

SOME ASPECTS OF THE BLOOD OF ALCIDS IN NEWFOUNDLAND

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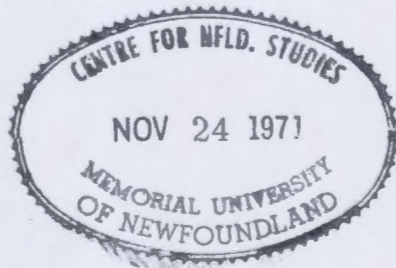
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SOME ASPECTS OF THE BLOOD OF
ALCIDS IN NEWFOUNDLAND

by

LESLIE WAYNE BRADLEY

A Thesis

submitted in partial fulfillment of
the requirements for the degree of
Master of Science

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ABSTRACT

Descriptions and measurements are given for the circulating blood cells of four species of alcids. The measurements of each cell type were very similar among the species examined. Ratios of the various cells of the definitive erythrocyte series were determined utilizing an ocular grid, a decrease in the number of cells of the earlier stages of the erythrocyte series being noted with increasing age.

Differential white blood cell counts from blood smears of 5 species of alcids namely, Alca torda, Uria aalge, Uria lomvia, Cepphus grylle and Fratercula arctica are recorded with wide variations occurring in the percentage values for the various white cell types. Fluctuations occur in the percentage of cells found in differential white blood cell counts of U. aalge and F. arctica during the sampling period. No correlation was noted between the sizes and weights of young U. aalge and F. arctica and the percentages of the various white blood cell types as determined from differential white blood cell counts. Results indicate that differences do occur in the percentage of cellular elements from differential white cell counts in the various species of alcids examined. Values are recorded for hematocrits, clotting times and red cell counts of U. aalge and F. arctica.

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INTRODUCTION

While the literature concerning the hematology of domesticated and semi-domesticated fowl, because of their economic importance, is dauntingly large, that on the blood indices of pelagic and other seabirds is very sparse. Cullen (1903) examined the blood of storm petrels (Hydrobates pelagicus), seagulls and "murs" (no scientific names given). He described four forms of leucocytes corresponding to the small mononuclear (small lymphocyte), large mononuclear (large lymphocyte) and eosinophilic leucocytes and mast cells (basophils) of man. He found 91.98% small mononuclears in the storm petrel and described eosinophilic cells as "not numerous" in this bird. No direct reference was made to the seagull and mur. Cleland and Johnston (1912) recorded measurements for the red cells of the Little penguin (Eudyptula minor) and a Larid (Micranous leucocapillus)¹, while Bennett and Chisholm (1964) recorded the erythrocyte sizes of two gull species (Larus argentatus and Larus delawarensis) and also the hematocrit values for L. argentatus. Kisch (1949) examined the hematocrit, hemoglobin content, erythrocyte size and the volume of the erythrocytes in a seagull (specific identity of bird not given) and Threlfall (1966)

¹ Anous minutus Boie, 1844 - White capped Noddy.

described the blood of the herring gull (L. argentatus) in association with a parasitological study. Nikitenko (1965) reported hematological values from five species of alcids and reviewed the work of Kartaschov (1963), who also worked on this group of birds.

The alcids (Charadriiformes: Alcidae) are a circumpolar group of seabirds which breed in large colonies on rocky islands and isolated cliffs in the Northern Hemisphere (Dement'ev and Gladkov, 1969; A. O. U. Checklist, 1957; Tuck, 1960). They are essentially pelagic seabirds coming to land only to breed. In the past the birds were ruthlessly exploited for food and feathers, however, this practice has now been replaced by management policies in the western world while some commercial exploitation still occurs in the Old World (Williamson, 1945; Uspenski, 1951; Cott, 1953; Belopol'skii, 1957; Tuck, 1960). Several alcid breeding colonies are located around the coast of Newfoundland, the major ones being on Funk Island and the three islands that constitute the Witless Bay Bird Sanctuary (Gull, Green and Great Island), with smaller populations at Cape St. Mary's and Baccalieu Island.

As reports on only two studies on alcid hematology (Kartaschov, 1963; fide Nikitenko, 1965) and Nikitenko (1965) were found in the world literature, an examination of the

blood indices of alcids in Newfoundland was initiated in 1969. Five species of alcids were examined in the present study, namely, the Razorbill (Alca torda), Common Murre (Uria aalge), Thick-billed Murre (Uria lomvia), Black Guillemot (Cepphus grylle) and Atlantic Puffin (Fratercula arctica) (Figs.2 -3). In this study, differential counts were made from blood smears of the adult and young of five species of alcids to determine if there were any specific differences between the birds. Hematocrit readings, red blood cell counts and clotting times were determined and analysed for age, sex and specific differences. Representatives of each cell type found in the circulating blood were measured in four species of alcids to determine if there were any significant cell size differences between species. Red cell ratios were estimated and the values obtained for the adults and young were compared to determine if there were any changes in relative numbers of these cells with age. The data from the differential counts were examined to see if there was any fluctuation in the percentage of the white cell types because of differences in age, sex or because of changes which occur with the different stages of the breeding cycle.

Hematology reflects physiological responsiveness of the organism to its environment (Atwal et.al., 1964) and hematological changes may indicate abnormal situations which

Fig. 2. Alcids examined in the present study.

- A. Razorbill (Alca torda)
- B. Common Puffin (Fratercula arctica)
- C. Common Murre (Uria aalge) - courtesy
Dr. W. Threlfall.



Fig. 3.. Alcids examined in the present study.

A. Puffin enmeshed in net.

B. Common Murre chicks of various ages.

C. Puffin nesting area on Gull Island.



are reflected by changes in the percentage proportion of the various white cell elements or by changes in other parameters such as hemoglobin concentration or hematocrit readings. Blalock (1956) found that bacterial infections will cause an increase in the number of heterophils in fowl. Other studies describe the effects of hormone injections on the differential counts of various birds (Bannister, 1951; Bhattacharyya and Sarkar, 1968). However, before the effect of such compounds on the blood of alcid birds can be studied, the normal blood pattern of these birds must be elucidated. It was hoped that the hematological values obtained in the present study would provide baseline data for further physiological studies on this group of birds.

HISTORICAL

According to Doan et. al. (1925), avian hematology stems from the work of Van der Stricht who demonstrated the erythrocyte to be the primary blood cell of the embryo and Danchakoff (1916) who gave a complete survey of the origin of blood cells in embryos. Doan et. al. (1925) studied the development of erythrocytes in the bone marrow of pigeons. This paper, along with those of Cunningham, Sabin and Doan (1925) and Sabin, Doan and Cunningham (1925) form the basis of our knowledge of the origin and development of avian blood cells. Much of the literature concerning avian hematological studies is presented in Appendix Table 1.

Blain (1928), Kyes (1929), Forkner (1929), Coates (1929), Wiseman (1931), Shaw (1933), Olson (1937), Darcel (1950), Natt and Herrick (1952), Hairston (1955), Rees-Eker (1923), Sadek (1955), Torbert and Dixon (1959) and Santamarina (1964) have all described methods of counting leucocytes and the various dilutants used in making these counts. Chubb and Rowell (1959) reviewed the procedures involved in several of these methods, tested them to determine their accuracy and concluded that the method of Natt and Herrick (1952) gave the best results. Cook (1959) described a method of staining fixed blood smears using a combination May-Greenwald-Wright-Phloxine-B stain. Lucas and Jamroz (1961)

Table 1. Evolution of the nomenclature for the eosinophil and heterophil granulocytes in avian blood. (From: Magath and Higgins, 1964).

Table 1

Author	Date	Eosinophilic Rods	Eosinophilic Granules
Bizzoeero & Torre	1880	Eosinophilic leucocytes "Little spindle shaped bodies"	Granular forms
Grunberg	1901	Eosinophilic leucocytes Crystalloid	Globular-like granules
Cullen	1903	Eosinophilic leucocytes Crystalloid	Granular forms
Warthin	1903	Polymorphonuclear eosinophils Crystalloid type	Granular type
Goodall	1910	Polymorphonuclear leucocyte with rods	Eosinophil
Klieneberger & Carl	1912	Pseudoeosinophil	Eosinophil (with small granules)
Schmeisser	1916	Polymorphonuclears Eosinophilic rods	Eosinophilic granules
Burnett	1917	"Polymorphs"	Eosins
Fritsch	1920	Pseudo-eosinophils	Eosinophils
Hayden	1927	Polymorphonuclears	Eosinophils
Blain 1928	1928	Polymorphonuclears Eosinophilic rods	Eosinophilic granules
Forkner	1929	Eosinophils	Pseudo-eosinophils
Thompson & Englebreth-Holm	1931	Polymorphonuclears Pseudo-eosinophils	Eosinophils
Maximow & Bloom [†]	1931	Heterophic	Eosinophic
Magath & Higgins	1934	Polymorphonuclears With eosinophilic rods	With eosinophilic granules

† From: De Villiers, 1938.

used a modified Wiseman (1931) procedure for their leucocyte counts and Tannen (1956) has described a method and a dilutant for making eosinophil counts. The major difficulty in making white blood cell counts has been the masking of the leucocytes by the lysed red cells and has caused considerable discrepancy over the years in the values given by various workers for total leucocyte counts (Kyes, 1928-1929).

Several extensive reviews are available on the hematology of various birds. Forkner (1929), Olson (1937), De Villiers (1938) and Diesem et. al. (1958) reviewed the literature on fowl, while hematological values for ducks were presented in a review by Hemm and Carlton (1967). Kennedy and Climenko (1929) reviewed the status of literature on pigeon hematology, De Villiers doing the same for ostrich blood.

Differential counts of the white blood cells of various species of birds (fowl, pigeons, ducks) have been attempted by various authors (Appendix Table 1). However, the range of percentage values given for the various cellular elements in the blood of birds is so varied that no clear picture can be obtained. No single, simple factor could account for the variations noted.

A major problem in avian hematology has been the inability of the many workers in the field to formulate a standard terminology for the various cellular components of the blood. Lucas (1959) discussed the synonymy in avian and mammalian hematological nomenclature. The group of cells in which most difficulties occur are the eosinophilic and heterophilic polymorphonuclear leucocytes. Table 1 shows the evolution of the terminology of these cells. Maximow and Bloom (1931) were the first to refer to these cells as eosinophils and heterophils.

Most authors fail to distinguish between the small and large lymphocytes. Cook and Dearstyne (1934) recognized three classes of lymphocytes; small, medium and large. Lucas and Jamroz (1961) identified small, medium and large lymphocytes but used nuclear size and staining appearance as well as cell diameter as their criteria. They classified lymphocytes with a diameter up to 7.8 μ as small, those from 7.9 μ to 10.3 μ as medium and those above 10.4 μ as large. They also noted that for all practical purposes, only two divisions of lymphocytes (small and large) are valid.

Monocytes have received varied recognition. Salomon (1919 - fide Klienberger and Carl, 1929) described a leucocyte in the fowl which resembled a large lymphocyte,

but for its reniform nucleus. Kennedy and Climenko (1929) observed these cells and grouped them with the large lymphocytes, but did state they comprised about 25% of the large lymphocytes.

Warthin (1907) found 16.5% unclassified cells in differential counts of fowl blood while Hirshfeld (1909) found only heterophils and lymphocytes. The values recorded for differential counts by the various authors are inconsistent, this probably being due to a lack of understanding of what was observed.

The hemoglobin concentration was found to vary not only according to the method used, but also within a particular method. Many authors have used the Sahli method and have obtained values ranging from 50% - 80% (Ellerman and Bang, 1908; Thomsen and Englebreth-Helm, 1931; Wirth, 1931; Klienberger and Carl, 1927). Olson (1937) examined the hemoglobin content of fowl and related the results obtained to the sex and age of the birds examined and the environmental conditions under which they were kept. He found seasonal variations occur in the hemoglobin content of fowl blood. Hemm and Carlton (1967) have reviewed the results of hemoglobin determinations for ducks as given by various authors. Few reports detail the hemoglobin content of the blood of other bird species. Miscellaneous reports

include those of Atwal et. al. (1964) who studied Japanese quail (Coturnix coturnix) and Wintrobe (1934) whose subjects were male guinea fowl.

Hematocrit values are recorded by various authors (Appendix Table 1). Blalock (1956) and Fredrickson and Chute (1958) feel that this test should be used as a diagnostic aid in chicken disease control. Lucas and Jamroz (1961) found that female Single Comb White Leghorn fowl had hematocrit values of 30.80% while the males had a 40.00% packed cell volume. Wintrobe (1933) found a value of 42.3% for the hematocrit in the pigeon (Ectopistes migrarius) (modern name unknown), while in the snow goose (Chen coerulescens (Linnaeus)), the values varied from 43.1% to 46.2%.

Numerous reports of red blood cell counts may be found in the literature (Appendix Table 1), the range of values for any given species of bird being very wide, for example, in the fowl they averaged from 2.0 million per cubic millimeter (Chaudhuri, 1926) to 4.6 million per cubic millimeter (Chaudhuri, 1926) and ranged from 1.0 million per cubic millimeter (Palmer and Biely, 1935) to 4.9 million per cubic millimeter (Hedfeld, 1911). Erythrocyte counts in pigeons ranged from 2.01 million per cubic millimeter (Welcker, no date) to 4.06 million per cubic millimeter

(Hedfeld, 1911; Klienberger and Carl, 1912). Venzlaff (1911) recorded the numbers of erythrocytes per cubic millimeter for five species of ducks, his values ranging from 2.165 million to 3.14 million.

Various authors have measured the cells in many species of birds, but this type of work has been mainly restricted to erythrocytes. Gulliver (1875) measured the red blood cells of the various classes of vertebrates and compared them morphologically and with regard to size, while Cleland and Johnston (1911) and Bennett and Chisholm (1964) gave erythrocyte measurements for a variety of birds. Wintrobe (1933) noted measurements from both wet and dry preparations and reported that the cells in wet preparations were larger and he also gave values for the erythrocyte sizes of geese and guinea fowl. Venzlaff (1911) measured the red cells of five species of ducks and geese. Kisch (1949) states that the volume of the erythrocyte of the seagull (no scientific name given) is $126 \mu^3$.

Goodall (1910), Forkner (1929), Kelly and Dearstyne (1935), Olson (1937), De Villiers (1938), Arvy (1943) and Lucas and Jamroz (1961) have described the circulating blood cells of fowl, while Magath and Higgins (1934) studied the blood of ducks. Pigeon blood cells have been described by Kennedy and Climenko (1929) and Shaw (1933), while those

found in the geese were illustrated by Kaleta and Bernhardt (1968). De Villiers (1938), in a study of the blood of ostriches, described the circulating cells.

METHODS AND MATERIALS

The study area, for the present work, where birds were sampled in July, 1969 and from May to August, 1970 was the Witless Bay Bird Sanctuary, which lies approximately 17 kilometers south of St. John's. The Sanctuary consists of a group of three rocky islands, two of which, Gull Island (Fig. 4A,5) and Green Island (Fig. 4B,6) are located at the mouth of Witless Bay, the third, Great Island, lying 1.7 kilometers south of Green Island.

Common Murre and Thick-billed Murre adults were captured using a salmon dip net, equipped with a long handle. Murre chicks, selected to obtain a varied size sample, were collected and bled on the ledges of Green Island (Fig. 3).

Puffin adults were captured on Gull Island in a 150 foot long, 2.5 inch mesh, cotton net strung between two poles on the grassy perimeter of the island where the Puffins were nesting (Fig. 3). Known aged Puffin chicks were examined for changes in the percentage of the white blood cell elements in differential counts of the circulating blood and puffin burrows had to be checked for eggs, marked and daily checks made for state of incubation and hatched chicks. To facilitate daily checking a hole was dug from

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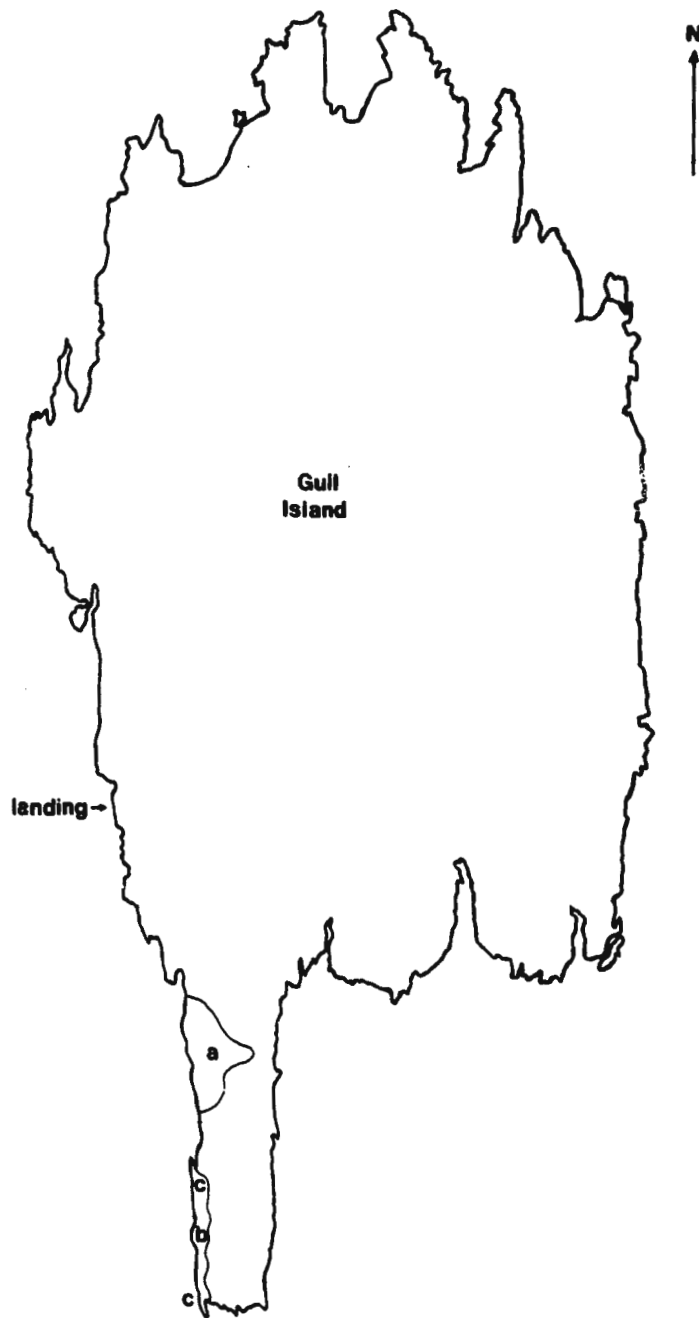
Fig. 4. Research areas.

A. Gull Island

B. Green Island



Fig. 5. Gull Island, showing the location of the sampling areas.




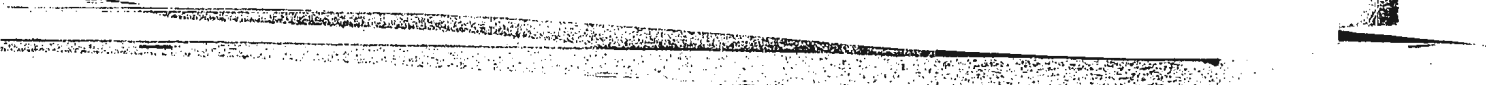

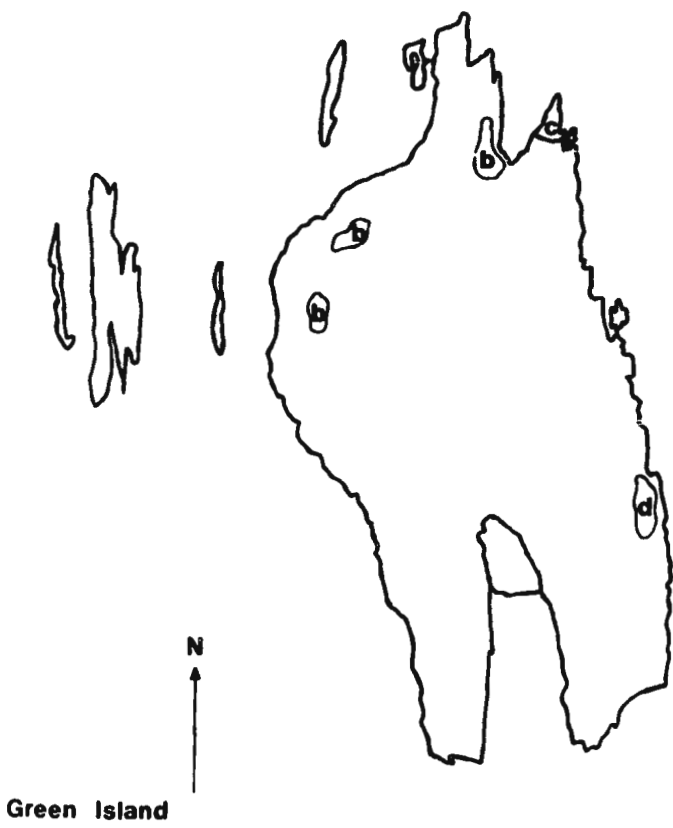


Fig. 6. Green Island, showing the location of the
sampling areas.





the surface to the nest cavity and a "plug" was constructed of turf and rocks. To determine whether or not any chicks had hatched the previous night or if the eggs were still warm the plug was simply removed. Each burrow had been originally marked with a numbered wooden peg, but these were removed by the adult birds, therefore, a number was spray painted in the vicinity of the mouth of the burrow.

The plug was also sprayed for ease of location.

The Razorbills (adults and chicks) examined were taken from nest locations, under rocks, on Green Island where they were easily trapped. The Black Guillemots were the most difficult of the alcids to obtain. The six specimens examined in the study, had been killed using a 12 gauge shotgun, and were bled via heart puncture. No young guillemots were examined.

The Common Murre, Puffin and Razorbill chicks were measured (culmen, tarsus, wing and tail length) and weighed (using a spring balance¹) before being bled. The measurements were made according to Godfrey (1966) and are recorded in Appendix Table 2.

¹Ohaus Mod. 8011, 250 gr. and Mod. 8014, 2000 gr.

Fig. 7. Diagram showing how the cells of the circulating blood were measured.

s.l. = small lymphocytes
l.l. = large lymphocytes
m. = monocytes
b. = basophils
e. = eosinophils
h. = heterophils
ery. = erythrocytes
t. = thrombocytes



s.l.



l.l.



m.

LENGTH ↑



b.



e.



h.



ery.



t.

WIDTH →

3

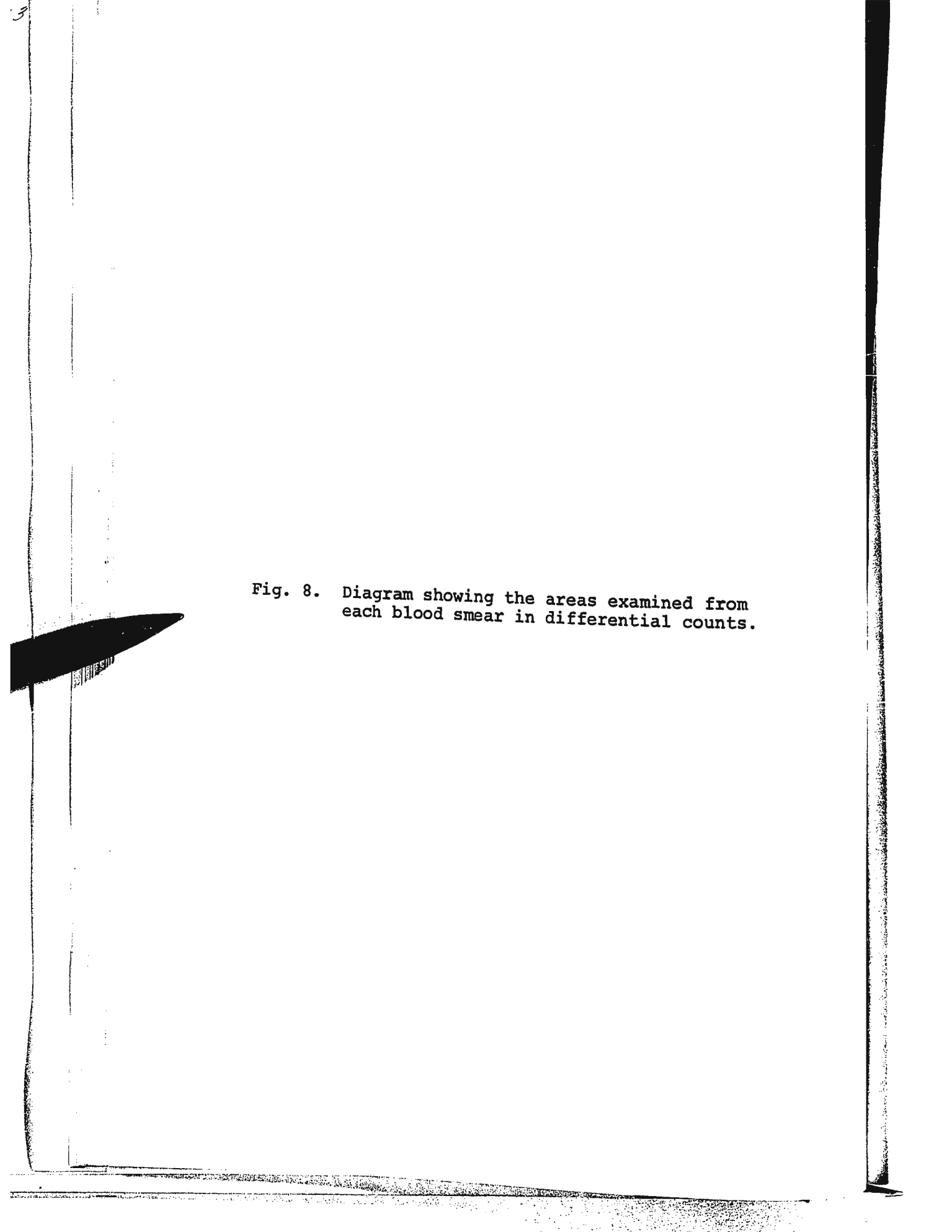
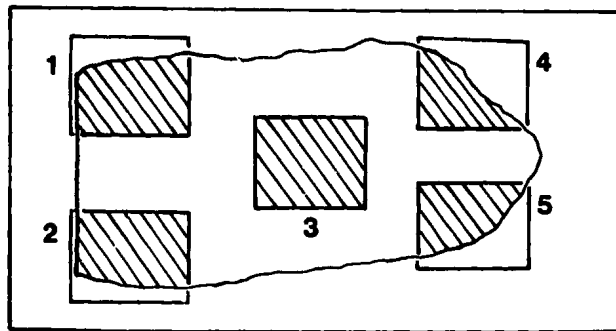


Fig. 8. Diagram showing the areas examined from each blood smear in differential counts.



 Areas Examined

Blood smears were made using the technique of Bennett (1970). The leg of the bird was first cleansed with 70% alcohol, the femoral vein was punctured with a blood lancet, and a smear was then made. The slides were air dried and fixed at a later date in 100% methanol for five minutes. The slides were routinely stained with Giemsa (Appendix 3).

For the differential counts, 200 leucocytes on each slide were counted using a Leitz-Wetzlar binocular microscope, at a magnification of 1000 x (oil). 40 cells were counted in each of the upper left, lower left, center, upper right and lower right regions of the slide (Fig. 8). Standard deviations and Student-t values for the mean values obtained in differential counts were determined according to Freund (1967).

Measurements of the length and width of the cytoplasm and nucleus of all the cell types found in the circulating blood of four species of alcids were made, using the Leitz-Wetzlar microscope and an ocular micrometer. Measurements were also made of the lobe sizes of the nuclei of heterophils and eosinophils and the length of the nucleus of monocytes at the narrowest point (Fig. 7).

The ratios of the various cells of the erythrocyte series were determined using an ocular grid. Five areas on

each slide, namely, the upper left, lower left, center, upper right and lower right were examined for numbers of erythroblasts, early-polychromatic erythrocytes, mid-polychromatic erythrocytes, late-polychromatic erythrocytes, mature erythrocytes and erythroplastids.

Red blood cell counts were made according to standard methods (Appendix 3). The pipettes were shaken for two minutes, stored in the refrigerator for 24 hours and reshaken for two minutes before the counts were made. Two counts were made per pipette utilizing a Neubauer Hemocytometer.

In the field blood was diluted and wide elastic bands were fitted over the ends of the pipettes, which were then in plastic bags in ice in a styrofoam freezing chest. They were then returned to the laboratory and refrigerated as usual.

Several adults and chicks of Uria aalge and Fratercula arctica were taken to the laboratory for examination. A compartmentalized carton or burlap bags were used for this purpose and on returning to the laboratory they were transferred to cages and examined immediately. The birds were first chloroformed, the wing vein exposed by removing several feathers, the area swabbed with 70% ethanol and the vein punctured with a blood lancet.

Hematocrit tubes were filled, clotting times determined, dilutions then made for red blood cell counts and smears made and fixed for differential counts. The hematocrit tubes were centrifuged in a hematocrit centrifuge¹ rated at 12,500 r.p.m. for 6 minutes and read using a dissecting scope and metric rule.

¹Clay-Adams Hematocrit Centrifuge, model CT 2900.

RESULTS AND DISCUSSION

Descriptions and Measurements of the Circulating Blood of Alcids

The following descriptions and measurements are based on cells observed in blood films which had been routinely stained with Giemsa. No measurements were made of the blood cells of Black Guillemots (C. grylle) due to distortion of the cells caused by length of time the birds had been dead. The numbers of cells measured is recorded in Table 2 while the values obtained are recorded in Tables 3 - 6. The range of measurements given is a compound of the range of size for each cell type from four species of alcids (A. torda, U. aalge, U. lomvia, F. arctica), there being no statistical difference in the size of the various cells in the bird species examined. Measurements of cells of various stages of the erythrocyte series are also recorded, the terminology following that of Lucas (1961). Non-nucleated erythrocytes, called erythroplastids (Lucas, 1961), were measured whenever found.

Ratios of the various cells of the erythrocyte series were determined for adults and chicks of U. aalge and F. arctica, the values being recorded in Table 8. Cytoplasmic colouration was the main criterion in the identification of the various cell stages (Lucas, 1961). The early-polychromatic is characterized by a blue cytosome, the mid-polychromatic

- Table 2. Numbers of various cell types measured.
- Table 3. Measurements of the circulating blood cells of the Razorbill (A. torda).
- Table 4. Measurements of the circulating blood cells of the Common Murre (U. aalge).
- Table 5. Measurements of the circulating blood cells of the Thick-billed Murre (U. lomvia).
- Table 6. Measurements of the circulating blood cells of the Common Puffin (F. arctica).

Table 2. Number of various cell types measured

Cell Types	<u>U.</u> <u>aalge</u> (ad) [†]	<u>U.</u> <u>aalge</u> (ch) [*]	<u>F.</u> <u>arctica</u> (ad)	<u>F.</u> <u>arctica</u> (ch)	<u>U.</u> <u>lomvia</u> (ad)	<u>A.</u> <u>torda</u> (ad)
Small Lymphocytes	50	50	50	38	10	15
Large Lymphocytes	50	35	40	22	20	14
Monocytes	7	3	8	3	4	6
Basophils	33	6	-	-	9	-
Eosinophils	30	15	15	15	8	-
Heterophils	25	17	50	20	25	12
Undifferentiated	3	2	2	1	-	7
Thrombocytes	50	50	50	25	15	25
Early-Polych. Eryth.	25	2	9	-	8	2
Mid-Polych. Eryth.	25	25	25	25	25	25
Late-Polych. Eryth.	25	25	25	25	25	25
Mature	25	25	25	25	25	25
Erythroplastids	3	-	1	-	2	4

† ad: adult
* ch: chick

Table 3. circulating cell sizes of the Razorbill (A. torda)

Cell Type	No.	Cytoplasm				Nucleus			
		Av. Length	Range	Av. Breadth	Range	Av. Length	Range	Av. Breadth	Range
Small Lymphocytes	15	9.9	(8.0-11.0)	9.5	(7.0-11.0)	8.0	(7.0-10.0)	8.6	(7.0-10.0)
Large Lymphocytes	14	13.3	(11.0-17.0)	12.6	(11.0-14.0)	10.0	(8.0-15.0)	10.2	(9.0-12.0)
Monocytes	6	13.0	(8.0-19.0)	10.8	(8.0-14.0)	10.8 5.5	(7.0-14.0) (4.0-7.0)†	9.0	(7.0-11.0)
Basophils	-	-	-	-	-	-	-	-	-
Eosinophils	-	-	-	-	-	-	-	-	-
Heterophils	12	14.9	(13.0-17.0)	13.3	(11.0-15.0)	12.3 5.2	(9.0-15.0) (4.0-7.0)*	8.3 6.0	(7.0-12.0) (4.0-8.0)*
Undifferentiated	7	13.0	(11.0-16.0)	10.9	(9.0-13.0)	9.7	(8.0-11.0)	8.3	(7.0-9.0)
Thrombocytes	25	9.8	(8.0-11.0)	6.0	(5.0-8.0)	7.0	(6.0-8.0)	5.9	(5.0-8.0)
Early-Polych. Eryth.	2	13.5	(13.0-14.0)	6.5	(6.0-7.0)	7.0	(7.0)	4.0	(4.0)
Mid-Polych. Eryth.	25	14.4	(13.0-16.0)	7.8	(6.0-9.0)	7.6	(7.0-8.0)	3.9	(3.0-5.0)
Late-Polych. Eryth.	25	15.2	(14.0-16.0)	8.3	(8.0-10.0)	8.0	(7.0-9.0)	4.0	(4.0)
Mature Eryth.	25	15.8	(15.0-17.0)	8.9	(8.0-10.0)	7.2	(7.0-8.0)	3.0	(3.0)
Erythroplastids	4	14.5	(12.0-16.0)	7.8	(7.0-9.0)				

Table 4. Circulating cell sizes of the Common Murre (U. aalge)

Cell Type	No.	Cytoplasm				Nucleus			
		Av. Length	Range	Av. Breadth	Range	Av. Length	Range	Av. Breadth	Range
Small Lymphocytes	100	9.8	(7.0-12.0)	9.8	(7.0-12.0)	7.9	(6.0-10.0)	9.0	(7.0-10.0)
Large Lymphocytes	85	13.2	(10.0-18.0)	12.9	(9.0-18.0)	9.6	(7.0-13.0)	10.7	(7.0-16.0)
Monocytes	10	15.4	(11.0-20.0)	12.5	(10.0-15.0)	13.7 6.2	(11.0-20.0) (5.0-7.0) [†]	8.9	(7.0-11.0)
Basophils	39	14.4	(10.0-19.0)	13.4	(10.0-17.0)	10.6	(7.0-16.0)	8.2	(4.0-15.0)
Eosinophils	45	12.9	(11.0-16.0)	12.5	(10.0-15.0)	10.3 4.3	(7.0-14.0) (3.0-7.0)*	7.8 4.0	(5.0-12.0) (3.0-8.0) ^x
Heterophils	42	13.3	(11.0-16.0)	12.3	(10.0-17.0)	11.0 3.6	(7.0-16.0) (3.0-7.0)*	8.4 3.6	(4.0-13.0) (3.0-8.0) ^x
Undifferentiated	5	15.3	(14.0-16.0)	11.8	(10.0-13.0)	6.0	(7.0-13.0)	10.2	(8.0-12.0)
Thrombocytes	100	9.5	(7.0-12.0)	6.0	(5.0-7.0)	6.7	(5.0-7.0)	5.0	(4.0-7.0)
Early-Polych. Eryth.	27	12.0	(10.0-15.0)	8.2	(7.0-14.0)	6.9	(5.0-8.0)	4.3	(3.0-5.0)
Mid-Polych. Eryth.	50	14.3	(13.0-16.0)	7.9	(7.0-9.0)	6.9	(6.0-8.0)	4.1	(3.0-6.0)
Late-Polych. Eryth.	50	14.8	(13.0-17.0)	8.5	(7.0-10.0)	7.2	(5.0-8.0)	4.0	(3.0-6.0)
Mature Eryth.	50	15.2	(14.0-16.0)	8.8	(8.0-10.0)	7.0	(6.0-9.0)	3.1	(3.0-4.0)
Erythroplastid	3	13.7	(11.0-15.0)	7.7	(6.0-9.0)				

Table 5. Circulating cell sizes of the Thick-billed Murre (U. lomvia)

Cell Type	No.	Cytoplasm				Nucleus			
		Av. Length	Range	Av. Breadth	Range	Av. Length	Range	Av. Breadth	Range
Small Lymphocytes	10	9.8	(8.0-11.0)	10.2	(10.0-11.0)	8.1	(7.0-10.0)	9.8	(9.0-10.0)
Large Lymphocytes	20	13.8	(11.0-17.0)	14.0	(12.0-19.0)	9.6	(7.0-13.0)	10.9	(7.0-16.0)
Monocytes	4	17.0	(14.0-20.0)	13.5	(12.0-15.0)	13.3 6.8	(10.0-15.0) (6.0-8.0) [†]	10.3	(8.0-12.0)
Basophils	9	14.4	(12.0-17.0)	13.6	(10.0-15.0)	11.3	(8.0-15.0)	10.4	(8.0-15.0)
Eosinophils	8	13.8	(12.0-16.0)	13.0	(11.0-16.0)	11.6 5.0	(10.0-13.0) (4.0-7.0) [*]	9.1 5.4	(6.0-13.0) (4.0-6.0) [*]
Heterophils	25	14.4	(11.0-17.0)	12.3	(9.0-18.0)	10.6 5.2	(4.0-16.0) (4.0-7.0) [*]	7.8 5.1	(5.0-11.0) (3.0-8.0) [*]
Undifferentiated	-	-	-	-	-	-	-	-	-
Thrombocytes	15	8.7	(7.0-10.0)	5.9	(5.0-7.0)	6.9	(6.0-8.0)	5.9	(5.0-7.0)
Early-Polych.	8	13.1	(11.0-21.0)	9.4	(8.0-12.0)	7.0	(5.0-7.0)	5.4	(5.0-7.0)
Mid-polych.									
Mid-Polych. Eryth.	25	14.7	(13.0-16.0)	8.2	(7.0-10.0)	7.0	(6.0-8.0)	4.2	(4.0-5.0)
Late-Polych. Eryth.	25	15.3	(13.0-17.0)	9.1	(8.0-11.0)	6.8	(4.0-8.0)	4.0	(3.0-6.0)
Mature Eryth.	25	15.3	(14.0-17.0)	8.8	(8.0-9.0)	6.6	(6.0-8.0)	3.0	(3.0)
Erythroplastid	2	11	(10.0-12.0)	9	(9.0)				

Table 6. Circulating cell sizes of the Common Puffin (*F. arctica*)

Cell Type	No.	Cytoplasm				Nucleus			
		Av. Length	Range	Av. Breadth	Range	Av. Length	Range	Av. Breadth	Range
Small Lymphocytes	88	9.7	(7.0-10.0)	9.4	(7.0-11.0)	7.7	(7.0-10.0)	8.5	(7.0-10.0)
Large Lymphocytes	62	12.7	(11.0-15.0)	12.0	(9.0-17.0)	9.3	(7.0-12.0)	10.2	(7.0-15.0)
Monocytes	11	13.9	(11.0-18.0)	10.7	(9.0-14.0)	11.6 5.8	(10.0-14.0) (4.0-9.0)	8.5	(6.0-10.0)
Basophils	-	-	-	-	-	-	-	-	-
Eosinophils	30	12.0	(8.0-14.0)	11.3	(7.0-14.0)	9.9 4.7	(7.0-18.0) (3.0-9.0)*	6.9 5.0	(4.0-10.0) (3.0-7.0)*
Heterophils	70	12.4	(10.0-18.0)	11.5	(9.0-15.0)	10.6 4.5	(6.0-15.0) (3.0-8.0)*	7.1 4.8	(4.0-11.0) (3.0-7.0)*
Undifferentiated	3	14.0	(11.0-16.0)	11.0	(9.0-13.0)	11.3	(9.0-13.0)	8.6	(8.0-9.0)
Thrombocytes	75	9.3	(7.0-12.0)	5.2	(4.0-7.0)	7.0	(6.0-9.0)	5.0	(4.0-6.0)
Early-Polych. Eryth.	9	11.8	(9.0-16.0)	8.6	(8.0-10.0)	7.0	(6.0-10.0)	5.6	(4.0-7.0)
Mid-Polych. Eryth.	50	14.4	(12.0-16.0)	8.6	(7.0-10.0)	6.9	(6.0-8.0)	4.1	(3.0-5.0)
Late-Polych. Eryth.	50	14.8	(10.0-17.0)	8.6	(10.0-18.0)	7.0	(6.0-8.0)	3.9	(3.0-5.0)
Mature Eryth.	50	15.9	(13.0-20.0)	8.9	(7.0-10.0)	7.0	(5.0-8.0)	3.0	(2.0-4.0)
Erythroplastid	1	11		9					

erythrocyte by a grey colouration, the late stages by various tints of orange, while the mature erythrocytes are of a definite pale orange colouration. The way in which the cells were measured is recorded in Figure 7.

Small Lymphocytes (Fig. 9A1, Tables 3 - 6)

These are rather small, round to oval cells ranging from 7 - 12 μ in length. The cytoplasm is weakly basophilic, staining grey-blue, the staining reaction in the peripheral part of the cell being more intense than around the nucleus. In some cases the cytoplasm is hardly visible due to the pinching off of bits of the cytoplasm. This condition in mammals, is identified as stimulation of the blood toward antibody formation (Lucas, 1961). The nucleus is variable - round, oval or slightly indented, centrally or eccentrically located. The nucleus may contain coarse chromatin clumps, but on occasion the chromatin does not stain.

Small lymphocytes, in the present study, are those cells in which the long axis of the cell was less than 10 μ or ones with a high nucleocytoplasmic (Table 7) ratio. The cell averaged 9.8 μ (range: 7 - 12 μ) in length, the width, having a mean of 9.7 μ (range: 7 - 12 μ). The nucleus was wider than it was long, the average length of the nucleus in all species being 7.9 μ (range: 6 - 10 μ), with a width of 9 μ (range: 7 - 10 μ).

Fig. 9. Circulating blood cells of alcids.

- A. 1. Small lymphocyte
- B. 1. Large lymphocyte
2. Monocyte
- C. 1. Monocyte
- D. 1. Heterophil

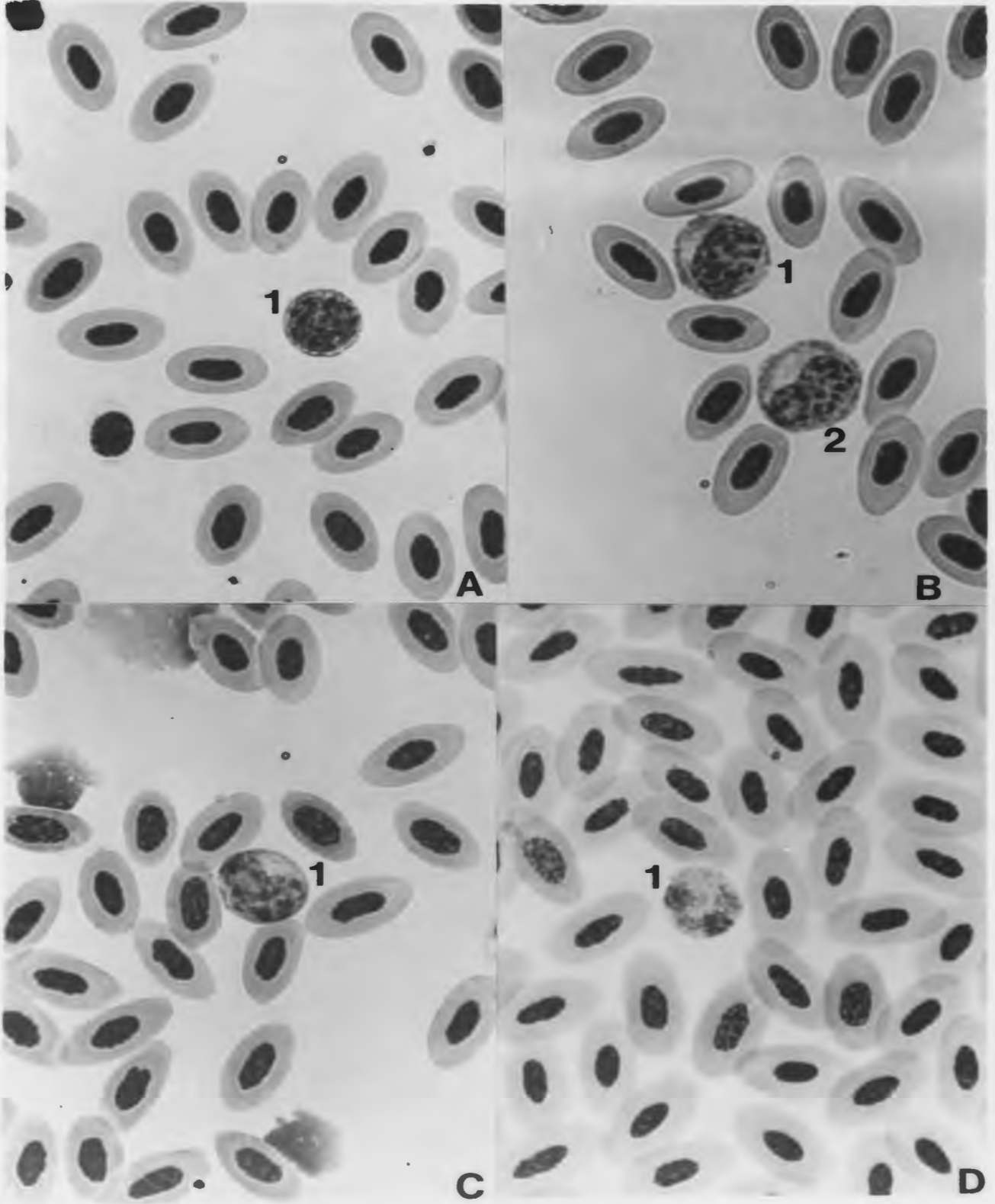
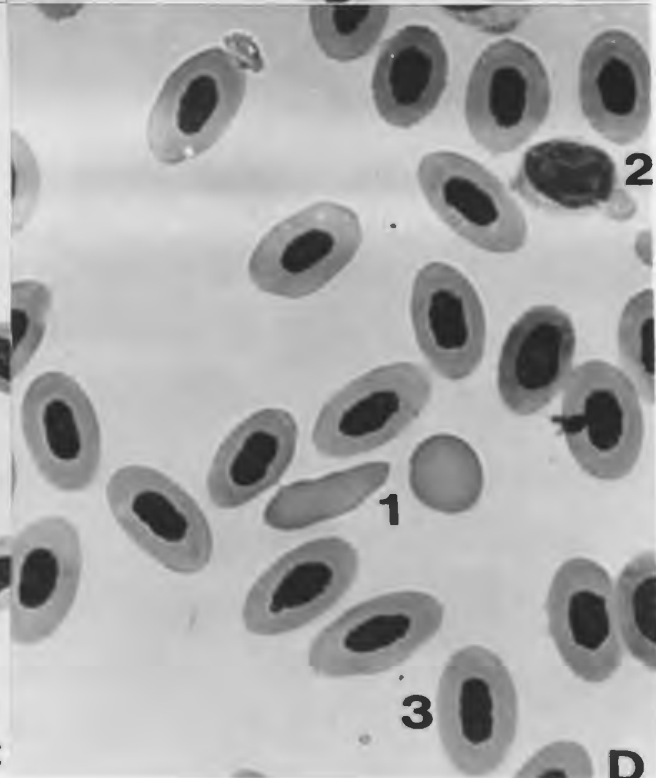
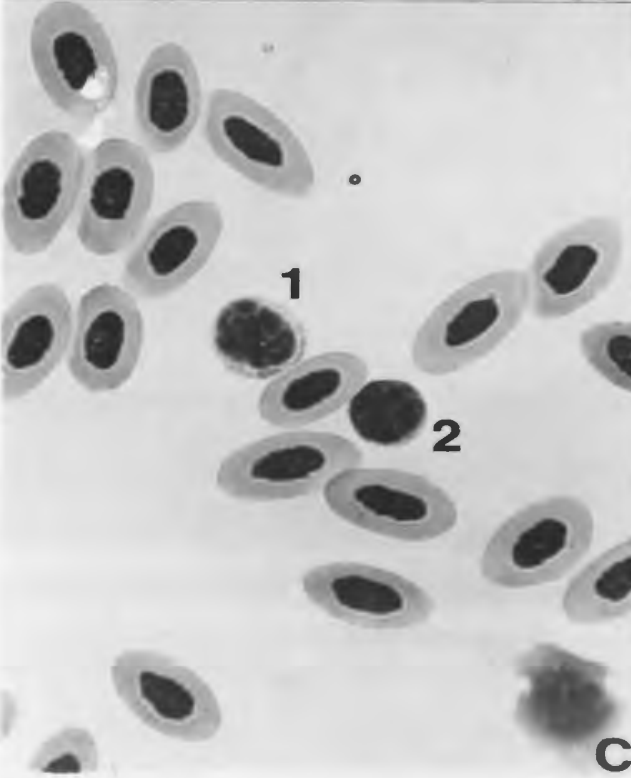
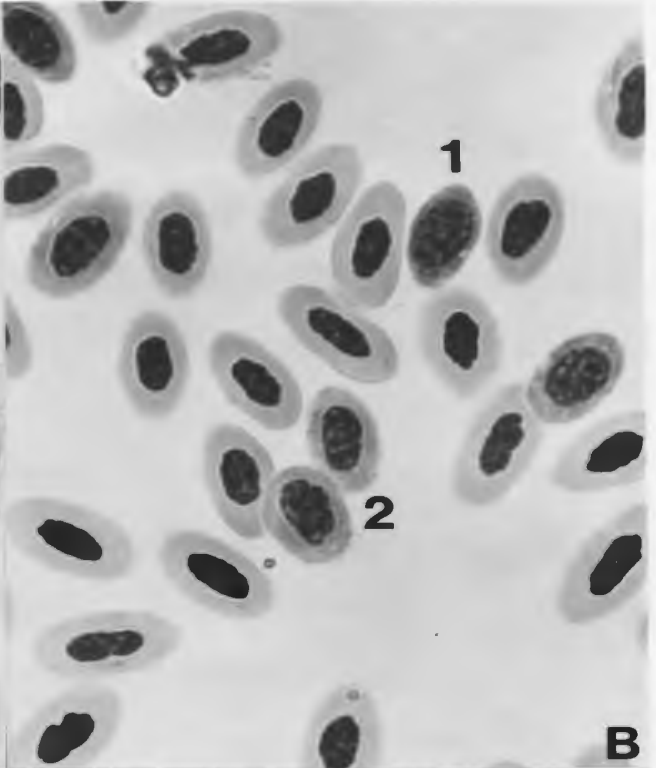
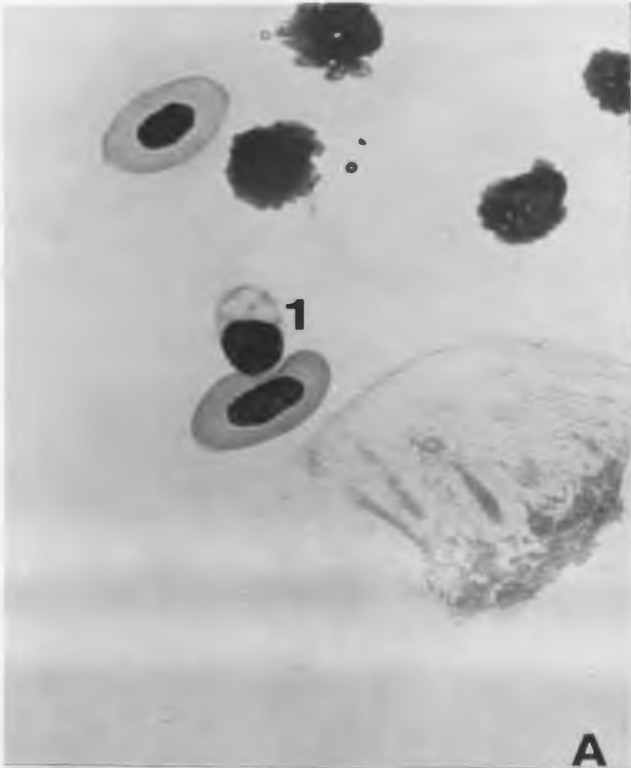


Fig. 10. Circulating blood cells of alcids.

- A. 1. Thrombocyte
- B. 1. Mid-polychromatic erythrocyte
2. Late-polychromatic erythrocyte
- C. 1, 2. Small lymphocytes
- D. 1. Erythroplastids
2. Small lymphocyte
3. Mature erythrocyte



Large Lymphocytes (Fig. 9B1, Tables 3 - 6)

These cells are larger than small lymphocytes, ranging from 10 - 18 μ in length and are much less regular in shape. The cytoplasm of these cells stains less intensely than that of the small lymphocytes, with a more uniform light-blue colouration. Some of the cells contain large azurophilic granules, which make them first appear as basophils. The nucleus was variable (round, oval or elliptical) and most often located eccentrically. The chromatin pattern is not as coarse as that found in small lymphocyte nuclei nor is the nuclear staining reaction as deeply basophilic.

The cell averaged 13.3 μ (range: 10 - 18 μ) in length, the breadth being 12.9 μ (range: 9 - 19 μ), and were, on the average, 3.5 μ longer than the long axis of the small lymphocyte. The nucleus averaged 9.5 μ in length (range: 7 - 15 μ), which is about the size of the length of the small lymphocyte. The nucleus was wider than it was long, averaging 10.5 μ (range: 7 - 16 μ), which is wider than the cell width of the small lymphocytes. The cells of the Thick-billed Murre showed a higher range of values than did the cells of the other three species examined. The large lymphocytes of the Common Puffin were the smallest of all the alcids examined.

Attempts have been made to classify lymphocytes into small and large according to the size of the cells. Kennedy and Climenko (1929) found a bimodal distribution for the total length of lymphocytes and adopted a standard whereby all cells below 6 μ in diameter were classified as small lymphocytes and all those above 6 μ were classified as large lymphocytes. As stated, in the present study, 10 μ was the figure selected below which all lymphocytes were classified as small and above which they were classified as large. However, an examination of the length and breadth of the alcid cells studied did not reveal any such bimodal distribution, the distribution tending toward poisson. Therefore, in the present study, there is no evidence for classifying the cells as either small or large lymphocytes on the basis of size criteria. In some cases the classification was arbitrary and based only on the appearance of the cells in stained preparations, hence the overlap of some measurements.

The areas of nucleus and cytoplasm for 10 small and 10 large lymphocytes were measured for each of the alcid species examined (Table 7). The results show that the small lymphocytes contain a proportionately smaller amount of cytoplasm (average: 17.0 μ^2) than that found in large lymphocytes (average: 53.7 μ^2). The average value for the nuclear area of the small lymphocytes was 50.4 μ^2 while that for the large lymphocytes was 74.9 μ^2 . The nuclear-cytoplasmic ratio

Table 7. Showing nuclear and cytoplasmic areas (μ^2) for small and large lymphocytes and the total area (μ^2) occupied by these cells in 4 species of aluids.

Table 7. Areas of small and large lymphocytes
of 4 species of alcid.

Species	Lymph. Size	Nuclear Area	Cytopl. Area	Total Area	N/C
<u>A. torda</u>	Small	40.1	14.7	54.8	2.73
	Large	73.3	60.1	133.4	1.22
<u>U. aalge</u>	Small	53.5	12.9	66.4	4.15
	Large	75.4	36.5	111.9	2.07
<u>U. lomvia</u>	Small	46.5	21.6	68.1	2.15
	Large	74	76.5	150.5	0.97
<u>F. arctica</u>	Small	61.4	18.9	80.3	3.25
	Large	76.7	41.5	118.2	1.85

for small lymphocytes is approximately twice that of the large lymphocytes, indicating that the large lymphocytes contain much more cytoplasm in relation to the nuclear size.

Monocytes (Fig. 9C1, Tables 3 - 6)

These are the largest cells of the agranulocyte series, ranging in length from 8 - 20 μ . They showed a somewhat irregular outline, but tended to be circular. The cytoplasm displayed a granular consistency and stained a deep-blue. The nucleus was most often eccentric and there was an indentation in the nucleus in which there was a very small, clear area of cytoplasm called the Hof (Lucas and Jamroz, 1961). The nucleus showed a coarse chromatin pattern and stained dark-blue, but in some examples the colouration was almost purple.

The cell averaged 14.8 μ in length (range: 8 - 20 μ) and 11.9 μ in width (range: 8 - 15 μ). The nuclear length averaged 12.4 μ (range: 7 - 20 μ) while the width averaged 9.2 μ (range: 6 - 12 μ). The constricted area of the nucleus averaged 6.1 μ (range: 4 - 9 μ) across.

Basophils (Tables 3 - 6)

These are large, ovoid cells ranging from 8 - 19 μ in length. The cytoplasm is colourless, but the large granules, which show an affinity for basic dyes, tend to mask the cytoplasm so that the cells appear blue. The nucleus is generally round, centrally located and has a coarse chromatin pattern. The nucleus generally is one large mass of nuclear material but Lucas (1961) has described a condition where two masses of nuclear material are connected by slender nuclear threads (bilobed) in about one in one hundred cells.

The mean length of the cell was 14.4 μ (range: 10 - 19 μ) with a mean width of 13.5 μ (range: 10 - 17 μ). The mean nuclear length was 11 μ (range: 8 - 16 μ) and the width 9.3 μ (range: 4 - 15 μ).

Eosinophils (Tables 3 - 6)

These cells are round to oval in shape varying in length from 8 - 16 μ . The cytoplasm is colourless, but contains small spherical granules that are acidophilic in nature and which appear uniform in size and staining reaction. The nucleus is round, centrally to slightly eccentrically

located and has a coarse chromatin network that stains deep blue. The nucleus is usually bilobed or more rarely, unilobed.

The length of the eosinophils averaged 12.9 μ (range: 8 - 16 μ) and 12.3 μ (range: 7 - 16 μ) in width with a mean nuclear length and width of 10.6 μ (range: 7 - 18 μ) and 7.9 μ (range: 4 - 13 μ) respectively. Lobe sizes averaged 4.7 μ in length and 4.8 μ in width.

Heterophils (Fig. 9D1, Tables 3 - 6)

These are ovoid cells which range from 10 - 18 μ in length. Some heterophils were found to be ruptured and their nuclei and rods, although intact, were widely scattered. Many bright-red spindle or rod-shaped granules were found in the colourless cytoplasm, some examples having both spherical and rod-shaped granules mixed together. The nucleus has a coarse chromatin pattern and shows varying degrees of lobation but in the present study, 2 to 3 per cell were usually found, which were either spherical or oval in shape.

The heterophilic cells were, on average, 13.8 μ (range: 10 - 19 μ) in length and 12.4 μ (range: 9 - 18 μ) in width. These cells were only slightly larger than the eosinophils and had a slightly larger range. The mean

nuclear length was somewhat larger (average: 11.1 μ ; range: 4 - 16 μ) in heterophils than in eosinophils (average: 10.6 μ), the width being 7.9 μ (range: 4 - 13 μ) on the average. The lobe size of the heterophils averaged 4.6 μ (range: 3 - 8 μ) by 5 μ (range: 3 - 8 μ) which is comparable to the lobe size of eosinophils.

Thrombocytes (Fig. 10A1, Tables 3 - 6)

These are oval cells ranging from 7 - 12 μ in length. The cytoplasm stains a very pale blue or is colourless and the cytoplasmic boundary is seen as a faint blue line, if it is seen at all. The cells occur either singly or more commonly in groups of 2 - 3 or more. The cytoplasm of these cells appears to consist of a cytoplasmic frame within which are many large spaces. Pink granules, varying in number and appearance, were observed in the cytoplasm of many of these cells. The nucleus is oval but not as elongate as the erythrocyte nucleus. In the birds examined, the nucleus was found to occupy almost the whole width of the cell and most of the length. The nucleus is centrally located along the long axis in most cases, but in others it was found to be slightly to completely eccentric. The nucleus is very strongly basophilic and contains many coarse chromatin clumps.

The thrombocyte cell averaged 9.3μ in length (range: $7 - 12 \mu$) and 5.8μ in width (range: $5 - 8 \mu$). The nucleus averaged 6.9μ (range: $5 - 9 \mu$) in length and 5.5μ (range: $4 - 8 \mu$) in width.

Erythroblasts (Tables 3 - 6)

These are rather large, irregular cells, the cytoplasm being lightly basophilic and containing vacuoles or spaces. The nucleus has a coarse network of chromatin which is clumped more than in the other blast cells (Lucas, 1961) and is extremely basophilic.

The cytoplasm of these cells averaged 14.1μ in length (range: $11 - 16 \mu$) and 12.2μ in width (range: $9 - 13 \mu$) with a nucleus having a mean length and width of 9μ (range: $7 - 13 \mu$) and 9μ (range: $7 - 12 \mu$) respectively. The largest erythroblast was found in the Common Murre and measured $16 \mu \times 11 \mu$.

These cells were apparently absent in the circulating blood of the adults when they were examined for red cell ratios and were only rarely found in the chicks. The values for Puffin chicks ranged from $0.4 - 1.5$ cells% per bird with a mean of $.6\%$ while those for Common Murre chicks ranged from $.3 - .9\%$ with a mean of $.5\%$ (Table 8). Lucas

Table 8. Ratios of the various cells of the erythrocyte series of adults and chicks of U. aalge and F. arctica (based on 1000 cells per blood smear).

Table 8. Ratios of erythrocyte stages in adults and chicks of U. aalge and F. arctica.

Date	Species	No	Red Cell Ratios	Erythroblasts	Early-Polych. Eryth.	Mid-Polych. Eryth.	Late-Polych. Eryth.	Miscell. Eryth.	Mature Eryth.
July 8, 1969	<u>Uria aalge</u> (ad)	36	Average	-	6.7	49.3	49.5	-	894.5
			Range	-	3.3-25.4	25.4-77.9	9.1-81.9	-	842.1-932.1
July 21, 1969	<u>Uria aalge</u> (ad)	40	Average	-	3.8	40.5	36.8	-	918.9
			Range	-	2.6-21.4	18.2-91.4	16-73.4	-	873.9-953.5
July 25, 1969	<u>Uria aalge</u> (ch)	12	Average	0.9	26.9	86	25.4	-	860.8
			Range	4.9-6.0	4.7-111.8	33.3-203.4	5.4-51.9	-	711.8-938.9
July 9, 1970	<u>Uria aalge</u> (ch)	17	Average	0.3	42.3	88.3	49.9	0.7	818.5
			Range	0.3	10.2-121.2	51.3-149	13.7-102.9	4.5-6.5	727.2-907.7
July 3, 1969	<u>F. arctica</u> (ad)	36	Average	-	5.5	45.6	26.7	0.2	922
			Range	-	4.1-20.6	17.7-76.0	4.1-49.3	4.1	873.2-965.2
July 19, 1970	<u>F. arctica</u> (ad)	30	Average	-	8.8	54.3	29.4	0.1	907.4
			Range	-	2.9-30.0	23.7-82.6	7.6-57.5	3.8	862 -952.6
July 8, 1970	<u>F. arctica</u> (ch)	5	Average	1.5	14.6	98.2	71.5	-	814.2
			Range	7.6	4.4-45.8	45.2-152.7	38.7-99.2	-	702.3-916.1
July 11, 1970	<u>F. arctica</u> (ch)	3	Average	-	3.8	42.8	37.3	-	916.1
			Range	-	-	15.4-93.2	19.2-80.7	-	826.1-1000
July 19, 1970	<u>F. arctica</u> (ch)	14	Average	0.4	1.9	42	41.3	0.7	913.7
			Range	0.1	-	10.3-89.5	15.4-75.2	4.7-4.8	842.1-974.3

and Jamroz (1961) state that these cells are not normally found, even in the circulating blood of very young birds, but when they are found in such low numbers they do not indicate an abnormal condition.

Early Polychromatic Erythrocytes (Tables 3 - 6)

These are generally round or irregular in shape ranging from 9 - 21 μ in length with a dark-blue cytoplasmic stain. The cytoplasm is vacuolated, and does not have the homogeneity of the typical mature erythrocyte. The nucleus is round, highly vacuolated and the chromatin shows definite clumping.

The cells of the early polychromatic erythrocytes averaged 12.6 μ (range: 9 - 21 μ) in length and 8.2 μ (range: 6 - 14 μ) in width while the nucleus measured 8.2 μ (range: 5 - 10 μ) in length and 4.8 μ (range: 3 - 7 μ) in width.

Cells of this second stage of the erythrocyte series were frequently encountered in Common Murre chicks (26.9‰ (4.7 - 111.8) in 1969; 42.3‰ (10.2 - 121.2) in 1970) with a mean value of 38 while Puffin chicks had a mean value of 6.8‰. It is presumed that, with increasing age the number of cells of the early series would continually decline, as was found in chickens by Hoshino and Toryu (1960).

Values for early polychromatic erythrocytes for adult Common Murres ranged from 2.6 - 25.4‰ with a mean of 5.3‰ while the range for the Puffin adults was 2.9 - 30‰ with a mean of 7.2‰ (Table 8).

Mid-Polychromatic Erythrocytes (Fig. 10B1, Tables 3-6)

This cell is elongate, with rounded ends and ranged in length from 12 - 16 μ . The cytoplasm shows a staining character that ranges from very lightly basophilic to slightly eosinophilic, the dominant colouration being grey. The nucleus was rather elliptical and has a coarse chromatin pattern.

Mid-polychromatic erythrocytes measured, on average, 14.5 μ (range: 12 - 16 μ) in length and 8.1 μ (range: 6 - 10 μ) in width. The cells are longer than the early-polychromatic erythrocytes but approximately the same width. However, the upper range of the length of the early-polychromatic erythrocytes is higher than that of the mid-polychromatic erythrocytes. The mean nuclear length and width was 7.1 μ (range: 6 - 8 μ) and 4.1 μ (range: 3 - 6 μ) respectively. The nuclei of these cells are smaller than those of the preceding stage and this may be due to chromatin clumping.

Table 9. Showing the areas (μ^2) of cytoplasm and nucleus and the ratio of cytoplasm to nucleus for the various stages of the erythrocyte series for three species of aluids.

Table 9. Areas of cells in the erythrocyte series for three species of alcids.

Bird Species	Cell	Area (μ^2)		Ratio of Cyto. to Nucleus
	Type	Cytoplasm	Nucleus	
<u>Uria aalge</u>	E	77.3	28.73	2.69
	M	88.76	22.23	3.99
	L	98.84	22.62	4.37
	ME	105.10	17.05	6.16
<u>Uria lomvia</u>	E	96.75	29.70	3.26
	M	94.71	23.1	4.10
	L	109.40	21.37	5.12
	ME	105.79	15.56	6.80
<u>Fratercula arctica</u>	E	79.73	30.80	2.59
	M	97.30	22.23	4.38
	L	100.01	21.45	4.66
	ME	109.79	16.50	6.65

Data on red cell ratios (Table 8) for Common Murre chicks and Puffin chicks resulted in respective mean values of 87.4‰ (range: 33.3 - 203.4‰) and 61‰ (range: 10.3 - 152.7‰). The mean value for Common Murres adults was 44.7 (range: 18.2 - 77.9‰) while that for the Puffin adult was 50‰ (range: 17.7 - 82.6‰).

Late-Polychromatic Erythrocytes (Fig. 10B2, Tables 3-6)

This cell is round to slightly oval ranging from 10 - 17 μ in length. The cytoplasm is more homogeneous at this stage and stains from light grey to pale orange. The nucleus is oval and there is an irregular pattern of chromatin clumping.

The cells averaged 15 μ in length (range: 10 - 17 μ) and 8.6 μ (range: 8 - 18 μ) in width. The cell is larger in size than any of the preceding stages. The mean nuclear length and width was 7.3 μ (range: 5 - 9 μ) and 4.1 μ (range: 3 - 6 μ) respectively and has approximately the same dimensions as the mid-polychromatic erythrocytes but is smaller than the nucleus of the early-polychromatic erythrocytes.

These cells were found in the highest numbers in Common Murre adults and Puffin chicks (Table 8) which averaged 42.8 cells‰ and 50.0 cells‰ respectively. 28.1 cells‰ were found in smears from 66 Puffin adults and 39.7 cells‰.

in smears from 29 Common Murre chicks. The values obtained for the adult Common Murres were higher than those for the chicks but the Puffin chicks had a value which was almost that found for the adults. The Murre adults and chicks showed very similar values.

Mature Erythrocytes (Fig. 10D3, Tables 3 - 6)

These cells are oval in shape and range from 13 - 20 μ in length. The cytoplasm has a uniform texture and stains reddish-orange. The nucleus is elongated and oval with rounded ends. Chromatin clumps are still seen in the younger cells but the older erythrocytes have a dense, homogeneous, nearly structureless nucleus.

The mature erythrocytes measured 15.6 μ (range: 13 - 20 μ) in length and 8.9 μ (range: 7 - 10 μ) in width with the nucleus being 7 μ (range: 5 - 9 μ) in length and 3 μ (range: 2 - 4 μ) in width. These cells are the largest of the erythrocyte series, but the nucleus was smaller than in any other stage. This appears to be due to further chromatin clumping.

In all birds examined, there was a very wide range in the number of mature erythrocytes found per thousand cells (702.3 - 1000%). Common Murre chicks averaged

836.0 cells ‰ (Table 8) with one chick having all mature cells in the areas sampled, while the Puffin chicks averaged 881.3 cells‰. Common Murre adults and Puffin adults, on the other hand contained 907.3 and 914.7‰ respectively. In the chicks of both species, there was a tendency for the number of mature erythrocytes to increase with increasing age, whereas the values for the adults within a particular species remained relatively constant over a period of time.

Erythroplastids (Fig. 10D1, Tables 3 - 6)

These cells are non-nucleated erythrocytes, which have a cytoplasmic colouration similar to that found in the mature erythrocytes. They are large cells, but have a very irregular outline. They showed a variation in length from 10 - 20 μ and averaged 12.6 μ , the width varying from 6 - 10 μ and averaging 8.4 μ .

These cells were seen infrequently in the smears. They were not observed at all in the Common Murre adults and only averaged 0.2 cells‰ in the Puffin adults. In the Common Murre and Puffin chicks the values averaged 0.4‰ and 0.2‰ respectively.

An attempt was made to determine if there was any decrease in the size of the nuclei of the various stages of

the definitive erythrocyte series because of clumping of the chromatin material. The areas of the cytoplasm and the nucleus were first measured assuming they were elliptical in shape and the ratio of the cytoplasmic area to the nuclear area determined (Table 9). The results show that the area of the cytoplasm increases with advancing erythrocyte maturity but that there is also a decrease in the nuclear area of the erythrocyte. The decrease in nuclear area is due to a progressive decrease in the width of the nucleus of the early-, mid- and late-polychromatic erythrocytes and mature erythrocytes respectively. The cytoplasmic area increases more than the nuclear area decreases and results in an increasing cytoplasmic/nuclear ratio. The exception in the present study was the Razorbill where the nuclear area first increased and then decreased. The cytoplasm/nucleus ratios for the Razorbill were: early: 3.13; mid: 3.79; late: 3.94; mature: 6.51.

Nikitenko (1965) found that the measurements of the mature erythrocytes varied from 12 - 15.6 μ in length in the five species of alcids (Table 10) which he examined, three species of which, U. lomvia, C. grylle, and F. arctica averaged under 15 μ in length. The Puffin contained the smallest erythrocytes, averaging 12 μ in length, which

Table 10. Comparison of the average length and width of mature erythrocytes of alcids as reported by Nikitenko (1965) and in the present study.

Table 10. Size of erythrocytes in present study compared with those of Nikitenko (1965).

Bird Species	Average Erythrocyte Measurements (μ)			
	Length (av.) [†]	Width (av.) [†]	Length (av.) [*]	Width (av.) [*]
<u>Alca torda</u>	15.6	9.1	15.8	8.9
<u>Uria aalge</u>	15.3	9.2	15.2	8.8
<u>Uria lomvia</u>	14.3	8.4	15.3	9.1
<u>Cepphus grylle</u>	14.7	9.1	-	-
<u>Fratercula arctica</u>	12	7	15.9	8.9

† Nikitenko (1965)
* Present study.

compare in size with the erythrocyte lengths of some anatids, for example, Anas rubripes (12.5 μ) and Anas boschas (12.3 μ) (Bennett and Chisholm, 1964). The width of these cells varied from 7 - 9.2 μ , the smallest being that of the Puffin. In the present study, the cells of the four species of alcids examined showed a close similarity in measurements, varying in length from 15.2 - 15.9 μ and in width, from 8.8 - 9.1 μ .

Differential White Cell Count

Lucas and Jamroz (1961) recognized seven types of white cells in the blood of birds, including small and large lymphocytes, monocytes, basophils, eosinophils, heterophils and thrombocytes. Differential counts were recorded from smears made on various days during 1969 and 1970 (Table 11) for 372 alcids of 5 species (Appendix IV, Tables 1 - 4). Little difference was noted in the mean values of any of the species examined (Table 12), but wide ranges of values were recorded for individual birds. Table 13 shows the percentage of birds in which each cell type was found. The percentages of white cell types found in U. aalge and F. arctica adults and chicks in various percentage classes are found in Figures 12 - 23.

Small Lymphocytes (Appendix IV, Tables 1 - 4;
Table 12)

Values ranged from 0-88% with an overall mean of 38% if all the species are considered together. There was only a slight difference between the averages for Uria aalge and Fratercula arctica adults and chicks and averages for Uria aalge chicks and Fratercula arctica chicks show a close relationship. Alca torda had a mean value of 24% small lymphocytes while Uria lomvia contained 59% small lymphocytes. However, due to the wide range of values and the small sample size, the results cannot be considered statistically significant.

The median point for the Common Murre and Puffin adults showed varying values, that for the Puffin being 46 - 50% while that for the Murre was in the 26 - 30% group. The chicks showed only slight variation. The first quartile did not show much variation, the values for the adults of Common Murres and Puffins being within two percentage groups, while the values for the chicks were similar (Figs. 12 & 14). This was also the case for the third quartile. The first quartile for both Common Murre and Puffin chicks was in the 26 - 30% group, while the third quartile for these birds was in the 51 - 55% group.

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- Table 11. Numbers and species of alcids (adults and chicks) examined during 1969 and 1970.
- Table 12. Average values of cell types found in differential white blood cell counts of 5 species of alcids in 1969 and 1970.
- Table 13. Percentage frequency of occurrence of various white blood cells in differential counts of 5 species of alcids.

Table 11. Number and species of alcids examined.

Species	1969			1970		
	Date	No Adults	No Chicks	Date	No Adults	No Chicks
<u>Alca torda</u>	-	-	-	June 15	1	-
				June 29	1	-
				July 9	-	4
				July 15	-	4
	Total				2	8
<u>Uria aalge</u>	July 8	37	18	June 24	20	-
	July 25	42	14	June 24	4	-
				July 9	24	19
				July 16	2	-
				July 24	-	5
				July 26	-	2
				July 31	-	2
	Total		79	32		50
<u>Uria lomvia</u>	July	8	-	-	-	-
<u>Cephus grylle</u>	All year	6	-	-	-	-
<u>Fratercula arctica</u>	July 2	-	2	June 19	15	-
	July 3	23	-	July 8	-	5
	July 7	5	-	July 10	-	1
	July 14	14	-	July 11	11	2
	July 18	37	-	July 14	4	-
	July 21	-	5	July 19	7	-
	July 26	-	1	July 21	-	3
	July 27	-	3	July 31	-	1
	July 28	-	4	Aug. 4	-	2
				Aug. 7	-	7
				Aug. 18	7	-
Total		79	15		44	21

Table 12. Average values for differential counts in 5 species of alcids.

Species & Age	Year	Cell Types (%)								
		S.L.	L.L.	T.L.	M.	B.	E.	H.	E + H	Und.
<u>A. torda</u> ad. [†]	1969	32	11	43	9	1	12	34	46	0
	1970	16	22	38	1	0	9	41	49	12
	Acc.	24	17	41	5	0	11	37	48	6
<u>A. torda</u> ch.*	1970	31	18	49	3	0	12	34	46	2
<u>U. aalge</u> ad.	1969	32	23	55	6	7	11	21	32	0
	1970	32	18	50	2	2	31	13	44	2
	Acc.	32	21	53	4	5	18	18	37	1
<u>U. aalge</u> ch.	1969	50	1	51	2	3	33	9	42	2
	1970	25	24	49	2	1	27	19	46	2
	Acc.	38	12	50	2	2	30	14	44	2
<u>U. lomvia</u> ad.	1969	59	2	61	4	2	8	25	33	0
<u>C. grylle</u> ad.	1969	31	1	32	3	2	59	4	63	0
<u>F. arctica</u> ad.	1969	52	9	61	2	1	16	20	36	0
	1970	39	18	57	2	0	14	26	40	1
	Acc.	47	12	59	3	1	15	22	37	0
<u>F. arctica</u> ch.	1969	46	19	65	1	0	18	12	30	4
	1970	38	23	61	3	0	11	24	34	2
	Acc.	42	21	63	2	0	14	19	33	2
All species	Acc.	38	13	51	3	2	21	22	43	1

† ad. = adult
* ch. = chick

Table 13. Percentage frequency of white cell types in five species of alcids.

Cell Type	Percentage Frequency of Cell Types							
	Razorbill		Common Murre		Thick-Billed Murre	Black Guillemot	Puffin	
	Adult (2)†	Chick (8)	Adult (125)	Chick (60)	Adult (8)	Adult (6)	Adult (123)	Chick (36)
Small Lymphocyte	100 (2)*	100 (8)	100 (125)	98.3 (59)	100 (8)	100 (6)	100 (123)	100 (36)
Large Lymphocyte	100 (2)	100 (8)	97.6 (122)	61.7 (37)	75 (6)	33.3 (2)	84.6 (104)	100 (36)
Small + Large Lymphocytes	100 (2)	100 (8)	100 (125)	100 (60)	100 (8)	100 (6)	100 (123)	100 (36)
Monocytes	100 (2)	75 (6)	87.2 (109)	56.7 (34)	100 (8)	88.3 (5)	71.6 (88)	63.9 (23)
Basophils	50 (1)	25 (2)	88 (110)	63.3 (38)	62.5 (5)	66.7 (4)	27.6 (34)	11.1 (4)
Eosinophils	100 (2)	87.5 (7)	96 (120)	100 (60)	100 (8)	100 (6)	94.3 (116)	94.4 (34)
Heterophils	100 (2)	100 (8)	95.2 (119)	88.3 (53)	100 (8)	100 (8)	98.4 (121)	94.4 (34)
Eosinophils + Heterophils	100 (2)	100 (8)	100 (125)	100 (60)	100 (8)	100 (6)	100 (123)	100 (36)
Undifferentiated	50 (1)	75 (6)	23.2 (29)	58.3 (35)	0 (0)	0 (0)	17.1 (21)	66.7 (24)

† No. birds examined.

* No. in parentheses indicates
No birds in which cells are found.

Statistically significant differences were noted between the means of Common Murre adults and Puffin adults ($p < .001$) while differences in means for Common Murre chicks and Puffin chicks and for Puffin adults and Puffin chicks were significant ($p < .01$ and $p < .05$ respectively). The differences in means of Common Murre adults and chicks were not significant.

Large Lymphocytes (Appendix IV, Tables 1 - 4;
Table 12)

These cells were less frequently encountered than the small lymphocytes and range from 0 - 50% of the total white cells with a mean of 13% (Table 12). Mean values of 24% and 23% were recorded for Common Murre chicks and Puffin chicks respectively. Lowest values obtained in the daily data were recorded for Puffin adults (9%), Common Murre chicks (1%) and the Black Guillemot (1%). The mean percentage of large lymphocytes for Common Murre adults and Puffin chicks was 21% while that for Common Murre chicks and Puffin adults was 12%. The two species of murre showed very dissimilar patterns, the mean value for U. lomvia being 2%. Large lymphocytes were seen in only 33.3% of the Black Guillemots examined.

The median and first quartile of the Common Murre chicks focussed in the 0 - 5% group, indicating a left skew, the third quartile was in the 21 - 25% group. In the adult Common Murres, the median was in the 11 - 15% group, the first quartile; the 0 - 5% group, with the third quartile at 26 - 30%. The Puffin adults and chicks showed a variation in medians, the adults being in the 6 - 10% group and the chicks at 21 - 25% group. The first quartile for the Puffin adults fell at 0 - 5% and the chicks at 11 - 15%. The third quartiles were in the 16 - 20% and 26 - 30% groups for adults and chicks respectively.

Mean values were all statistically significantly different ($p < .001$) for Common Murre adults, Puffin adults; Common Murre chicks, Puffin chicks; Common Murre adults, Common Murre chicks; Puffin adults and Puffin chicks.

Total Lymphocytes (Appendix IV, Tables 1 - 4;
Table 12)

The percentage values of these cells ranged from 12 to 89% in all species with a mean of 51%. They represent the most common white cell element in the blood. The values for the lymphocytes of Common Murre adults and chicks (53% and 50% respectively) were very similar as they were for the Puffin adults and chicks (59% and 63% respectively).

The Black Guillemots (32%) and Razorbill adults (41%) had lower values but the Razorbill chicks had a value (49%) similar to that for the Common Murre chicks. U. lomvia averaged 61% total lymphocytes.

The median point differs only slightly in the Common Murre adult (51 - 55% group) and Puffin adults (56 - 60%) while in the Common Murre chicks and Puffin chicks the medians fell in the 46 - 50% and 61 - 65% groups respectively. In Common Murre adults and chicks the first quartile was in the 41 - 45% group, but in the adult the third quartile fell at 61 - 65% and that of the chicks at 56 - 60%. In Puffin adults and chicks the third quartile was in the same group (71 - 75%).

The differences in mean values between Common Murre and Puffin adults and between Common Murre and Puffin chicks were statistically significantly different ($p < .001$) there being no statistically significant difference between Common Murre adults and Common Murre chicks and between Puffin adults and chicks.

Monocytes (Appendix IV, Tables 1 - 4; Table 12)

The values obtained for monocytes in differential counts ranged from 0 - 19% with a mean of 3% and in all species examined, the mean ranged from 0 - 5%. For some

unexplained reason, many of the Common Murres gathered on July 25, 1969 contained unusually high numbers of monocytes (one specimen, 11.5%). They were found in 87.2% of the Common Murre adults but, only 56.7% of the chicks and in 100% of the Black Guillemots.

In all cases, the median, the first and third quartiles fell within the 0 - 5% percentage class.

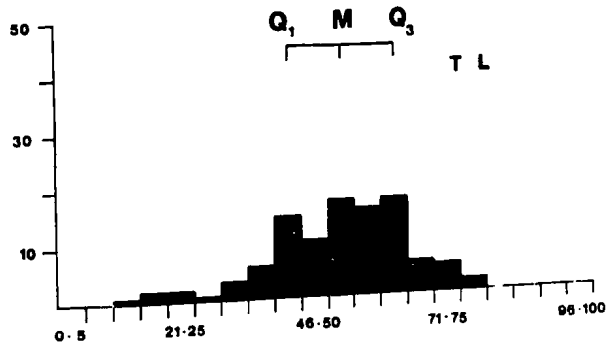
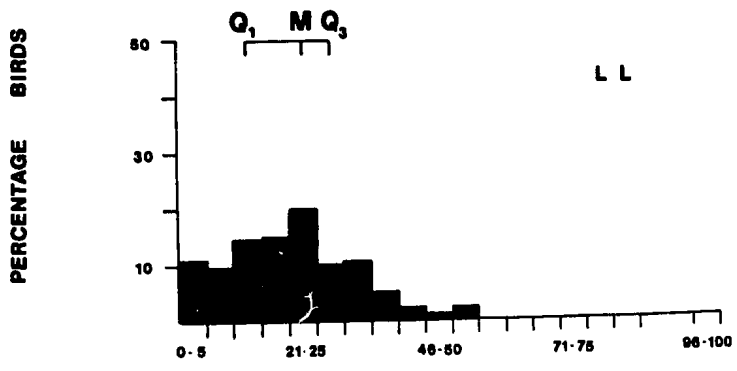
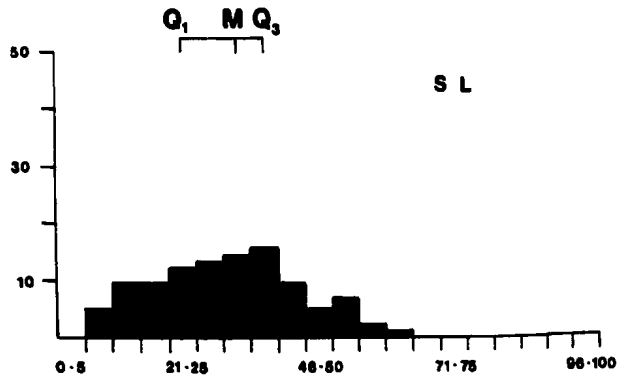
The means were significantly different ($p < .001$) between Common Murre adults and chicks and between Common Murre adults and Puffin adults. Differences in mean values for Puffin adults and chicks were statistically significantly different ($p < .02$).

Basophils

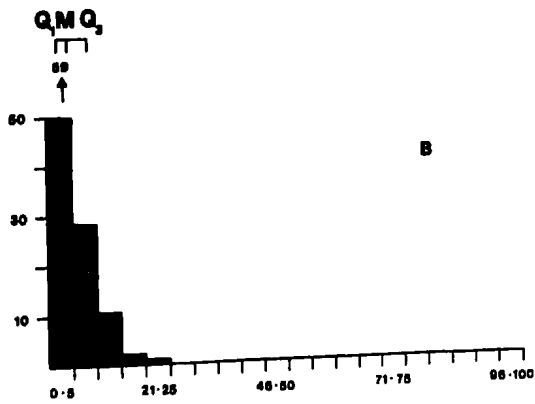
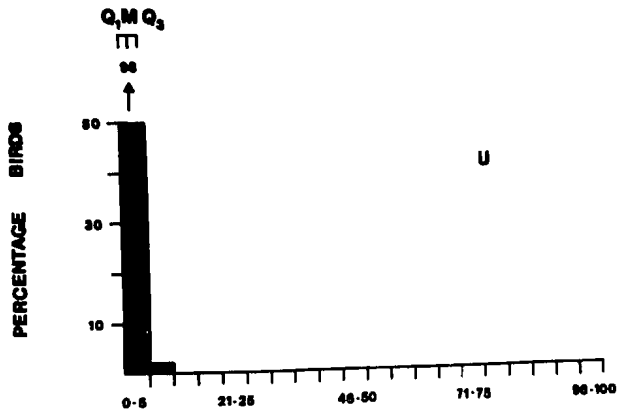
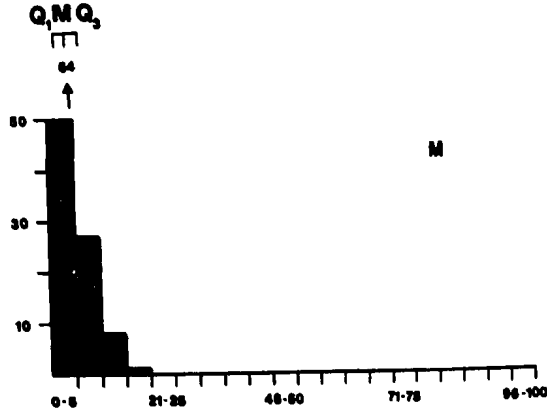
These cells ranged from 0 - 25% of the total leucocyte count with an overall mean of 2%. Few basophils were found in Puffin chicks while some Common Murre adults had values ranging as high as 25%. The range of values for basophils was much lower in the Common Murre chicks than in the adults (2% and 5% respectively). Basophils were found in 63.3% of the Common Murre chicks and 88% of the Common Murre adults. In Puffins, however, they were found in 11.1% of the chicks and 27.6% of the adults. Values similar to those in the

Fig. 11. Histograms showing the percentage of various leucocytes in the blood of Uria aalge adults, obtained from differential counts.

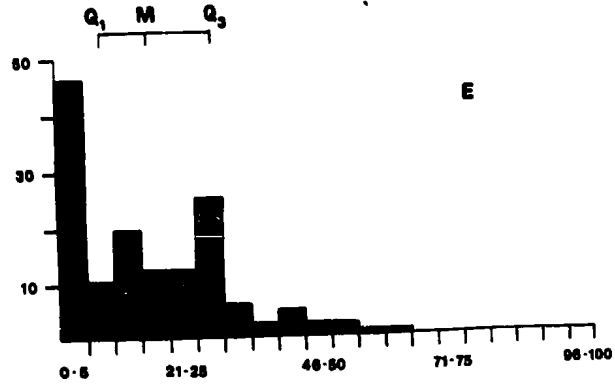
S.L. = small lymphocytes
L.L. = large lymphocytes
T.L. = total lymphocytes
M. = monocytes
U. = undifferentiated
B. = basophils
E. = eosinophils
H. = heterophils
E+H = eosinophils and heterophils



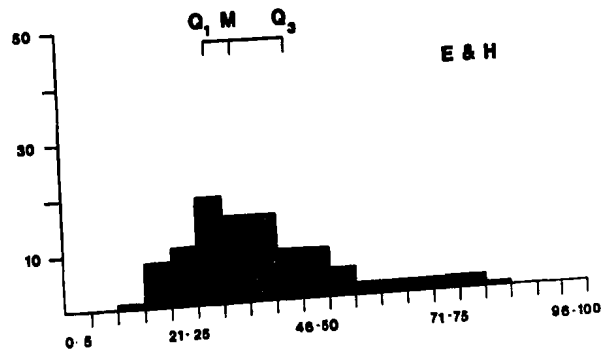
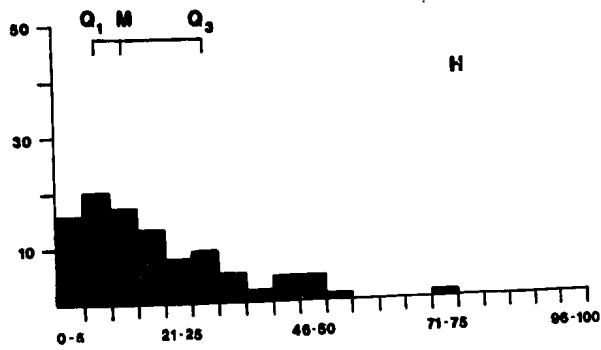
PERCENTAGE CLASSES



PERCENTAGE CLASSES



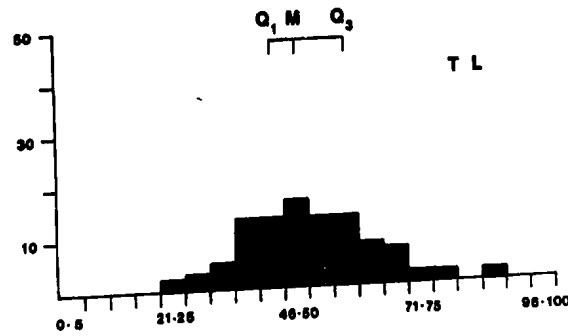
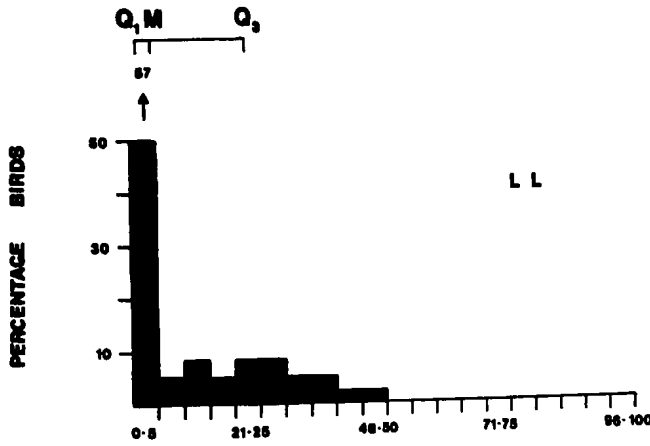
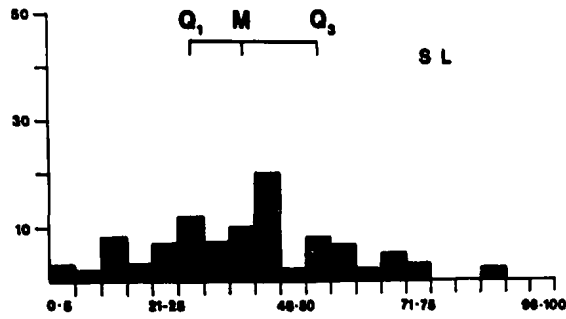
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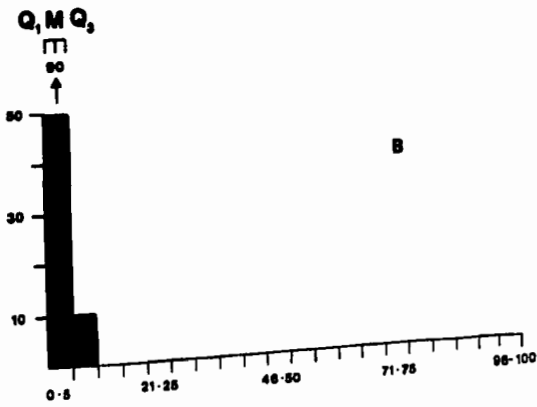
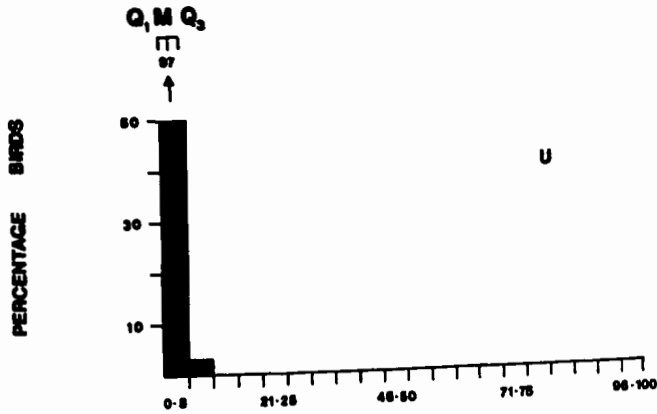
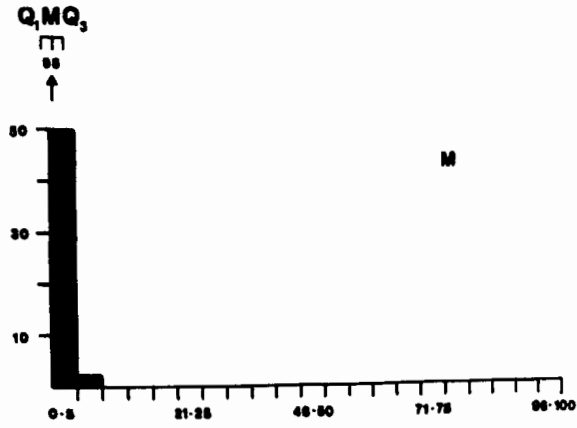
PERCENTAGE CLASSES

Fig. 12. Histograms showing the percentage of various leucocytes in the blood of Uria aalge chicks, obtained from differential counts.

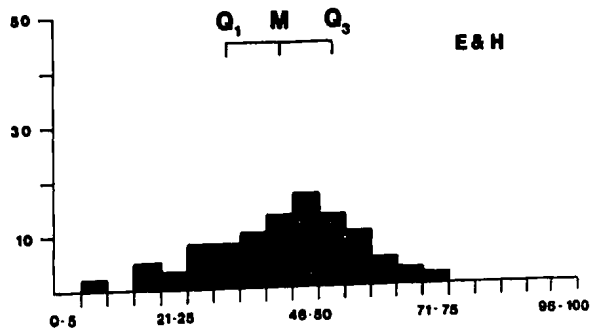
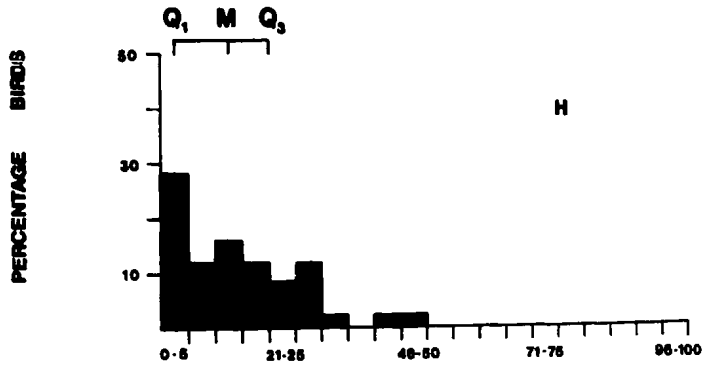
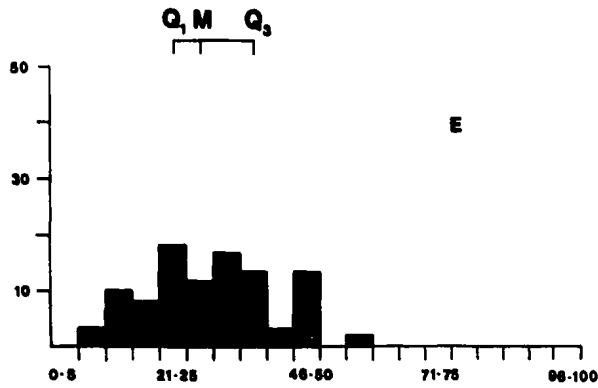
- S.L. = small lymphocytes
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- M. = monocytes
- U. = undifferentiated
- B. = basophils
- E. = eosinophils
- H. = heterophils
- E+H = eosinophils and heterophils



PERCENTAGE CLASSES



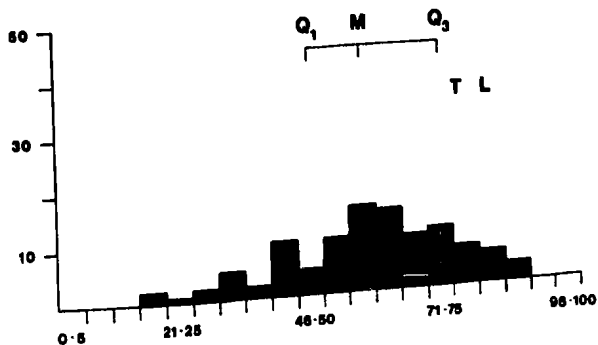
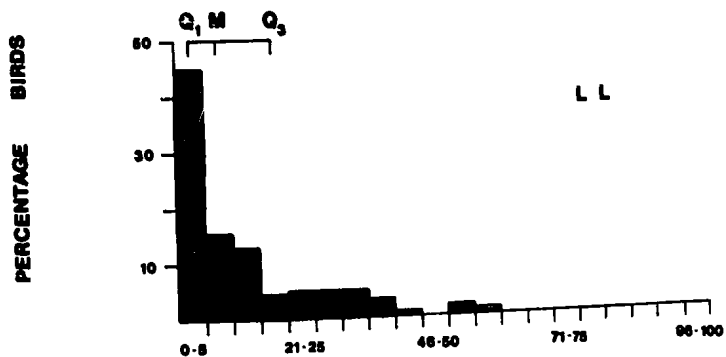
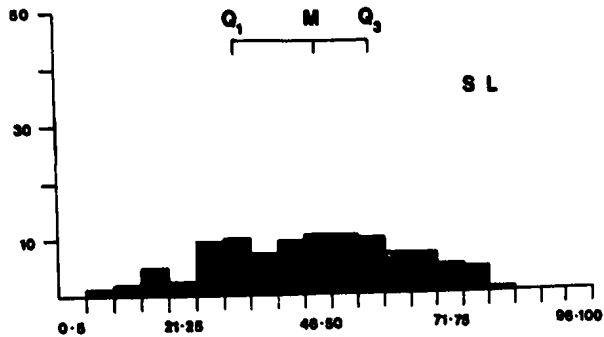
PERCENTAGE CLASSES



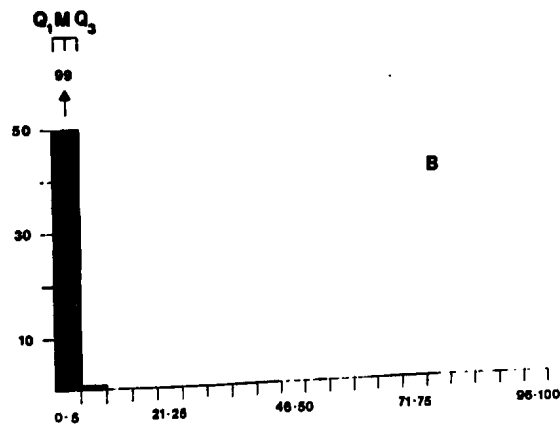
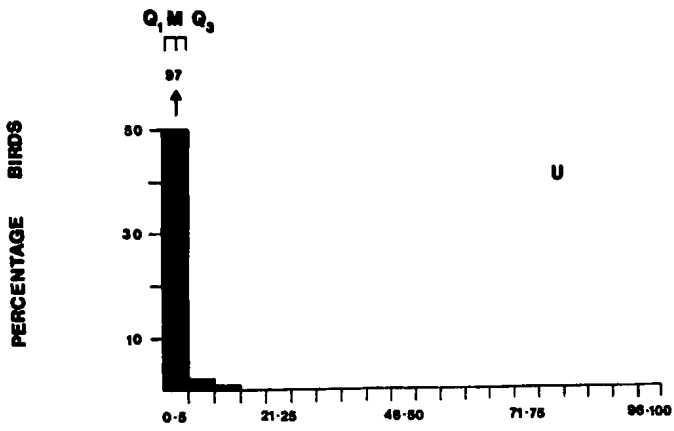
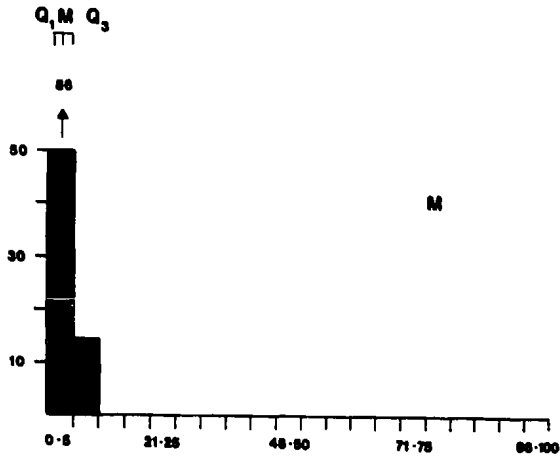
PERCENTAGE CLASSES

Fig. 13. Histograms showing the percentage of various leucocytes in the blood of Fratercula arctica adults, obtained from differential counts.

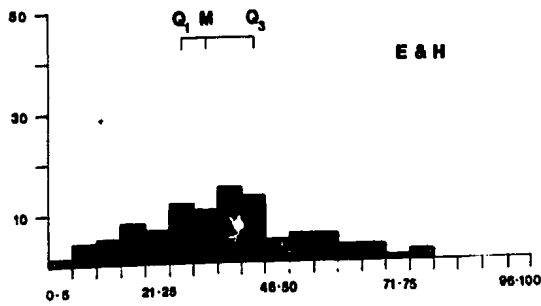
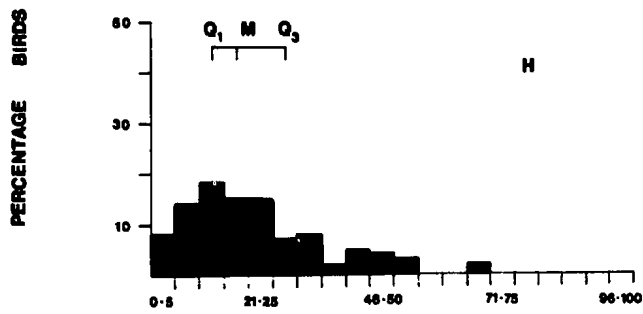
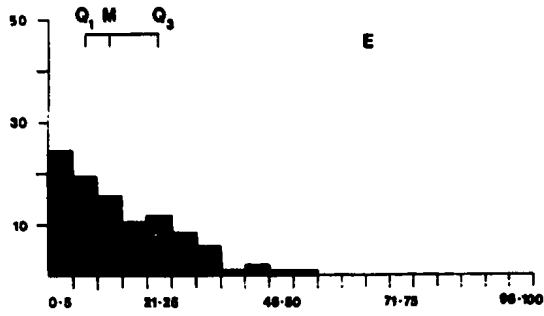
S.L. = small lymphocytes
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E. = eosinophils
H. = heterophils
E+H = eosinophils and heterophils



PERCENTAGE CLASSES



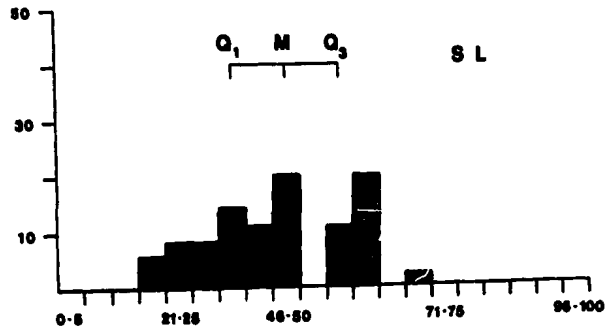
PERCENTAGE CLASSES



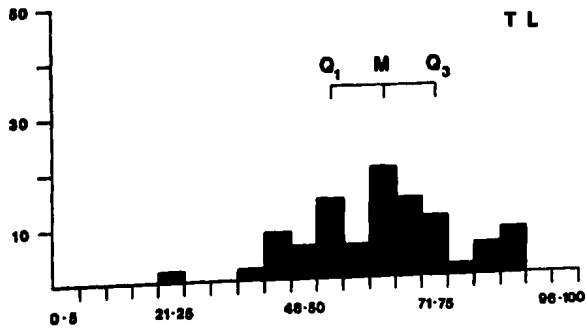
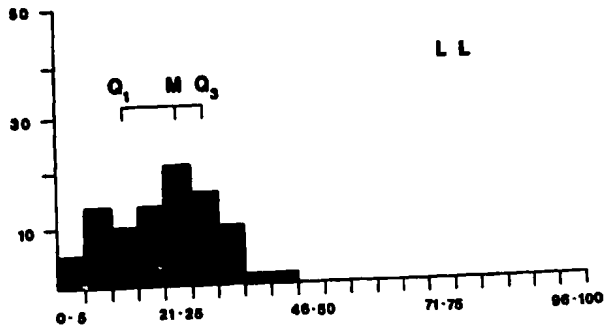
PERCENTAGE CLASSES

Fig. 14. Histograms showing the percentage of various leucocytes in the blood of Fratercula arctica chicks, obtained from differential counts.

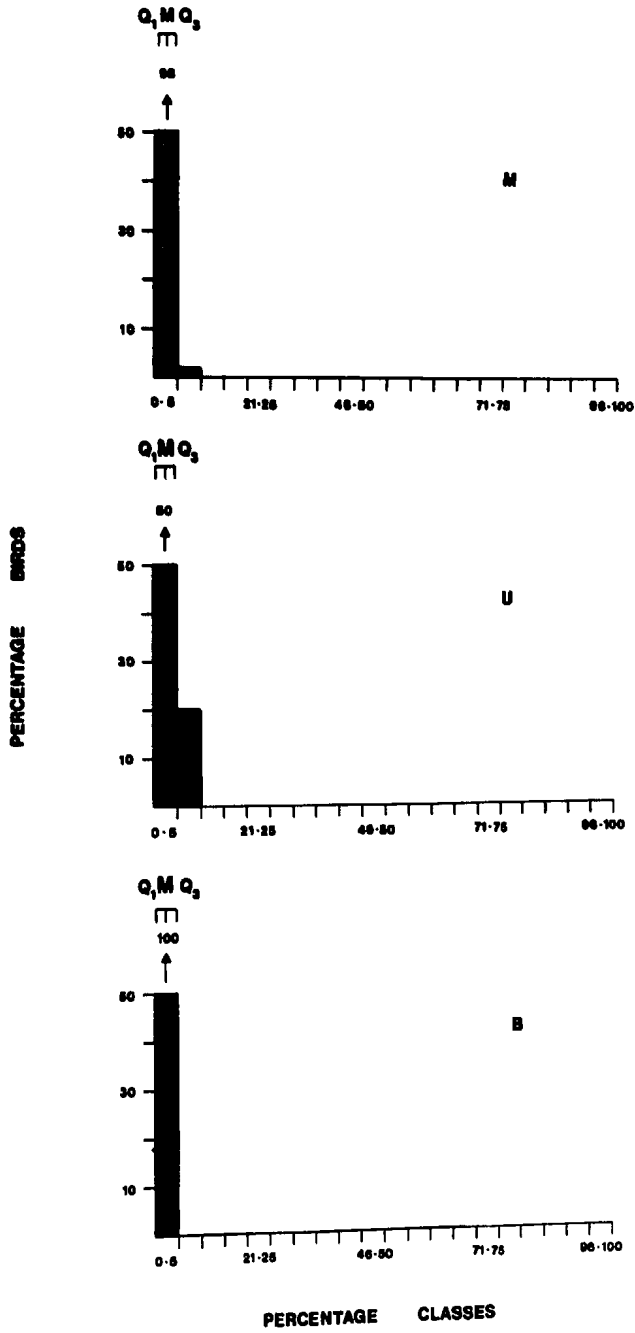
S.L. = small lymphocytes
L.L. = large lymphocytes
T.L. = total lymphocytes
M. = monocytes
U. = undifferentiated
B. = basophils
E. = eosinophils
H. = heterophils
E+H = eosinophils and heterophils

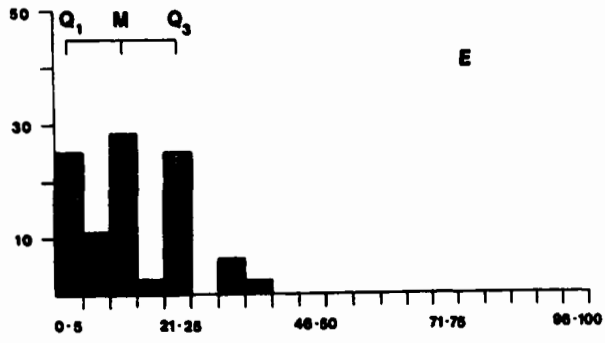


PERCENTAGE BIRDS

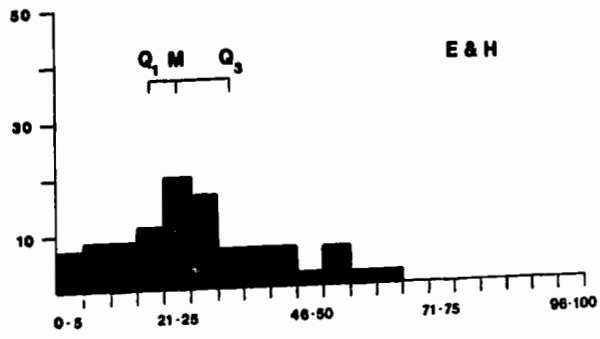
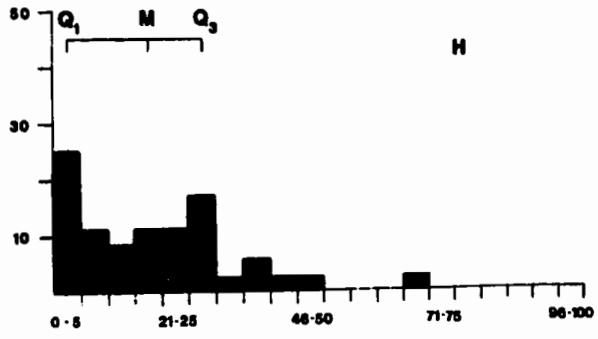


PERCENTAGE CLASSES





PERCENTAGE BIRDS



PERCENTAGE CLASSES

Common Murre chicks are found in adult Guillemots and Thick-billed Murres. Basophils were recorded from 50% of the adults and 25% of the Razorbill chicks.

In all Common Murres and Puffins, with the exception of the median and third quartile of the Common Murre adults in 1969, the median, first and third quartiles lay within the 0 - 5% group. All Puffin adults and chicks had a range of basophil values from 0 - 5%.

Basophil levels were significantly different between Common Murre and Common Puffin adults ($p < .001$); Common Murre and Common Puffin chicks ($p < .001$); Common Murre adults and chicks ($p < .001$) and Puffin adults and chicks ($p < .02$).

Eosinophils (Appendix IV, Tables 1 - 4; Table 12)

These cells range from 0 - 79% of the white blood cell count with an overall mean of 21%. Values were highest in the Black Guillemot, where 59% of all the leucocytes seen were eosinophils. The mean values found for Puffin adults and chicks (15% and 14% respectively) were similar to those found in Razorbill adults (11%), Razorbill chicks (12%) and Common Murre adults (18%).

The median values for Common Murre adults and chicks were in the 16 - 20% and 26 - 30% intervals respectively while those for Puffin adults and chicks were the same, being in the 11 - 15% category. First quartile values for Common Murre adults and Puffin adults were in the 6 - 10% group, while those for Common Murre chicks and Puffin chicks were in the 21 - 25% and 0 - 5% group respectively. Third quartile values were in the 26 - 30% and 36 - 40% groups respectively, while those for Puffin adults and chicks were the same, being in the 21 - 25% group.

Mean values for eosinophils were statistically significantly different between Common Murre adults and chicks ($p < .001$) as were the values for Common Murre and Puffin chicks ($p < .001$) and Common Murre and Puffin adults ($p < .02$).

Heterophils (Appendix IV, Tables 1 - 4; Table 12)

The values for this cell type vary from 0 - 70% with an overall mean of 22%, those for U. aalge and F. arctica chicks being approximately the same (44% and 33%, respectively) while the mean values for the adults of these species were the same (37%). The values for A. torda were slightly higher (48%). Least values were found in the Black Guillemot where a mean of 9% was noted.

The median values for Puffin adults and chicks were in the 16 - 20% category while that for the Common Murre adults and chicks was in the 11 - 15% interval. The third quartile for both species of adult birds was in the 26 - 30% class, but for the Common Murre chicks and Puffin chicks, it was in the 11 - 15% and 16 - 20% intervals respectively.

Means for Common Murre and Puffin adults were statistically significantly different ($p < .01$); those for Common Murre and Puffin chicks also being significantly different ($p < .05$).

Eosinophils and Heterophils (combined) (Appendix IV,
Tables 1 - 4; Table 12)

The values for these cells range from 3 - 88% with an overall mean of 43% considering the alcids examined as a composite group. Values are relatively consistent, Razorbill adults and chicks having 48% and 46% respectively, while little difference is found between Common Murre adults and chicks (37% and 44%) and between Puffin adults and chicks (37% and 33%). Highest values were found in the Black Guillemot (mean: 63%).

The values for the median, first quartile and third quartile for Puffin and Common Murre adults were the same

being in the 31 - 35%, 26 - 30% and 41 - 45% classes, respectively. The median, first and third quartile values for Common Murre and Puffin chicks were quite different; the median being in the 41 - 45% and 21 - 25% class. The first quartiles fell in the 31 - 35% and 16 - 20% intervals with the third quartiles in the 51 - 55% and 31 - 35% intervals respectively.

Eosinophil and heterophil values (combined) were significantly different between Common Murre and Puffin chicks ($p < .001$) while the difference in the mean between Common Murre adults and chicks was also statistically significant ($p < .01$).

Undifferentiated Cells (Appendix IV, Tables 1 - 4;
Table 12)

Values in differential counts ranged from 0 - 17% with an overall mean of 1%. These cells, found only infrequently in the circulating blood of adult birds, were seen most often in chick blood (Table 12). The highest mean value (12%) was found in Razorbill adults in 1969.

The values for the median, the first and third quartiles fell in the 0 - 5% group for all species and all ages of birds examined (Figs. 11-14).

The difference in the means of Puffin adults and chicks was statistically significant ($p < .001$) as was that for Common Murre adults and chicks ($p < .01$). No significant difference was noted between the means for Common Murre and Puffin adults and for Common Murre chicks and Puffin chicks.

Since differences in the blood picture associated with the breeding cycle occur in chickens, an attempt was made to show if any similar fluctuations occurred in the differential white blood cell counts of alcids and, if so, could they be correlated with the stresses of breeding. No extensive data is available for actual times of laying and hatching but generalizations can be made. The figures represent the mean values for the cell type found on that days sampling.

Common Murre (Uria aalge)

Murre eggs were noted in early May, 1969 and by June 13, 1969 approximately one-third of them had hatched. The period of incubation is approximately four weeks (Tuck, 1960; Bent, 1963). By late July or early August many of the chicks had already fledged. On July 8, 1969 the Common Murre adult lymphocyte counts were low (28%) and the percentage of heterophils rather high (37%). Most of the eggs were

hatched at this time and the young were being fed by the adults. By July 25, 1969 the situation had reversed, the lymphocyte value being 35%, that for the heterophils being 27%. No significant changes were observed in either the basophils or undifferentiated cells. At this time the Common Murre adults showed a relative increase in monocytes (from 4% to 8%) and also a rapid increase in eosinophil level (Appendix IV, Tables 1 - 4).

In 1970, approximately one-half of the eggs had hatched by June 16, and, assuming a 5 to 6 week fledging time, then these birds were going to sea by the end of July. June 24 was the first sampling day of 1970. The lymphocyte values were initially high at the beginning of the breeding season but they then declined and stabilized in July. An increase was noted in the heterophils from the beginning to the end of the breeding season. The daily counts of heterophils in adult Murres ranged from 5% (June 24, 1970) to 31% (July 16, 1970). The eosinophils decreased rapidly and the numbers appeared to become stable toward the end of the breeding season. At the beginning of July large numbers of alcids were being taken in the nets of the fishermen in the area, the time when intensive feeding of the young was occurring. Highest values for total lymphocytes in differential white blood cell counts occur on June 24, 1970 (53%) and July 9,

1970 (49%). No significant changes were observed in the percentage values of the monocytes, basophils or undifferentiated cells.

The Common Murre adults brought to the laboratory for examination on June 24, 1970 showed a dissimilar differential white blood cell picture to the birds examined in the field on the same day (Appendix IV, pages 161-165). There was a decrease in small lymphocytes from 45% to 17% and an increase in heterophils from 5% to 28% for the field and laboratory birds respectively and total lymphocytes decreased from 53% to 30% and combined heterophils and eosinophils increased from 41% to 68%. The percentage of eosinophils in the birds examined in the laboratory (40%) increased only slightly from those examined in the field (36%). The percentage decrease in total lymphocyte values and the increase in heterophil values in differential white cell counts were similar to those found by Bhattacharyya and Sarkar (1968) in their studies on the effect of ACTH on various birds. Thus, the values found could be the result of the stresses placed on the birds caused by capturing, transportation and handling.

The total lymphocytes in Common Murre chicks comprised 50% of the differential white blood cell count in 1969 while the value increased from 48% on July 9, 1970 to

65% on July 31, 1970 and stabilized at this level at the end of the breeding season. The total lymphocyte values of murre chicks sampled on July 8, 1969 (51%) and July 9, 1970 (48%) and, on July 25, 1969 (52%) and July 24, 1970 (45%) were similar. Eosinophil values showed a continual decline in 1970 from 29% on July 9, 1970 to 16% on July 31, 1970 and all values were lower than those found in birds sampled in 1969. Only 3% heterophils were found on July 25, 1969, the values remaining constant in 1970 (13 - 18%) with a slight increase to 26% on July 24, 1970. The percentage values for monocytes, basophils and undifferentiated cells remained constant throughout the breeding season.

An attempt was made to correlate the lengths of the culmen, tarsus, wing and tail and the weights of the Common Murre chicks with the percentages of the individual white blood cell types as determined from differential counts. No correlation was noted.

Atlantic Puffin (Fratercula arctica)

Puffin adults incubate their eggs for 25 - 28 days and fledging does not occur until 4 - 5 weeks after hatching (Bent, 1963). In 1969, Puffin eggs were first recorded on May 20, and by June 27 hatching was already occurring on the east side of the island (John Maunder-pers. comm.). The

percentage of small lymphocytes on the adult birds examined in 1969 was relatively constant (Appendix IV, Tables 1 - 4) but there was a decrease to 33% on July 7, while large lymphocytes, which initially had a high value at the beginning of the breeding season (17 - 18%) decreased in numbers toward the end of the breeding season (3% on July 18, 1969). The total lymphocyte values for differential counts were also relatively constant but the values were high (68%) when the birds were first examined on July 3, 1969. Eosinophils increased from 9% to 21% through the 1969 breeding season, with the exception of July 7, 1969, when 36% were found. The percentage of heterophils remained at 18 - 19%. Eosinophils and heterophils, when combined, were found to comprise only 27% of the blood cells on July 3, 1969 and then increased in numbers but the values stabilized by July 17, and July 18, 1969 (38 - 40%). The percentages of monocytes, basophils and undifferentiated cells remained constant throughout the breeding season.

In 1970, hatching was first recorded on June 26. Small lymphocyte values were high on July 19, 1970 (60%) and August 18, 1970 (42%). The values were lower and stable (28 - 37%) until July 19, when the sudden increase occurred. The percentage of large lymphocytes in the differential white blood cell counts were initially stable (22 - 25%) but then began to decline and comprised only 1% of the cells on July 19,

1970. By August 18, the values had commenced to increase again. The total lymphocyte values appeared to decline from the onset of the breeding season. Eosinophil values were high at the beginning and end of the breeding season (16% and 22% respectively). Heterophils increased from 17% on June 19, 1970 to 40% on July 14, 1970 and decreased to 19% on August 18, 1970. The values for combined eosinophils and heterophils also increased toward the middle of the breeding season and then stabilized at a value slightly higher (37 - 41%) than that found at the beginning of the breeding season (19%). Undifferentiated cells were observed and in one specimen comprised 13% of the differential count. Very little fluctuation was observed in the values for monocytes and eosinophils.

Since Puffin chicks were beginning to hatch by July 26 in 1969 and 1970 all samples and smears collected from adult birds before this date are assumed to be from incubating birds. Bent (1963) gives the egg dates for Puffins as being the first week in June for Newfoundland and Labrador, but on Gull Island they are thought to be somewhat later. The earliest record of chicks in burrows in the present study is July 2, 1969. Incubating adults had a high percentage of total lymphocytes, with a corresponding decrease in the percentage of heterophils and eosinophils (Appendix IV, Tables 1 - 4). The percentage of lymphocytes then dropped

and the heterophil and eosinophil values increased. A similar situation occurred in 1970. No data is available on Puffin adults during the hatching period, but on August 8, 1970, the last day for which data is available, there was a decline in the percentage of lymphocytes.

During the incubation period there were signs of stress which correspond to those encountered with ACTH injections (Bhattacharyya and Sarkar, 1968), but toward the end of the breeding season there was a stabilizing of the percentages of lymphocytes and combined eosinophils and heterophils, the lymphocytes having the higher value.

Small lymphocyte values in Fratercula arctica chicks, in 1969, increased from hatching to fledging. The lowest value noted was 39% on July 21, 1969 with a high of 60% on July 27, 1969 (Appendix IV, Tables 1 - 4). From July 2, 1969 to July 21, 1969 there was an increase from 7 to 17% large lymphocytes which then stabilized at 21 to 23%. Total lymphocytes increased to 82% on July 27, 1969 and then declined to 69% on July 28, 1969. According to the measurements, the birds from July 27, were considerably older than those collected on July 28, having longer culmen, tarsus, wing and tail lengths, and this could account for the wide variation in the percentage of total lymphocytes on the two days. Monocyte values were high on July 2 (6%) and they then declined

and stabilized at 1%. Basophils remained constant in the chicks ranging in value from 0 - 2% while the undifferentiated cells varied from 0 - 5% through the fledging period. Eosinophils formed 25% of the differential count on July 21, 1969, declined and became stable at 11 - 16% from July 26, onward. Heterophil values stabilized after an initially high count of 29% on July 2, 1969. Only 1% heterophils were found in Puffin chicks on July 27, there being a corresponding increase in eosinophils and the highest recorded count of lymphocytes (82%). It was during this period that Puffin chicks were beginning to hatch in large numbers.

In 1970, large numbers of Puffin chicks were hatching by July 27. The results obtained for differential counts for July 21, 1970 and August 4, 1970 are very similar. The percentage of small lymphocytes tended to increase in 1970, the highest value being 53% on July 31, with a slight reduction occurring after this period. Total lymphocytes increased from 64% to 83% from July 21 to July 31, 1970. Eosinophils increased from 4 to 21% from July 8 to July 10, decreased in the middle of the breeding season (4%) only to increase to 18% on the last sampling day (August 7, 1970). Heterophil values fluctuated but decreased toward the end of the breeding season (13%). Highest values were recorded early in July (37%). Percentage values for total heterophils

Table 14. Values of differential counts from 17 known age Puffin chicks collected during 1969 and 1970.

Table 15. Mean values of differential counts from known age Puffin chicks in 1969 and 1970.

Table 14. Differential counts from 17 known age Puffin chicks.

Age (Days after hatching)	S.	L.	S+L	M.	B.	E.	H.	E+H	Und.
<u>1969</u>									
12	45	28	73	1	0	19	4	23	3
14	58	8	66	0	0	23	4	27	7
19	18	27	45	3	0	22	27	51	1
20	28	11	39	2	0	24	27	51	8
25	44	10	54	2	0	38	0	38	6
Aver.	39	17	55	2	0	25	12	38	5
<u>1970</u>									
7	29	33	62	4	0	0	42	42	2
8	32	12	44	4	0	12	34	46	6
9	22	24	46	3	0	2	47	49	2
9	36	25	61	5	0	0	26	26	8
10	22	43	65	4	0	21	9	30	1
10	23	39	62	3	0	4	27	31	4
20	40	18	58	6	0	15	21	36	0
22	42	23	65	2	0	6	25	31	2
33	53	30	83	1	0	4	11	15	1
36	34	33	67	4	0	6	22	28	1
36	34	18	52	2	1	21	24	45	0
39	58	10	68	1	0	8	19	27	4
Aver.	35	26	61	3	0	8	26	34	2
Acc. Aver.	36	23	59	3	0	13	22	35	3

Table 15. Mean values of differential counts from known-age Puffin chicks.

Date	Data	S.	L.	S + L	M.	B.	E.	H.	E + H	Und.
1969	Mean	38	17	55	2	0	25	13	38	5
	±S.D.	14.02	8.80	12.66	1.02	0	6.62	12.51	11.70	2.61
	Range	18-58	8-28	39-73	0-3	0	19-38	0-29	23-51	1-8
1970	Mean	35	26	61	3	0	8	26	34	2
	±S.D.	11.01	9.85	10.02	1.48	0.28	7.11	10.68	9.58	2.36
	Range	22-58	10-43	44-83	1-6	0-1	0-21	9-47	15-49	0-8
1969-1970	Mean	36	23	59	3	0	13	22	35	3
	±S.D.	8.25	10.37	11.17	1.55	0.24	10.40	12.61	10.42	2.67
	Range	18-58	8-43	39-83	0-6	0-1	0-38	0-47	15-51	0-8

and eosinophils were inconsistent, ranging from 15 to 53% with the high value (53%) recorded on July 11, 1969.

In 1969, five known age puffin chicks, ranging in age from 12 to 25 days, were obtained, smears being made via heart puncture and, in 1970, 12 chicks from 7 to 39 days of age were examined, but these were bled from the femoral vein. Results of these counts are recorded in Table 14.

Since there are no statistically significant differences in the data collected in two years field studies and since no trends of the percentage of cell types either increasing or decreasing with age is apparent, it might be assumed that there are no changes in the differential white blood cell count with age. However, the sample of known age birds is so small that it is difficult to draw any conclusions. The values for means, standard deviations and the range of values for the differential white cell counts are recorded in Table 15.

An attempt to correlate the percentages of the individual white cell types of the circulating blood with measurements of the culmen, tarsus, wing and tail lengths and the weights of the puffin chicks revealed no statistically significant differences.

Differential counts, recorded in Table 13, for eight Thick-billed Murres (Uria lomvia) were as follows: small lymphocytes, 59% (49 - 67%); large lymphocytes, 2% (0 - 8%); total lymphocytes, 61% (56 - 72%); monocytes 4% (2 - 6%); basophils, 2% (0 - 8%); eosinophils, 8% (2 - 21%); heterophils, 25% (11 - 39%); eosinophils and heterophils, 33% (24 - 42%); undifferentiated, 0% (0%).

Only two adult Razorbills (Alca torda) were examined with the following values being obtained (Table 13): small lymphocytes, 24% (16 - 32%); large lymphocytes, 17% (11 - 22%); total lymphocytes, 41% (38 - 43%); monocytes, 5% (1 - 9%); basophils, 0% (0 - 1%); eosinophils, 11% (9 - 12%); heterophils, 37% (34 - 41%); eosinophils and heterophils, 48% (46 - 49%); undifferentiated, 6% (0 - 12%). Values for 8 Razorbill chicks (Table 13) are: small lymphocytes, 32% (19 - 46%); large lymphocytes, 17% (3 - 31%); total lymphocytes, 49% (29 - 70%); monocytes, 3% (0 - 10%); basophils, 0% (0 - 2%); eosinophils, 12% (0 - 24%); heterophils, 34% (23 - 47%); eosinophils and heterophils, 46% (27 - 63%); undifferentiated, 2% (0 - 7%). There was no significant difference between the differential white cell counts of adult and chick Razorbills.

A comparison of the results of the present study with those of Nikitenko (1965), (Table 16), lead to several immediate generalizations. A greater percentage of lymphocytes

Table 16. Comparison of differential white blood cell counts obtained in the present study with those of Nikitenko (1965).

Table 16. Comparison of differential white blood cell counts in the present study with those of Nikitenko (1965).

Bird Species	Author & Date	Differential Counts (%)								
		S.L.	L.L.	T.L.	M.	B.	E.	H.	E + H	Und.
<u>Alca torda</u>	1 [†]	-	-	25	2	3.8	5.25	65	-	-
	2* (ad)	24	17	41	5	0	11	37	48	6
	(ch)	31	18	49	3	0	12	34	46	2
<u>Uria aalge</u>	1	-	-	29.5	2	4	3	61.5	-	-
	2 (ad)	32	21	53	4	5	18	18	37	1
	(ch)	38	12	50	2	2	30	14	44	2
<u>Uria lomvia</u>	1	-	-	33	3	5	10	49	-	-
	2 (ad)	59	2	61	4	2	8	25	33	0
<u>Cepphus grylle</u>	1	-	-	30.6	0	3.2	4	60.4	-	-
	2 (ad)	31	1	32	3	2	59	4	63	0
<u>Fratercula arctica</u>	1	-	-	29	3	5	5	58	-	-
	2 (ad)	24	17	41	5	0	11	37	48	6
	(ch)	31	18	49	3	0	12	34	46	2

† Nikitenko (1965)

* Present study

was found in all species in the present study, with the exception of the Black Guillemot, where the values were approximately equal (Nikitenko, 30.6%; present study, 32%). In all cases the percentage of heterophils was lower in the present study, In the Guillemots, the percentage of eosinophils found in the present study (59%) was equivalent to that found for heterophils by Nikitenko (60.4%) and the percentage of heterophils was equal to that found for eosinophils (4%). In this study, the percentage of lymphocytes was approximately twice that found by Nikitenko (1965) and conversely the values of heterophils was decreased by approximately one-half. Approximately twice the percentage of eosinophils were found in the present study, the one exception being U. lomvia where there were less eosinophils. Monocyte and basophil values were similar, except no basophils were found in A. torda and F. arctica adults and chicks in this study, whereas Nikitenko (1965) found 3.8% and 5% respectively.

The values found for the alacids examined at Witless Bay did not exhibit the regularity found by Nikitenko. His results were consistent for all species of alacids examined, whereas, the results in the present study seem to indicate specific differences for the birds. These conditions could also result from subspecific differences in the alacids such as the variation found in different strains of fowl by

Kitaeva (1939). The differences could also be due to times of sampling, the physical condition of the birds, or the time during the breeding cycle when the sampling occurred.

Other Hematological Indices

Values for hematocrit, clotting time and red blood cell counts were determined for 12 U. aalge (7 adults and 5 chicks) and 11 F. arctica adults.

Hematocrit readings varied greatly, ranging from 53.4 to 69% (mean: 60.5%) in Puffin adults (buffy layer: 0.7%) to 55.8% in one female Common Murre adult and 37.7 to 43.5% (mean: 40.6%) in two Common Murre chicks.

Clotting times are apparently highest in Common Murre, the mean time being 52 sec. (range: 20 - 75 sec), while that for the Puffin adults is 31 sec (range: 25 - 50 sec). The difference between the mean clotting time of Common Murre and Puffin adult blood were significant ($p < .02$). Clotting times for Common Murre chicks averaged 36 sec.

Male Puffins have higher red cell counts than female Puffins the mean value for the males being 5.26 million per cubic millimeter, that for the female being 3.925 million per cubic millimeter.

The works of Kartaschov (1963) and Nikitenko (1965) show a close similarity in results. These authors recorded highest red blood cell counts in A. torda and F. arctica the range of values recorded for red blood cell counts for all species in both studies being 2.403 million to 3.192 million per cubic millimeter (S.D. \pm 0.25) while those values for white blood cell counts ranged from 27.1 thousand to 33.1 thousand per cubic millimeter (S.D. \pm 2.02).

Current Trends in Avian Haematology

Various authors (e.g. Blalock, 1956; Fredrickson, et. al. 1957) feel that the value of hematology has been overlooked as an indicator of disease conditions, particularly in domestic fowl, and have attempted to find several simple tests which could be used to assess avian disease conditions. Blalock (1956) used the hematocrit, differential count, hemoglobin determination and polyvalent antigen test as his parameters in disease diagnosis. According to Fredrickson, Chute and O'Meara (1957): "Relatively little use has been made of clinical hematology by poultry pathologists despite the fact that it is used extensively in the diagnosis and prognosis of many disease conditions in human and veterinary medicine." They suggest two reasons; firstly, that difficulties arise in performing tests on chicken blood, and, secondly, that there is a lack of standard normal ranges for any component of chicken blood. In their studies, they attempted to show whether any of the standard hematological tests including erythrocyte, leucocyte and thrombocyte counts, hemoglobin, hematocrit, erythrocyte sedimentation rate (ESR), erythrocyte fragility, whole blood and serum specific gravity (SG) and the differential count of white blood cells could be adapted for disease diagnosis.

Perhaps the most useful diagnostic aid is the hematocrit. Most anemias could be detected immediately because of the decrease in packed cell volume, and if there is a greater buffy coat than usual, a lymphocytosis is indicated. The nature of this condition can then be ascertained by the use of other parameters such as differential counts and hemoglobin determinations.

The blood picture of birds can be used to indicate an abnormal condition and when dealing with hematological indices, it must be realized that the blood picture can vary with intrinsic or environmental stresses. Blalock (1956) found that bacterial infections cause a heterophilia, while Chan (1967) found an increase in the basophil cells in guinea pigs after the injection of ova of Ascaris suis Goeze, 1782. Wickware (1947) found, that after the administration of eggs of Heterakis gallinae Gmelin, 1790, there was a significant increase in the number of heterophils and eosinophils in the circulating blood.

Hormonal and other intrinsic factors also cause changes in the blood picture of birds. Bhattacharyya and Sarkar (1968) found that injections of ACTH extract gave rise to a relative lymphocytosis and a quantitative heterophilia. Bannister (1951) showed an increase in the number of heterophils and a decrease in eosinophils and lymphocytes following the injection of cortisone into

White Leghorn hens. Glick (1958) reported increases in the total white cell count and absolute counts of lymphocytes after the administration of penicillin and suggested that it may activate a leucocytic factor.

Bhattacharyya and Sarkar (1968) also quote the results of other workers. Shapiro and Schechtman (1949) reported a transient lymphopenia and leucocytosis following a single ACTH injection in adult fowl. Weller and Schechtman (1949) found no effect of adrenal cortical extract on lymphocytes in chick embryos, but there was an increase in polymorphonuclear cells. Stamler et. al. (1950) found that there was little effect of ACTH on eosinophils. In general then, it may be stated that ACTH or cortisone injections decrease the relative lymphocyte counts and increase the percentage of heterophils in birds.

Little work has been done on sexual dimorphism in hematological values in birds. Atwal (1964) found in a study on the Japanese quail (Coturnix coturnix) that sexual dimorphism in erythrocyte counts and hemoglobin concentration became statistically significant at one day of age, the males having the higher values. Other studies include those of Salomon (1919), Fritsch (1920) and Klienberger and Carl (1927). Kitaeva (1939) found sexual differences in erythrocyte counts in several breeds of fowl. Gilbert (1965) found that

the sexually mature male domestic fowls have larger erythrocytes than sexually mature females, while Banerjee (1964) found that there was no statistically significant sexual difference in the length and breadth of the erythrocytes of fowls and pigeons. Olson (1937) summarizing the results of studies by other authors found that there were differences in the blood cells and hemoglobin under conditions of age, sex, and egg production. Lucas (1961) states that there is a difference in the appearance of blood smears from female laying hens and those from males, non-laying females and young, the laying female smears having a vacuolated appearance from the lipid content of the blood. Venzlaff (1911) found there were sexual differences in the hemoglobin content and erythrocyte numbers in ducks, but Magath and Higgins (1934) found no significant differences between the total number of leucocytes or in the proportion of different cell types in male and female ducks.

Olson (1937) found no significant sexual differences in hemoglobin values in young chickens up to eight months of age. In the older birds, the males had a higher hemoglobin content and higher erythrocyte count but the female had a higher thrombocyte count. The female chickens had a higher percentage of lymphocytes than the males but the males had a higher percentage of heterophils and monocytes. The percentage of eosinophils and basophils were similar in both sexes.

Kitaeva (1939), working on geese, states there is a difference in the blood indices of male and female, with the males being significantly higher. He found that in young chicks which have not yet reached sexual maturity, the hematological variation is slight, but does increase with age.

Atwal (1964) found a significant difference in erythrocyte counts between male and female chicks at one day of age, and continued until the 10th day after hatching. From 10 to 36 days there was no significant difference but after this there was a dimorphism exhibited in which the male had the higher values. Dimorphism in hematocrit values was not significantly different until the 43rd day. Hemoglobin concentrations were higher in the male than in the female on day 1 and from the 43rd day onward. No statistically significant difference was found in the total leucocyte count, but the female had the consistently higher range.

Authors have also attempted to show that age affects the hematological picture. Hoshino and Toryu (1965) investigated the hematology of chicks from the 3rd day of incubation to the 17th day after hatching found large changes in the hematological picture. In differential erythrocyte counts from the 3rd day of incubation there was a steady

decline in the percentage of cells of the early stages of the primitive erythrocyte series. The erythroblast I stage comprised 97.4 percent of the cells but this decreased to 0.8 percent on the 5th day of incubation. Erythroblasts of the primary series were found to the 18th day of incubation. By the 17th day of incubation the erythrocytes differential counts were showing 98.2 percent erythrocytes. The numbers of erythrocytes increased to day 17 and then declined and stabilized at about 2,200,000 cells at hatching followed by an increase to almost the normal adult value at 8 - 9 days after hatching. In the results on differential counts, only pseudoeosinophils (heterophils) were found up to 13 days of incubation, eosinophils and basophils appeared at 14 days, lymphocytes at 15 days and monocytes at 18 days. An increase in lymphocytes was found 3 days after hatching, but they found that the percentage of leucocytes of hatched chicks 3 - 4 days old was about the same as that of the adult.

Olson (1937) concluded that there is little change in the constituents of the blood of young chickens between the ages of 2 weeks and 7 months. Atwal et. al. (1964) found that there was a significant difference between the erythrocyte counts of chicks at one day of age but the values for both sexes increased steadily.

Fennell (1947) found that the primitive erythroblasts and hemocytoblasts were the dominant cells in the peripheral circulation until the 7th day of incubation, while after this only cells of the definitive series were found.

Kitaeva (1939) comparing 4 breeds of fowl for hematological indices, found that the larger breeds show higher hemoglobin values and numbers of erythrocytes than do medium and dwarf fowl. Bennett and Chisholm (1964) state that hematological values for packed cell volume, number of erythrocytes/ mm^3 differ among individual species, and with age and sex but also between adults and immature birds, the latter having the lower value.

Bennett and Chisholm (1964) found that the more primitive avian species have the larger erythrocytes and that, since the larger birds are often more primitive (Bennett and Chisholm, 1964), then the largest birds have the largest erythrocytes, Bartsch, Ball, Rosenweig and Salomon, 1937, reporting similar results. Passerines generally have the smallest erythrocytes, while the alcids, in the present study showed values similar to those found in Larids by Bennett and Chisholm (1964). Cleland and Johnston (1912) also found high values for erythrocyte measurements in the Ardeiformes (Ciconiiformes), Sphenisciformes, Podicipediformes and Pelecaniformes. Threlfall (1965)

found the blood cells of L. argentatus to be smaller than those found in L. argentatus examined by Bennett and Chisholm (1964).

Forkner (1929), when recording red and white blood cell values stated that there are four causes for most of the discrepancies in the literature, which include, study of insufficient numbers of animals, failure to make a sufficient number of observations on single animals, lack of an adequate method of counting white blood cells, and confusion of thrombocytes with other elements of the blood.

Some evidence is available to indicate that diurnal rhythms occur in the percentage proportion of the white cell elements of the circulating blood. Shaw (1933) found that, in the morning, the percentage of lymphocytes is always greater than that for the polymorphonuclear leucocytes, but, in the afternoon, the number of polymorphs increases and may be greater than, equal to or less than the percentage of lymphocytes. The other leucocytes showed no change. In some birds this phenomenon did not occur, but it was felt that these rhythms were independent of any other condition, such as starvation. Domm and Taber (1946) found a definite tendency towards a high erythrocyte value at midnight and a low one at noon in male fowls. The same tendencies were evident in the females, but the difference

in averages at these two times of day were not as great in the females as in males. They also found a seasonal variation in erythrocyte counts with the highest values occurring at the period of highest reproductive activity and the lowest counts at the time of lowest activity.

In addition to human hunting pressures many seabirds are killed annually by oil (Tuck, 1960). Although no actual numbers involved have been determined for Newfoundland, estimates indicate that several hundred thousand murres are killed every year by oil (L. M. Tuck - pers. comm.). Hartung (1964) reported on the numbers of seabirds and seaducks destroyed in various oilspills in the Northern Hemisphere, as found in the literature. From Newfoundland two reports are quoted; namely, Horwood (1959) who reported 12,000 common eiders, murres, oldsquaws and other seabirds were killed in an oilspill in that year, and Tuck (1960) who reported a kill of 150,000 murres, razorbills and other seabirds. These represent large numbers of individual flocks of these birds. Efforts were made to rehabilitate oiled seabirds after the Torrey Canyon disaster of 1967, largely without success, due to our almost complete lack of baseline physiological data and the knowledge of the stresses placed on physiological systems as a result of the oiling and handling by people. Because they are still commercially important in some areas, with adequate data on the

physiological processes, it is possible that a method may be formulated to save oiled seabirds and combined with data on breeding biology, reproductive success and climatological data as it affects reproduction, it may prove possible to ensure adequate management and cropping of these birds.

Hartung (1964) showed that the reduction in red cell counts of Pekin ducks and Mallards after the ingestion of fuel oil was statistically significant (95% level), but that the reduction in packed cell volume and hemoglobin concentration was significant only for the Pekin ducks but not for the Mallards, and felt that the anemia produced was due to blood loss into the intestine. He found that the ingestion of oil stressed the ducks so that the adrenal glands were enlarged according to the symptoms of the general adaptation syndrome of Selye (1946). He found that this was because of hyperplasia of the cortical tissue. He found there was a significant reduction in blood sugar 4 hours after the ingestion of oil but within 24 hours there was an increase which was significant at the 95% level. Some other post-mortem changes were atrophied pancrei, fatty degeneration of the liver in all experimental ducks and in a few of the controls and 63% of the wild oiled ducks showed swollen kidneys. The eggs of the birds were also susceptible to oil and only 5 of 24 oiled Mallard eggs hatched (21%) and 8 of 9 control eggs hatched (89%).

The alcids examined showed such extreme individual variation in all the indices examined that it is very difficult to describe "normal" values. The values obtained in differential counts varied greatly within a particular species, with the age of the bird, and also among the five species of alcids examined. From casual observation, it appears that changes in the percentage values of the different cell types occur throughout the breeding season and apparently can be correlated with periods of egg-laying, incubation times and feeding activity but much more work needs to be done in this area.

Since little is known of the physiology of the alcids, and how environmental conditions and internal changes in physiology affect the hematological indices in these birds, more work must be initiated in this area.

SUMMARY

1. Descriptions and measurements of the cells found in the circulating blood of four species of alcids namely, Alca torda, Uria aalge, Uria lomvia, Fratercula arctica, are given.
2. Erythrocyte measurements were very similar in all species examined (length: 15.2 - 15.9 μ , width: 8.8 - 9.1 μ) as were the measurements for small lymphocytes, large lymphocytes, monocytes, basophils, eosinophils, heterophils, thrombocytes and the various stages of definitive erythrocyte series.
3. The ratios of the various cells of the erythrocyte series were determined for U. aalge and F. arctica utilizing an ocular grid. Erythroblasts were apparently absent in the circulating blood of adult birds. There was also a decrease in the number of cells of the earlier stages of the erythrocyte series with increasing age.
4. Several definitive erythrocyte stages are found. These include the erythroblasts, early-polychromatic erythrocytes, mid-polychromatic erythrocytes, late-polychromatic erythrocytes, mature erythrocytes and erythroblastids.
5. The erythrocytic cytoplasm to nuclear ratio increases with increasing erythrocyte maturity for most alcids examined, the exception being the Razorbill (A. torda).

6. Relatively more cytoplasm was noted in large lymphocytes than in small lymphocytes. The nuclear-cytoplasmic ratio for small lymphocytes was 2.02 times greater than that found in large lymphocytes.

7. Differential white blood cell counts were made from 372 blood smears of 5 species of alcids namely, Alca torda, Uria aalge, Uria lomvia, Cepphus grylle, Fratercula arctica.

8. Results of differential counts revealed wide variations in the percentage values for the various white cell types (small lymphocytes, 0-88%; large lymphocytes, 0-50%; total lymphocytes, 12-89%; monocytes, 0-19%; basophils, 0-25%; eosinophils, 0-79%; heterophils, 0-70%; eosinophils and heterophils, 3-88%; undifferentiated, 0-17%).

9. Statistically significant differences were noted in the percentage of the various cellular elements found in the circulating blood of adults and young of U. aalge and F. arctica.

10. Fluctuations in the percentage of cells found in differential white blood cell counts were noted during the sampling times for U. aalge and F. arctica and these may occur because of stress associated with the breeding cycle.

11. No correlation was noted between the measurements of the culmen, tarsus, wing and tail and weights of the young

of U. aalge and F. arctica and the percentages of the white blood cell types as determined from differential counts.

12. No differences were noted in the percentages of the various circulating white blood cells of the known-aged

F. arctica chicks.

13. The results indicate that differences in the percentage of cellular elements obtained from differential counts do occur in the various species of alcids examined.

14. Common Murres brought to the laboratory for hematological examination on June 24, 1970 showed a large decrease in the percentage of lymphocytes and an increase in the percentage of heterophils from field birds examined on the same day.

15. Values for hematocrits, clotting times and red blood cell counts are given for twelve U. aalge (7 adults and 5 chicks) and 11 F. arctica adults.

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Appendix Table 1. Selected list of avian hematological literature.

RBC = Red blood cell counts
WBC = White blood cell counts
Throm. = Thrombocyte counts
Diff. = Differential counts
Hb. = Hemoglobin determinations
Hem. = Hematocrite
Ery
size = Erythrocyte size

Table I. Selected list of avian haematological data.

Author	Date	Species of Bird	RBC	WBC	Throm.	Diff.	Hb.	Hem.	Ery. Size
Albertoni & Mazzoni	1891	Fowl	x	x	x				
"	1891	Pigeon		x					
Albritton	1952	Ducks					x		
Arvy	1943	Cock	x	x		x			
Atwal, McFarland & Wilson	1964	<u>Coturnix coturnix</u>	x	x		x	x	x	
Banerjee	1966	<u>Columba livia, Gallus sp.</u>							x
Bannister	1951	Fowl (ACTH inj.)		x		x			
Bartsch et. al.	1937	Variety of birds							x
Bayon	1930		x	x			x		
Bell et. al.	1965	Hens	x				x		
Bennett & Chisholm	1964	Variety of birds	x	x		x	x	x	x
Bhattacharyya & Sarkar	1968	Fowl		x		x			
Biely & Palmer	1935	Fowl	x	x					
Blakemore	1934	Fowl	x	x		x			
Blain	1928	"		x		x			
Blalock	1956	"						x	
Blacher	1926	"	x						
Blount	1939	Chickens	x	x		x	x		
Bond & Gilbert	1958	Ducks						x	

Table I (contd.)

Author	Date	Species of Bird	RBC	WBC	Throm.	Diff.	Hb.	Hem.	Ery. Size
Breusch	1928	Fowl	x	x		x			
Buchbinder	1931	<u>Struthio camelus</u>							
Burkhardt	1912	Fowl	x	x		x			
Burmester	1941	White leghorn chicks	x	x		x			
Burnett	1908	Pigeon		x					
Burnett	1917	Fowl	x		x	x	x		
Chaudhuri	1926	Fowl	x						
Cook & Dearstyne	1934	Fowl	x	x		x	x		
Cook & Harmon	1933	Capon					x		
							x		
							x		
							x		
		Chick					x		
Cleland & Johnston	1912	Variety of birds							x
Cullen	1903	Variety of birds				x			
De Eds	1926	Pigeons (many) heart	x	x	x	x			
		(many) leg	x	x	x	x			
De Villiers	1938	Ostrich	x	x	x	x	x	x	x

Table I (contd.)

Author	Date	Species of Bird	RBC	WBC	Throm.	Diff.	Hb.	Hem.	Ery. Size
Didisheim et. al.	1959	Ducks (white perin)				x		x	
Diesem, Venzke & Moore	1958	Fowl (chick)	x	x	x			x	
Dukes & Schwarte	1931	Ducks					x		
Ellerman	1921	Fowl				x			
Ellerman & Bang	1908	Fowl	x	x	x	x			
Fantham	1916	Fowl	x						
Fennell	1947	Fowl (embryos)				x RBC			
Fenstermacher	1932	Fowl	x	x			x		
Ferguson, Golan, Trammel Smith, Omar & Couch		Turkeys	x	x			x	x	
Fink	1924	Fowl	x	x					
Forkner	1929	Fowl	x	x	x	x	x		
Fredrickson & Chute	1958	White rock ch. (infect with newcastle disease virus)	x					x	
Fredrickson, Chute & O'Meara	1957	Broilers	x	x	x		x	x	
Fritsch	1920	Fowl	x		very few	x	x		
Fritsch	1920	Pigeons	x		very few	x	x		
			x			}x			

Table I (contd.)

Author	Date	Species of Bird	RBC	WBC	Throm.	Diff.	Hb.	Hem.	Ery. Size
Gardner	1930	Variety of birds	x						
Gibbs	1934	Fowl	x	x			x		
Glick	1958	Chickens		x					
Gohs	1928	Fowl	x		x				
Goodall	1910	Fowl	x	x		x			
Groebbels	1932	Ducks (Ad - domestic)	x						x
Gulliver	1875	Many birds							x
Hartung	1964	Oiled ducks	x				x	x	
Hayden	1927	Fowl	x	x		x	x		
Hayem	1879	<u>Struthio camelus</u>	x	x					x
Hayem	1889	Fowl	x	x	x				
Hayem	1889	<u>Struthio camelus</u>	x	x					x
Hayem	1889	Pigeon		x					
Hedfeld	1911	Fowl	x	x		x			
Hedfeld	1911		x						
Hedfeld	1911	Pigeon	x		x	x			
Heinz	1901	Fowl	x						
Hemm & Carlton	1967	Ducks (review)	x	x		x	x	x	x
Hewitt	1942	Ducks	x	x					

Table I (contd.)

Author	Date	Species of Bird	RBC	WBC	Throm.	Diff.	Hb.	Hem.	Ery. Size
Hoshino & Toryu	1960	Fowl ch. & embryo	x	x		x			
Huble	1955	Rir cockerels				x			
		ACTH - absolute WBC C							
Johnson	1955	Chick embryo						x	
Juhn & Domm	1930	Fowl	x						
Kakara & Kawasima	1939		x		x	x			
Kaleta & Barnhardt	1968	Geese	x	x		x		x	
Kartashov	1963	Alcids	x	x			x		x
Kaupp	1918	Fowl	x	x					
Kaupp	1929	Fowl	x	x	x	x			
Kelly & Dearstyne	1935	Fowl	x	x		x	x		
Kennedy & Climenko	1929	Pigeon	x			x			
			x			x			
Kennett	1926	Fowl	x	x					
Kisch	1949	Seagull	x				x	x	x
Kitaeva	1939		x				x		x
Klienberger & Carl	1912	Fowl							
Klienberger & Carl	1927	Fowl	x	x	x	x	x		
Kozma	1913	Fowl	x						

Table I (contd.)

Author	Date	Species of Bird	RBC	WBC	Throm.	Diff.	Hb.	Hem.	Ery. Size
Kuhl, Fritsch, Welsh & Werner	(No date)	Ducks	x					x	
Kyes	1929	Pigeon		x					
		Fowl		x					
Lanco et. al	1960	Fowl			x				x
Landauer & David	1933	Fowl	x						
Lucas & Jamroz	1961	Ducks				x			
Mack	No date	Fowl	x	x		x	x		
Mack	No date	Pigeon		x					
Magath & Higgins		Ducks (Mallards)	x	x		x	x		x
Malan	1930	Struthio camelus (phosphates in blood)							
Mallassez	1872	Fowl	x						
Mallassez	1872	Ostrich	x						
Medway	1959	White leghorn						x	
Moore	1895- 1896	Fowl	x	x					
Moore	"	Pigeon		x					
Nice et. al.	1957	Duck	x						
Niggermaier	1925	Fowl	x	x		x			
Nikitenko	1965	Alcids	x	x		x	x		x

Table I (contd.)

Author	Date	Species of Bird	RBC	WBC	Throm.	Diff.	Hb.	Hem.	Ery. Size
O'Connor	1952	Chicken embryo	x			x			
Olson	1937	Fowl	x	x	x	x	x		
Palmer & Biely	1935	Fowl	x	x					
Pickens	1915	Fowl	x	x					
Riddle & Brancher	1934	Doves & Pigeons	x				x		
Rodman et. al.	1957	White pekin						x	
Romer	1921		x			x	x		
Rostorfer & Rigdon	1926	Ducks	x			x			
Rusov	1965	Fowl						x	
Salomon	1919	Fowl	x	x		x			
Salomon	1919	Fowl		x		x			
Schmeisser	1915	Fowl	x	x		x	x		
Schwartz	1960	Fowl	x				x		x
Seager	1933	Fowl	x	x					
Shaw	1933	Pigeons forenoon afternoon				x x			
Soliman et. al.	1966	Ducks		x		x	x		
Stolzing	1856	Fowl	x						

Table I (contd.)

Author	Date	Species of Bird	RBC	WBC	Throm.	Diff.	Hb.	Hem.	Ery. Size
Taylor	1916	Fowl				x			
Thomsen & Englebreth-Helm	1931	Fowl	x	x		x	x		
Threlfall	1966	Herring gull		x		x			x
Ventzloff	1911	<u>Struthio camelus</u>	x						x
Ventzloff	1911	<u>Nettion crecca</u>	x						x
Ventzloff	1911	<u>Anas superciliosa</u>	x						x
Ventzloff	1911	<u>Fuligula marila</u>	x						x
Ventzloff	1911	<u>Choristopus melanoleucus</u>	x						x
Ventzloff	1911	<u>Cygnus olor</u>	x						x
Ward	1904	Fowl	x	x					
Warthin	1907	Fowl	x	x		x			
Welcker	No date	Pigeon	x						
Wels & Horn	1965	Fowl						x	
Wetmore	1940	Fowl	x	x	x				
Wintrobe	1933	Fowl	x					x	x
Wintrobe	1933	Geese	x					x	x
Wintrobe	1933	Guinea fowl	x					x	x

Table I (contd.)

Author	Date	Species of Bird	RBC	WBC	Throm.	Diff.	Hb.	Hem.	Ery. Size
Wirth	1931	Fowl	x			x		x	
Wiseman	1936	Fowl		x					
Yakimoff & Paste- gaieff	1929	Fowl	x			x			

Appendix Table II. Summary of measurements of
young of three species of
alcids.

Table II. Summary of measurements of young of three species of alcids.

Species	Year	No.	Data	Culmen (mm)	Tarsus (mm)	Weight (gr)	Wing (mm)	Tail (mm)	Middle toe (mm)
<u>A. torda</u>	1969	9	Average	19	32	166	67	-	-
			±S.D.	4.30	2.76	40.05	9.85		
			Range	15-28.5	27-36	88-220	51-79		
<u>U. aalge</u>	1969	52	Average	16	30	193	48	-	-
			±S.D.	2.16	2.46	51.84	14.59		
			Range	11-19	24-35	90-280	26-89		
<u>U. aalge</u>	1970	64	Average	16	31	161	44	-	42
			±S.D.	2.14	3.55	56.88	14.80		5.30
			Range	11-26	25-38	54-265	24-77		33-62
<u>F. arctica</u>	1969	14	Average	27	25	263	95	-	-
			±S.D.	2.66	2.57	72.45	26.26		
			Range	21-30	20.5-29	90-340	32-130		
<u>F. arctica</u>	1970	31	Average	23	24	115	75	35	-
			±S.D.	4.20	4.28	62.05	36.32	3.86	
			Range	18.5-29	20-30	40-260	27-135	31-43.5	

Appendix Table III

Red Cell pipettes:

Fisher brand, 11-line (accuracy: $\pm 1\%$). Blood was diluted 1 : 200 times.

Hayem's Solution:

Sodium sulfate 2.5 gr.
Sodium chloride 0.5 gr.
Mercuric chloride 0.25 gr.
Distilled water 100 ml.

Procedure for Giemsa stain:

Blood smears were stained with Giemsa (Azure B, Hartman - Leddon Co., Item 619); 1 part Giemsa stock to 50 parts buffered water (pH 7.2) for 45 minutes. The buffered water was prepared by adding 10 ml. of buffer (Hartman - Leddon Co., Buffer Salt Mixture; containing Sodium and Potassium Phosphates, Item 4036) to 1000 ml. distilled water. The slides were then washed in tap water for two minutes, to allow for differentiation, and were then air dried in an upright position to allow all the excess stain and water to run off and were stored for later differential counts.

Appendix Table IV. Differential white blood cell values, obtained on various sampling days, in two species of alcids examined.

S.L. = small lymphocytes
L.L. = large lymphocytes
S+L L. = small + large lymphocytes
M. = monocytes
B. = basophils
E. = eosinophils
H. = heterophils
E+H = eosinophils and heterophils
Und. = undifferentiated cells

Table IV. Differential white blood cell values for Uria aalge (adult).

Date	No. Birds in Sample	Diff. Count	S.L.	L.L.	S+L L.	M.	B.	E.	H.	E + H	Und.
8/7/1969	37	Average	28	23	51	4	7	6	31	37	1
		±S.D.	9.86	9.40	11.51	3.41	5.02	5.10	12.59	11.37	1.86
		Range	8-58	8-39	24-73	0-13	0-17	0-20	10-72	21-72	0-10
25/7/1969	42	Average	35	23	58	8	7	16	11	27	0
		±S.D.	11.03	9.20	9.05	3.89	4.48	6.98	6.37	7.47	-
		Range	11-65	5-52	43-77	1-19	1-21	2-30	0-32	14-45	0
24/6/1970	20	Average	45	8	53	2	2	36	5	41	2
		±S.D.	7.76	7.55	10.80	0.92	1.65	12.48	4.88	11.67	2.44
		Range	28-57	0-29	35-80	0-4	0-6	18-65	0-15	18-65	0-8
24/6 [†] /1970	4 lab tests	Average	17	13	30	0	1	40	28	68	1
		±S.D.	9.28	6.69	15.13	-	1.00	9.36	15.13	14.46	1.30
		Range	9-33	5-22	17-55	0	0-1	30-55	4-42	45-83	0-3
9/7/1970	24	Average	22	27	49	3	4	27	17	44	0
		±S.D.	9.44	10.50	12.87	2.36	2.81	7.33	10.71	12.07	0.76
		Range	8-46	5-51	13-70	0-9	0-9	11-43	4-46	27-79	0-2
16/7/1970	2	Average	26	13	39	0	2	23	31	54	5
		±S.D.	18.00	1.50	19.50	0.50	0.50	5.00	18.50	23.5	4.00
		Range	8-44	12-15	20-59	0-1	1-2	18-28	12-49	30-77	1-9

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Table IV (contd.) Differential white blood cell values for Uria aalge (chicks).

Date	No. Birds in Sample	Diff. Count	S.L.	L.L.	S+L L.	M.	B.	E.	H.	E + H	Und.
8/7/1969	18	Average	51	0	51	2	3	29	14	43	1
		±S.D.	15.19	0.82	15.06	2.04	2.01	11.73	8.47	15.00	1.34
		Range	29-88	0-3	29-88	0-8	0-7	10-49	0-29	10-67	0-4
25/7/1969	14	Average	50	2	52	1	3	38	3	41	3
		±S.D.	13.24	2.53	14.17	1.51	2.51	13.02	6.96	15.32	4.39
		Range	22-73	0-7	22-80	0-4	0-6	14-56	0-26	16-73	0-17
9/7/1970	19	Average	22	27	48	2	1	29	18	47	1
		±S.D.	12.11	10.78	7.92	1.55	1.65	8.03	9.42	8.32	2.18
		Range	0-41	5-49	36-64	0-5	0-7	12-41	3-43	33-62	0-9
24/7/1970	5	Average	31	14	45	2	0	27	26	53	0
		±S.D.	10.31	5.16	10.88	2.06	0.80	6.15	15.69	13.19	0.80
		Range	16-42	6-22	32-64	0-5	0-2	20-36	7-48	31-68	0-2
26/7/1970	2	Average	32	30	62	1	0	22	15	37	0
		±S.D.	5.00	8.50	8.00	1.00	-	10.00	2.50	12.50	-
		Range	27-37	21-38	48-64	0-2	0	12-32	13-18	25-50	0
31/7/1970	2	Average	41	24	65	0	0	16	13	29	6
		±S.D.	9.0	8.0	1.0	-	-	6.0	6.0	8	1.0
		Range	32-50	16-32	64-66	0	0	10-22	7-19	29-29	5.0-7.0

Table IV (contd.) Differential white blood cell values for *Fratercula arctica* (adult).

Date	No. Birds in Sample	Diff. Count	S.L.	L.L.	S+L L.	M.	B.	E.	H.	E + H	Und.
3/7/1969	23	Average	51	17	68	4	1	9	18	27	0
		±S.D.	14.27	12.97	10.93	2.45	1.18	7.47	9.51	11.74	-
		Range	20-75	2-51	41-87	0-9	0-4	0-34	3-42	6-57	0
7/7/1969	5	Average	33	18	51	2	1	10	36	46	0
		±S.D.	12.77	11.72	18.41	1.50	2.00	10.06	21.02	17.03	-
		Range	16-54	5-39	27-74	0-4	0-5	0-5	0-29	26-68	0
14, 17/7/1969	14	Average	53	26	59	3	0	19	19	38	0
		±S.D.	19.67	4.35	20.38	2.01	0.52	11.60	12.49	20.10	-
		Range	19-80	0-13	22-89	0-7	0-2	1-41	0-49	7-74	0
18/7/1969	37	Average	55	3	58	1	1	21	19	40	0
		±S.D.	13.77	3.38	14.49	0.91	2.06	12.43	13.49	14.45	-
		Range	32-81	0-12	32-85	0-7	0-10	1-53	0-54	10-66	0
19/6/1970	15	Average	37	25	62	3	0	16	17	33	2
		±S.D.	13.51	14.84	8.71	2.51	-	8.76	7.78	11.16	3.24
		Range	12-68	8-57	46-82	0-8	0	0-29	3-31	3-52	0-13
11/7/1970	11	Average	29	22	51	3	1	11	33	44	1
		±S.D.	12.08	15.57	19.15	6.15	0.98	5.89	19.06	20.82	1.80
		Range	8-50	5-54	16-74	0-7	0-3	0-19	13-70	18-80	0-6
14/7/1970	4	Average	28	17	45	2	1	11	40	51	1
		±S.D.	7.56	10.82	15.02	2.45	0.87	4.85	11.02	14.74	0.83
		Range	18-39	4-32	34-71	0-6	0-2	3-16	24-51	27-64	0-2
19/7/1970	7	Average	60	1	61	2	0	6	31	37	0
		±S.D.	6.23	0.73	6.34	1.28	-	6.99	9.87	6.14	-
		Range	51-71	0-2	52-71	0-4	0	0-19	12-43	26-44	0
18/8/1970	7	Average	42	12	54	1	1	22	19	41	3
		±S.D.	13.77	11.96	21.59	1.13	1.36	14.59	11.81	21.83	2.90
		Range	16-58	0-32	19-83	0-3	0-4	3-42	2-27	13-79	0-9

Table IV (contd.) Differential white blood cell values for Fratercula arctica (chicks).

Date	No. Birds in Sample	Diff. Count	S.L.	L.L.	S+L L.	M.	B.	E.	H.	E + H	Und.
2/7/1969	2	Average	43	7	50	6	0	18	29	47	3
		±S.D.	3.54	2.00	4.50	0.50	-	15.00	9.00	6.00	2.00
		Range	40-45	5-9	45-54	0-1	0	3-33	20-38	41-53	1-5
21/7/1969	5	Average	39	17	56	1	0	25	13	38	5
		±S.D.	14.02	8.80	12.60	1.02	-	6.62	12.51	11.70	2.61
		Range	18-58	8-28	39-73	0-3	0	19-38	0-29	23-51	1-8
26/7/1969	1	Average	52	21	73	0	2	11	11	22	3
		±S.D.	-	-	-	-	-	-	-	-	-
		Range	52	21	73	1	2	11	11	22	3
27/7/1969	3	Average	60	22	82	1	0	16	1	17	0
		±S.D.	4.64	6.48	5.44	0.94	-	4.99	0.82	5.56	0.47
		Range	55-66	16-31	74-86	0-2	0	11-23	0-2	12-25	0-1
28/7/1969	4	Average	46	23	69	1	1	13	11	24	5
		±S.D.	9.98	6.83	7.92	0.87	0.83	6.50	5.85	5.89	1.87
		Range	31-57	15-34	59-75	0-2	0-2	3-21	2-17	17-31	2-7
8/7/1970	5	Average	29	22	51	4	0	4	37	41	4
		±S.D.	4.82	5.46	6.05	1.02	-	4.45	7.16	7.94	2.33
		Range	22-36	12-28	44-61	2-5	0	0-12	26-47	26-49	2-8

Fratercula arctica (Chicks) (contd.)

Date	No. Birds in Sample	Diff. Count	S.L.	L.L.	S+L L.	M.	B.	E.	H.	E + H	Und.
10/7/1970	1	Average	22	43	65	4	0	21	9	30	1
		±S.D.*	2.63	17.05	19.60	1.70	-	7.41	24.24	20.51	1.41
		Range	22	43	65	4	0	21	9	30	1
11/7/1970	2	Average	20	22	42	1	0	6	47	53	4
		±S.D.	-	-	-	-	-	-	-	-	-
		Range	17-43	5-39	22-62	0-3	0	4-7	27-67	31-74	4
21/7/1970	3	Average	40	24	64	3	0	11	21	32	1
		±S.D.	1.63	5.35	4.55	2.49	-	3.68	3.27	3.30	1.25
		Range	38-42	19-31	58-69	0-6	0	6-15	17-25	28-36	0-3
31/7/1970	1	Average	53	30	83	1	0	4	11	15	1
		±S.D.	-	-	-	-	-	-	-	-	-
		Range	53	30	83	1	0	4	11	15	1
4/8/1970	2 measured	Average	39	27	66	3	0	10	21	31	0
		±S.D.	6.36	6.00	1.50	1.00	-	3.50	0.50	3.00	0.50
		Range	34-43	21-33	64-67	2-4	0	6-13	21-22	28-34	0-1
7/8/1970	7	Average	49	18	67	2	0	18	13	31	0
		±S.D.	10.33	8.15	10.34	1.40	0.35	8.92	9.78	13.67	1.39
		Range	34-58	10-30	46-88	0-4	0-1	5-31	1-27	11-50	0-4

* ±S.D. for data of July 10, 1970 and July 11, 1970.

Appendix Table V. Values for the median, the first and third quartiles for U. aalge and F. arctica.

S.L. = small lymphocytes
L.L. = large lymphocytes
S+L L. = small + large lymphocytes
M. = monocytes
B. = basophils
E. = eosinophils
H. = heterophils
E+H = eosinophils and heterophils
Und. = undifferentiated cells

Table V. Values for median, first and third quartiles for Uria aalge (adult).

Date	No.	Data	S.L.	L.L.	S+L L.	M.	B.	E.	H.	E + H	Und.
8/7/1969	37	M	31-35	21-25	46-50	0-5	6-10	0-5	26-30	31-35	0-5
		1	16-20	11-15	41-45	0-5	0-5	0-5	16-20	26-30	0-5
		3	36-40	26-30	61-65	6-10	11-15	6-10	31-35	41-45	0-5
21/7/1969	42	M	31-35	21-25	56-60	6-10	6-10	11-15	6-10	26-30	0-5
		1	26-30	16-20	51-55	0-5	0-5	11-15	6-10	21-25	0-5
		3	41-45	26-30	61-65	6-10	6-10	21-25	11-15	31-35	0-5
1969 Acc.	79	M	31-35	21-25	51-55	5-10	5-10	11-15	16-20	26-30	0-5
		1	21-25	16-20	46-50	0-5	0-5	0-5	6-10	21-25	0-5
		3	36-40	26-30	61-65	5-10	5-10	16-20	26-30	36-40	0-5
24/6/1970	20	M	46-50	0-5	51-55	0-5	0-5	31-35	0-5	36-40	0-5
		1	36-40	0-5	41-45	0-5	0-5	26-30	0-5	31-35	0-5
		3	51-55	11-15	56-60	0-5	0-5	41-45	6-10	46-50	0-5
24/6/1970	4	M	11-15	6-10	16-20	0-5	0-5	31-35	26-30	66-70	0-5
		1	6-10	0-5	16-20	0-5	0-5	26-30	0-5	41-45	0-5
		3	11-15	11-15	26-30	0-5	0-5	41-45	36-40	76-80	0-5
9/7/1970	24	M	21-25	26-30	46-50	0-5	0-5	26-30	11-15	41-45	0-5
		1	11-15	16-20	41-45	0-5	0-5	21-25	6-10	36-40	0-5
		3	26-30	31-35	56-60	0-5	0-5	26-30	16-20	46-50	0-5
1970 Acc.	129	M	26-30	11-15	51-55	0-5	0-5	26-30	6-10	36-40	0-5
		1	16-20	0-5	41-45	0-5	0-5	21-25	0-5	31-35	0-5
		3	41-45	26-30	56-60	0-5	0-5	31-35	11-15	46-50	0-5
1969-1970 Acc.	129	M	31-35	21-25	51-55	0-5	0-5	16-20	11-15	31-35	0-5
		1	21-25	11-15	41-45	0-5	0-5	6-10	6-10	26-30	0-5
		3	36-40	26-30	61-65	6-10	6-10	26-30	26-30	41-45	0-5

Table V (contd.) Values for median, first and third quartiles for Uria aalge (chicks).

Date	No.	Data	S.L.	L.L.	S+L L.	M.	B.	E.	H.	E + H	Und.
8/7/1969	18	M	41-45	0-5	46-50	0-5	0-5	26-30	11-15	41-45	0-5
		1	36-40	0-5	36-40	0-5	0-5	16-20	0-5	26-30	0-5
		3	56-60	0-5	56-60	0-5	0-5	36-40	16-20	51-55	0-5
25/8/1969	14	M	41-45	0-5	51-55	0-5	0-5	36-40	0-5	41-45	0-5
		1	41-45	0-5	41-45	0-5	0-5	21-25	0-5	21-25	0-5
		3	51-55	0-5	56-60	0-5	0-5	46-50	0-5	46-50	0-5
1969 Acc.	32	M	41-45	0-5	46-50	0-5	0-5	31-35	0-5	41-45	0-5
		1	41-45	0-5	41-45	0-5	0-5	21-25	0-5	26-30	0-5
		3	56-60	0-5	51-55	0-5	0-5	46-50	16-20	51-55	0-5
9/7/1970	19	M	26-30	21-25	46-50	0-5	0-5	26-30	16-20	46-50	0-5
		1	11-15	16-20	36-40	0-5	0-5	21-25	6-10	36-40	0-5
		3	36-40	31-35	56-60	0-5	0-5	31-35	21-25	51-55	0-5
1969-1970 Acc.	60	M	36-40	0-5	46-50	0-5	0-5	26-30	11-15	41-45	0-5
		1	26-30	0-5	41-45	0-5	0-5	21-25	0-5	31-35	0-5
		3	51-55	21-25	56-60	0-5	0-5	36-40	16-20	51-55	0-5

Table V (contd.) Values for median, first and third quartiles for Fratercula arctica (adults).

Date	No.	Data	S.L.	L.L.	S+L L.	M.	B.	E.	H.	E + H	Und.
3/7/1969	23	M	51-55	11-15	66-70	0-5	0-5	6-10	16-20	25-30	0-5
		1	41-45	0-5	56-60	0-5	0-5	0-5	6-10	16-20	0-5
		3	61-65	26-30	71-75	6-10	0-5	11-15	21-25	30-35	0-5
7/7/1969	5	M	31-35	11-15	41-45	0-5	0-5	6-10	21-25	51-55	0-5
		1	26-30	11-15	36-40	0-5	0-5	0-5	16-20	26-30	0-5
		3	36-40	16-20	71-75	0-5	0-5	6-10	51-55	56-60	0-5
14,17/7/ 1969	14	M	46-50	0-5	56-60	0-5	0-5	16-20	11-15	36-40	0-5
		1	26-30	0-5	31-35	0-5	0-5	0-5	6-10	11-15	0-5
		3	71-75	6-10	76-80	0-5	0-5	21-25	26-30	46-50	0-5
18/7/1969	15	M	51-55	0-5	56-60	0-5	0-5	16-20	11-15	36-40	0-5
		1	41-45	0-5	41-45	0-5	0-5	6-10	6-10	26-30	0-5
		3	61-65	0-5	66-70	0-5	0-5	26-30	21-25	46-50	0-5
1969 Acc.	79	M	51-55	0-5	61-65	0-5	0-5	11-15	16-20	31-35	0-5
		1	41-45	0-5	46-50	0-5	0-5	6-10	6-10	21-25	0-5
		3	61-65	11-15	71-75	0-5	0-5	21-25	21-25	46-50	0-5
19/6/1970	15	M	31-35	21-25	61-65	0-5	0-5	16-20	16-20	31-35	0-5
		1	26-30	11-15	56-60	0-5	0-5	11-15	11-15	26-30	0-5
		3	46-50	36-40	66-70	0-5	0-5	21-25	21-25	36-40	0-5

F. arctica (adult) (contd.)

Date	No.	Data	S.L.	L.L.	S+L L.	M.	B.	E.	H.	E + H	Und.
11/7/1970	11	M	26-30	6-10	51-55	0-5	0-5	6-10	21-25	36-40	0-5
		1	16-20	6-10	41-45	0-5	0-5	6-10	16-20	21-25	0-5
		3	31-35	21-25	56-60	0-5	0-5	11-15	31-35	41-45	0-5
14/7/1970	4	M	26-30	6-10	36-40	0-5	0-5	11-15	36-40	51-55	0-5
		1	16-20	0-5	31-35	0-5	0-5	0-5	21-25	26-30	0-5
		3	26-30	21-25	36-40	0-5	0-5	11-15	46-50	61-65	0-5
19/7/1970	7	M	56-60	0-5	56-60	0-5	0-5	0-5	31-35	41-45	0-5
		1	56-60	0-5	56-60	0-5	0-5	0-5	21-25	31-35	0-5
		3	66-70	0-5	66-70	0-5	0-5	11-15	36-40	41-45	0-5
18/8/1970	7	M	46-50	6-10	56-60	0-5	0-5	26-30	21-25	36-40	0-5
		1	26-30	0-5	31-35	0-5	0-5	0-5	6-10	16-20	0-5
		3	51-55	26-30	71-75	0-5	0-5	36-40	31-35	56-60	0-5
1970 Acc.	44	M	36-40	11-15	56-60	0-5	0-5	10-15	21-25	36-40	0-5
		1	26-30	0-5	46-50	0-5	0-5	0-5	11-15	26-30	0-5
		3	51-55	26-30	66-70	0-5	0-5	15-20	31-35	41-45	0-5
1969-1970 Acc.	123	M	46-50	6-10	56-60	0-5	0-5	10-15	16-20	31-35	0-5
		1	31-35	0-5	46-50	0-5	0-5	6-10	10-15	26-30	0-5
		3	56-60	16-20	71-75	0-5	0-5	21-25	26-30	41-45	0-5

Table V (contd.) Values for median, first and third quartiles for Fratercula arctica (chicks).

Date	No.	Data	S.L.	L.L.	S+L L.	M.	B.	E.	H.	E + H	Und.
1969	15	M	41-45	16-20	66-70	0-5	0-5	16-20	6-10	26-30	0-5
		1	36-40	6-10	51-55	0-5	0-5	11-15	0-5	16-20	0-5
		3	55-60	26-30	71-75	0-5	0-5	21-25	16-20	41-45	6-10
1970	21	M	31-35	21-25	61-65	0-5	0-5	6-10	31-35	21-25	0-5
		1	26-30	11-15	51-55	0-5	0-5	0-5	26-30	6-10	0-5
		3	41-45	26-30	66-70	0-5	0-5	11-15	36-40	26-30	0-5
1969-1970	36	M	41-45	21-25	61-65	0-5	0-5	11-15	16-20	21-25	0-5
		1	26-30	11-15	51-55	0-5	0-5	0-5	0-5	16-20	0-5
		3	51-55	26-30	71-75	0-5	0-5	21-25	26-30	31-35	0-5

Table VI. Taxa of animals examined during the present study, according to the American Ornithologists' Union Checklist (1957).

Razorbill	<u>Alca torda</u> Linnaeus
Common Murre	<u>Uria aalge</u> (Pontoppidan)
Thick-billed Murre	<u>Uria lomvia</u> (Linnaeus)
Black guillemot	<u>Cepphus grylle</u> Salomonsen
Common Puffin	<u>Fratercula arctica</u> (Linnaeus)





