20	1.90	5.3 ± 0.21	2.2 ± 0.07	2.41
Thraupidae						
Tanagra icterocephala	11.4 ± 0.07	6.3 ± 0.21	1.82	5.1 ± 0.19	2.4 ± 0.18	2.13
Thraupis episcopus	11.7 ± 0.33	7.0 ± 0.19	1.62	5.7 ± 0.38	2.3 ± 0.21	2.48
" "	11.0 ± 0.27	7.0 ± 0.09	1.57	5.0 ± 0.15	2.2 ± 0.02	2.27
Ramphocelus passerinii	12.0 ± 0.18	6.6 ± 0.13	1.82	4.8 ± 0.08	2.4 ± 0.04	2.00
Chlorospingus pileatus	12.0 ± 0.86	6.7 ± 0.50	1.71	5.9 ± 0.25	2.6 ± 0.00	2.27
" "	10.8 ± 0.57	6.6 ± 0.46	1.64	5.8 ± 0.39	2.7 ± 0.20	2.15
Fringillidae						
Saltator atriceps	12.5 ± 0.49	7.5 ± 0.64	1.66	5.3 ± 0.22	2.9 ± 0.20	1.83
Saltator albicollis	12.2 ± 0.68	7.6 ± 0.28	1.68	5.2 ± 0.42	3.1 ± 0.19	1.68
" "	12.0 ± 0.18	6.8 ± 0.15	1.77	5.2 ± 0.12	2.8 ± 0.09	1.86
Pheucticus tibialis	11.7 ± 0.63	6.5 ± 0.49	1.80	5.3 ± 0.28	2.7 ± 0.23	1.92
Tiaris olivacea	11.3 ± 0.20	6.9 ± 0.25	1.64	4.9 ± 0.14	2.4 ± 0.08	2.04
Arremonops conirostris	11.0 ± 0.21	6.2 ± 0.04	1.83	5.5 ± 0.15	2.2 ± 0.05	2.50
" "	11.7 ± 0.15	6.2 ± 0.08	1.88	5.4 ± 0.15	2.1 ± 0.04	2.57
Zonotrichia capensis (5)	11.4 ± 0.15	6.1 ± 0.15	1.88	4.8 ± 0.07	2.1 ± 0.06	2.29

The range of measurements of the erythrocytes is from 10.7 μ × 6.1 μ, in *Selasphorus*, to 15.8 μ × 10.2 μ, in *Tigrisoma*. The larger erythrocytes appear in the lower forms. Most of the passerines and trochilids contain the smaller red cells. The corvid *Cyanocitta* contains large erythrocytes (13.7 μ × 7.8 μ). In a few families these cells are smaller in the smaller species. This is so in the ardeids (*Butorides*, 13.0 μ × 8.3 μ; *Florida*, 12.8 μ × 7.3 μ; *Leucophoyx*, 13.1 μ × 7.7 μ compared with *Ardea*, 14.3 μ × 7.4 μ; *Casmerodius*, 15.0 μ × 7.9 μ; *Tigrisoma*, 15.8 μ × 10.2 μ); falconids (*Falco*, 11.8 μ × 7.3 μ compared with *Caracara*, 14.1 μ × 8.7 μ) and alcedinids (*Chloroceryle aenea*, 12.6 μ × 6.7 μ compared with *Chloroceryle amazona*, 14.0 μ × 7.6 μ). The erythrocyte size is nearly the same in the three species of cathartids and in all parulids.

In most species the nucleus is more oblong than is the cytosome (compare the ratios). The cotingid nucleus is unusually elongated except in *Tityra*.

We can assume that, in order to permit free movement of erythrocytes, the diameter of the smallest capillaries must be no less than the smaller diameter of the erythrocytes. With this assumption in mind, it is interesting to compare the minimal diameters of different species. In our series this range is from 5.6 μ in *Campylopterus* to 10.2 μ in *Tigrisoma*, but in a majority of birds the range is much smaller, being 6 μ to 8 μ.

DISCUSSION

Cytosome size.—Since the erythrocyte is the most important carrier of oxygen and CO_2, its surface area to size ratio is a determining factor in the exchange of these gases with the tissues. Thus, a small corpuscle offers the possibility of a greater rate of exchange than a larger one. Likewise an elliptical body is more efficient than a spherical one of the same volume. Avian erythrocytes are efficient in both of these respects. The high rate of metabolism of birds demands greater efficiency of gaseous exchange than that of many vertebrates. The difference in metabolic rate among birds is partially reflected by erythrocyte size, smaller species tending to possess smaller erythrocytes than do larger species.

It is interesting, however, that some of the largest birds, the Struthionidae, have erythrocytes no larger than those of the species reported by us. Gulliver (1840) gave the following values: Ostrich (*Struthio camelus*) cytosome—15.4 μ × 8.5 μ, nucleus—7.9 μ × 2.8 μ; Emu (*Dromiceius n. hollandiae*) cytosome — 15.0 μ × 8.4 μ; *Rhea americana*, cytosome — 13.4 μ × 7.8 μ. But later (1846), for the Cassowary (*Casuarius*), he gave the size of the erythrocyte as 17.5 μ × 9.1 μ.

In general our findings agree with those of Cleland and Johnston

(1912), that the lower forms possess the larger erythrocytes. Many of their families are the same as ours but the species are not.

Bartsch *et al.* (1937) show values in their tables little different from ours. However, in their text they give a much greater range than those in their tables.

Comparison of the erythrocytes of birds with other warm-blooded animals is interesting. In mammals their diameters range from 5 μ and 6 μ (horse, cow, pig, mouse, and rat), to 7 μ and 7.4 μ (chimpanzee, woodchuck, and llama) (Wintrobe, 1961).

The red cell count in mammals is high, ranging from 6,300,000 (chimpanzee) to 15,000,000 per cubic mm (llama), while in birds it is 2,810,000 (fowl) to 3,530,000 (pigeon) (Wintrobe, 1961).

Comparison of birds with their ancestral relatives, the reptiles, shows how great the divergence is between these groups. According to Wintrobe (1961), reptilian erythrocytes range from 18.1 $\mu \times$ 8.7 μ (turtle) to 23.2 $\mu \times$ 12.1 μ (alligator) while the red cell count is 740,000 (turtle) to 670,000 (alligator) per cubic mm. These differences indicate how far ahead birds are on the metabolic scale.

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SUMMARY

Measurements of erythrocytes and their nuclei were made in 124 species of birds in 46 families collected in Panamá and the United States. The range of the erythrocytes extended from 10.7 $\mu \times$ 6.1 μ in *Selasphorus* to 15.8 $\mu \times$ 10.2 μ in *Tigrisoma.* The lower forms have the largest erythrocytes. In most species the nucleus is more oblong than is the cytosome. In a few families the erythrocytes are smaller in the smaller species. The cytosomes of trochilids and passerine birds, in keeping with their high rate of metabolism, are smaller than those in many other bird groups. Based on the assumption that the width of the erythrocytes indicates the minimum diameter of the capillaries, trochilids and some passerines must possess the smallest capillaries.

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