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EXTERNAL SURFACE STRUCTURES OF RACHIS, RAMI AND RACHIDIAL BARBULES OF FEATHERS AND THEIR POTENTIAL FOR DETERMINATION PURPOSES.

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SUMMARY

Microstructures were discovered by SEM analysis of the surface of the rachis, rami and rachidial barbules of bird feathers. These appear to be intraspecifically stable. Up to now 108 bird species belonging to 54 families and 17 orders were studied. Many structures were found, appearing in numerous combinations. These data will be used for determination purposes and will eventually elucidate some classification problems in the class of Aves.

INTRODUCTION

It is generally accepted that one of the first actions to be taken to solve the birdstrike problem is the proper identification of the bird(s) involved (Brom 1984, 1988, Brom & Buurma 1981, Buurma 1982, Buurma & Brom 1980, Buurma, Dekker & Brom 1984). Birdstrikes of the Belgian Air Force are reported by the pilot and/or maintenance personnel. A "Bird Identification Form" is send to the laboratory together with the bird remains. The identification is carried out at the macroscopical, microscopical and scanning electron microscopical (SEM) level. This procedure results in a positive identification in 90% of the cases.

Up to now none of the morphological methods available gives an identification up to species level. Examination of the shape and presence or absence of the tegmen (Gladstone 1918, Lucas & Stettenheim 1972), studies of the internal structure of feather parts (rachis, barbs and barbules) (Auber 1957, 1964, Swales 1970, Dyck 1977) and of the structure of the downy barbules (Brom 1980, 1986, Chandler 1916, Day 1966) provide insufficient resolution.

Therefore I examined to which extent external surface structures on the rachis, rami and rachidial barbules are useful to identify bird remains up to the species level. I looked whether these features were intraspecifically stable. If so, they will be used as diagnostic character and eventually to solve some problems in the classification of birds.

MATERIAL AND METHODS

Small pieces of rachis (± 1 cm) with cut-off barbs were used for SEM examination. A review of the different feather parts is given in Fig. 1 and 2.

"FIGURE 1: Cross section through a feather with dorsal lateral surface of the rachis (1), ventral lateral surface of the rachis (2), dorsal surface of the rachis (3), rachis (4), proximal surface of the ramus (5), distal surface of the ramus(6)."

"FIGURE 2: Position of the rachidial barbules with rachis (1), barb (2), barbules (3), rachidial barbules (4)."

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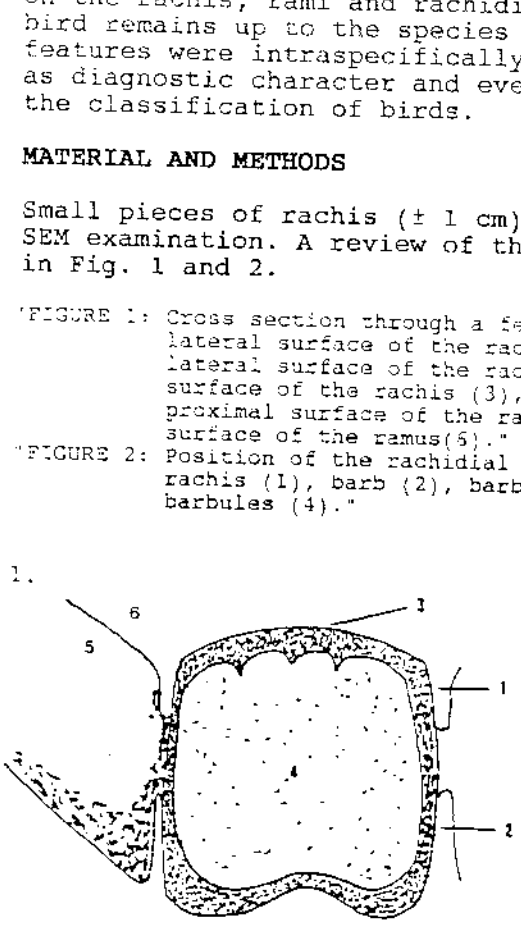

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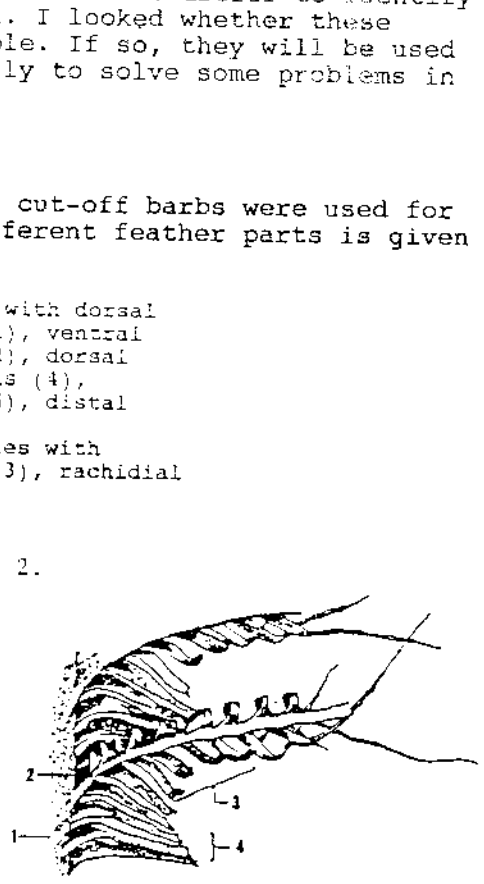

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RESULTS

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For the intraspecific study the following feathers were subjected to an extensive morphological study: feathers of the tail, an upper and under tail-covert, a feather of the rump, of the back, of the nape, of the crown, of the throat, of the breast, of the belly, of the flank and a primary and an upper and under wing-covert.
Only the ninth primary was used in the interspecific study.
Nine sites on the feather (I to IX) together with the type of cell boundary (X) were examined.

RESULTS

1.Intraspecific study

The dorsal surface of the rachis, the dorsal and ventral lateral surface of the rachis, the proximal and distal surface of the rami and the ventral surface of the rachidial barbules all exhibit externally the same structures along the entire length of the rachis, with the exception of the lower 0.75 to 1.50 mm. This observation is true as well for the primaries and tail feathers as for the body contour feathers. These structures are absent on the calamus.

I also examined whether the site of feather implantation has an influence on the appearance of these microstructures. For this study a Woodpigeon (*Columba palumbus*) and a Collared Dove (*Streptopelia decaocto*) were taken. The results are presented in Table 1.
All feathers investigated of the Woodpigeon nearly show the same features. Three of these categories of features are however not fully constant and consist of the presence or absence of villi on the ventral lateral surface of the rachis ventral to the rami (feature I), the structure on the dorsal surface of the rachis (feature IX) and the type of cell boundary (feature X). For determination purposes these three categories have to be treated with care.
Similar results were obtained with the Collared Dove.

We compared feathers of 23 species (2 to 16 individuals per species) to determine to which extent there are individual differences for these structures within one species. No differences between individuals of the same species were found.

Feathers of both sexes of nine species were compared. In none of the examined species, not even in species with a strong sex-linked colour dimorphism such as the Mallard (*Anas platyrhynchos*) and the Ring-necked Pheasant (*Phasianus colchicus*), were differences between the sexes for the described structures found.

The rachis of one juvenile and one adult specimen of 18 different species were compared to study the age differences. They proved to be identical to each other.

Feathers of seven fresh specimens of the Mallard and eight museum specimens (preserved for over 40 years) were compared (Table 2). No differences in external surface features were found between both groups.

"TABLE 1: Woodpigeon (*Columba palumbus*). External surface structures of rachis, rami and rachidial barbules at different implantation sites."

	I	II	III	IV	V	VI	VII	VIII	IX	X
tail feather	Vi(b)	Vi(b)	Vi b)	Vi(a)	o	Vi(e)	Vi(a)	RF	F	4
upper tail-covert	Vi(a)	Vi(a)	Vi(a)	Vi(a)	o	Vi(d)	Vi(d)	RF	VSP	4
rump feather	Vi(c)	Vi(c)	Vi(c)	Vi(c)	o	Vi(c)	Vi(d)	Vi(e)	VSP	
back feather	-	Vi(c)	Vi(c)	Vi(c)	Vi	Vi(e)	Vi(e)	Vi(e)	RS	-
nape feather	-	Vi(c)	Vi(c)	Vi(c)	Vi	Vi(d)	Vi(d)	Vi(e)	RS	-
crown feather	-	Vi(c)	Vi(c)	Vi(c)	Vi	Vi(c)	Vi(d)	Vi(e)	F	-
throat feather	-	Vi(b)	Vi(b)	Vi(b)	Vi	Vi(d)	Vi(d)	Vi(e)	VSP	-
breast feather	-	Vi(b)	Vi(b)	Vi(b)	Vi	Vi(c)	Vi(c)	Vi(c)	VSP	-
belly feather	-	Vi(c)	Vi(c)	Vi(c)	Vi	Vi(e)	Vi(e)	Vi(e)	VSP	-
flank feather	Vi(c)	Vi(c)	Vi(c)	Vi(c)	Vi	Vi(e)	Vi(e)	RF	F	-
under tail-covert	Vi(b)	Vi(b)	Vi(b)	Vi(b)	Vi	Vi(e)	Vi(e)	Vi(<e)	RS	4
primary	Vi(b)	Vi(b)	Vi(b)	Vi(b)	Vi	Vi(<e)	Vi(e)	Vi(<e)	F	4
under wing-covert	Vi(b)	Vi(b)	Vi(b)	Vi(b)	o	FF	Vi(e)	Vi(<e)	VSP	4
upper wing-covert	Vi(b)	Vi(b)	Vi(b)	Vi(b)	Vi	Vi(e)	o	o	RS	4

"TABLE 2: Mallard (*Anas platyrhynchos*). External surface structures of rachis, rami and rachidial barbules of fresh and museum specimens."

	I	II	III	IV	V	VI	VII	VIII	IX	X
fresh specimens Mallard 1 --> 7	R(FF)	R(FF)	R(FF)	R(FF)	F	R(FF)	R(FF)	RF	VSP	5
museum specimens Mallard 1 --> 8	R(FF)	R(FF)	R(FF)	R(FF)	F	R(FF)	R(FF)	RF	VSP	5

Legend Table 1 and 2
I= structure on the ventral lateral surface of the rachis ventral to the rami, II= structure on the ventral lateral surface of the rachis between the rami, III= structure on the proximal surface of the ramus at the ventral lateral part of the rachis , IV= structure on the distal surface of the ramus at the ventral lateral part of the rachis , V= structure on the ventral surface of the rachidial barbules , VI= structure on the dorsal lateral surface of the rachis between the rami, VII= structure on the proximal surface of the ramus at the dorsal lateral part of the rachis , VIII= structure on the distal surface of the ramus at the dorsal lateral part of the rachis , IX= structure on the dorsal surface of the rachis, X= type of cell boundary.
With: -= absent; o= unknown; R(FF)= rachidial ribs containing a finely frayed surface; Vi (a to e)= rachidial villi with densities ranging from abundant, common, frequent, ordinary to rare; RF= roughly frayed; FF= finely frayed; RS= relatively smooth; F= frayed; VSP= very small pits; 4= cell boundary type 4= incomplete cell boundaries; 5= cell boundary type 5= very thick lines.

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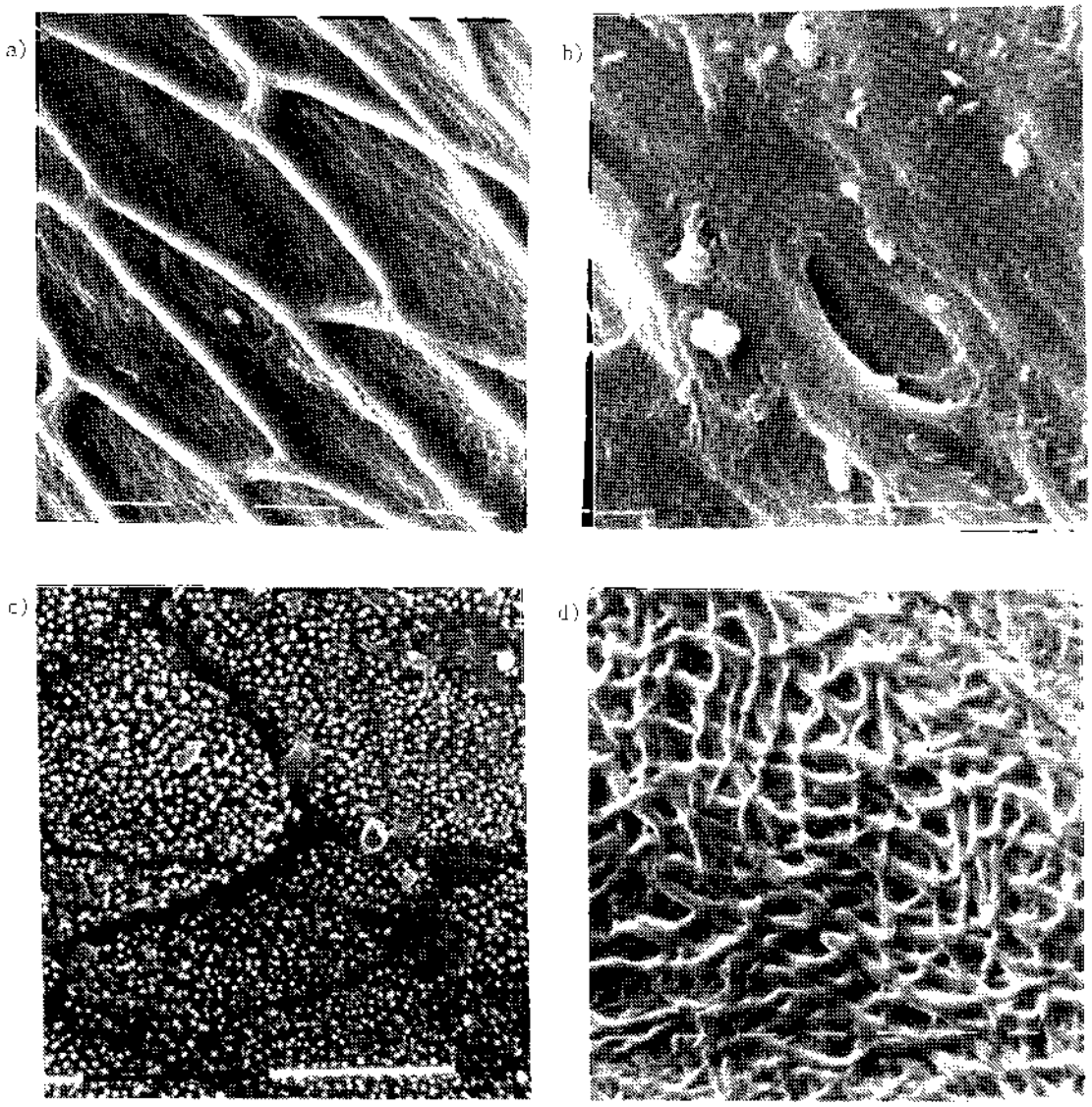
2. Interspecific study

An interspecific study was carried out since there were no intraspecific differences in the features examined. Special attention was given to their possible use as determination characteristics and to their possible use in solving some of the problems in bird classification.
A lot of different structures (e.g.: Fig.3a to d) were discoverd in the examination of the surface of the feather rachis, rami and rachidial barbules.

"FIGURE 3a to d: Structure on the lateral ventral surface of the rachis: a) between the rami: R(FF): Mallard (*Anas platyrhynchos*), b) ventral to the rami: GDP: Green Woodpecker (*Picus viridis*), c) between the rami: Vi with cell boundaries type 1: Northern Gannet (*Morus bassanus*), d) between the rami: R(VRF): Common Gallinule (*Gallinula chloropus*)." One graduation equals 10 µm.



2.1.Structures on the lateral surface of the rachis (dorsal and ventral) and on the proximal and distal surface of the rami

Up to now, five main different structures were found on the dorsal and ventral lateral surface of the rachis and on the proximal and distal surface of the rami: 1) rachidial ribs containing either a granular (R(FF)), a roughly frayed (R(RF)) or a very roughly frayed (R(VRF)) surface; 2) rachidial villi (Vi) in various shapes and densities; 3) roughly frayed (RF); 4) finely frayed (FF) and 5) great deep pits (GDP) only found, when present, on the ventral lateral surface of the rachis ventral to the rami.

The structures described above are more pronounced on the ventral part of the feather in most cases. In some species these structures appeared with the same intensity on the dorsal part of the feather. At the proximal and distal surface of the ramus, close to the attachment of the ramus with the rachis, mostly the same structure was found as on the corresponding lateral surface. Away from the attachment, these structures become more and more indistinct although there are certain species for which the rami show no fading of the present structures along the cut-off piece. In still other species the structure on the rami surface differs from that on the lateral surface of the rachis.

2.2.Structures on the ventral surface of the rachidial barbules

In the species so far examined this part of the rachidial barbules may be frayed or may carry rachidial villi.

2.3.Structures on the dorsal surface of the rachis

The ventral surface of the rachis is simply frayed, while its dorsal surface may carry different structures. The dorsal rachis surface may be relatively smooth, frayed, pitted (small or deep pits, whether containing a kind of a core or not), may carry villi or show the structure of a honeycomb.

2.4.Different types of cell boundaries

The cell boundaries are supposed to correspond with the cell borders of the surface cells. Five types are distinguished:
Type 1: fine, deep laying lines
Type 2: fine, rising lines
Type 3: thick rising lines
Type 4: incomplete cell boundaries
Type 5: very thick lines.

All features described above are found in numerous combinations.

3. Conclusions

Although I am aware that statistical analysis and quantification of certain features will provide more precise conclusions, I can, at the moment, draw your attention to a few striking observations.

An advantage of using external surface structures of the rachis, rami and rachidial barbules as determination features is that all the feathers of a bird show the same structures along the whole length of the rachis. At the same time no intraindividual, sex linked or age differences are found. I agree with Brom (1986) and Frank (1939) that there are no differences in micromorphology between fresh feathers and feathers from bird skins that have been preserved for many years.

Concerning the interspecific study, a lot of external surface structures appear in numerous combinations.

No differences are found among the species studied in the order Anseriformes, family Anatidae. The only difference that the Common Pochard (*Aythya ferina*), Black Scoter (*Melanitta nigra*) and Common Goldeneye (*Bucephala clangula*) show with the other anseriform species is that the dorsal surface of the rachis exhibits a regular cell pattern with an elevation between the cell borders.

In the order Passeriformes differences between species are minute. Only the nature of cell boundary and the dorsal surface of the rachis show slight differences.

In other orders (e.g. O. Pelecaniiformes, Ciconiiformes, Gruiformes, Charadriiformes, Coraciiformes) large differences between families have been observed.

Before drawing any further conclusions, I will quantify certain parameters and perform a detailed statistical analysis of my observations. Further study will give more information on the exact value of this set of characters for determination purposes and for avian taxonomy.

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REFERENCES

Auber, L. 1957. The structures producing "non-iridescent" blue colour in bird feathers. Proc. zool. Soc. Lond. 129: 455 - 486.

Auber, L. 1964. The possible evolutionary significance of differences in feather structure between closely related Pittidae (Passeres: Mesomyodes). J. Linn. Soc. (Zool.) 45(305): 245 - 250.

Brom, T.G. 1980. Microscopic identification of feather remains after collisions between birds and aircraft: 1 - 89 (mimeographed report, Amsterdam, The Netherlands).

Brom, T.G. 1984. Microscopic identification of feathers in order to improve the birdstrike statistics. Proc. Wildlife Hazards to Aircraft. Conference and Training Workshop, Charleston, S.C.: 107 - 119.

Brom, T.G. 1986. Microscopic identification of feathers and feather fragments of Palearctic birds. Bijdr. Dierk. 56(2): 181 - 204.

Brom, T.G. 1988. The analysis of feather remains: evaluation and perspectives. 19th Meeting BSCE: 14pp.

Brom, T.G. & Buurma, L.S. 1981. Microscopische herkenning van veerresten: hulpmiddel bij de analyse van aanvaringen tussen vliegtuigen en vogels. Het Vogeljaar 29(1): 9 - 17.

Buurma, L.S. 1982. Birdweight and aircraftspeed in birdstrike statistics. 16th Meeting BSCE: 12pp.

Buurma, L.S. & Brom, T.G. 1980. Harde feiten over zachte veren. Veilig Vliegen, januari 1980: 9 - 13.

Buurma, L.S.; Dekker, A. & Brom, T.G. 1984. On the spatial and temporal distribution of bird species involved in RNLAF birdstrikes. 17th Meeting BSCE: 15pp.

Chandler, A.C. 1916. A study of the structure of feathers, with reference to their taxonomic significance. Univ. Calif. Publs. Zool. 13(11): 243 - 446.

Clements, J. 1981. Birds of the world: a checklist. 562 pp.

Day, M.G. 1966. Identification of hair and feather remains in the gut and faeces of stoats and weasels. J. Zool., Lond. 148: 201 - 217.

Dyck, J. 1977. Feather ultrastructure of Pesquet's Parrot Psittrichas fulgidus. Ibis 119: 364 - 366.

Frank, F. 1939. Die Färbung der Vogelfeder durch Pigment und Struktur. Journ. Orn. 87(3): 426 - 524.

Gladstone, J.S. 1918. A note on the structure of the feather. Ibis (Ser.10) 6: 243 - 247.

Lucas, A.M. & Stettenheim, P.R. 1972. Avian anatomy. Integument. Agr. Handb. Forest Serv. U. S. No. 362.

Swales, M.K. 1970. A preliminary study on the application of the internal structure of feather barbs to avian taxonomy. Ostrich Suppl. 8: 55 - 66.