



Structure, development and composition of the integument of the  
southern right whale, *Eubalaena australis*.

by

Desray Reeb

Submitted in partial fulfilment of the  
requirements for the degree of

Philosophiae Doctor

in the  
Faculty of Natural and Agricultural Science  
University of Pretoria  
Pretoria

September 2001

Structure, development and composition of the integument of the southern right whale, *Eubalaena australis*.

by

Desray Reeb

- Supervisor: Dr Peter B. Best  
Mammal Research Institute  
Department of Zoology and Entomology  
University of Pretoria  
Pretoria, 0002
- Co-supervisor: Dr Eddie. C. Webb  
Department of Animal and Wildlife Sciences  
University of Pretoria  
Pretoria, 0002
- Co-supervisor: Prof. Rudy J. Van Aarde  
Department of Zoology and Entomology  
University of Pretoria  
Pretoria, 0002

**Abstract**

The general architecture of the skin of the southern right whale, *Eubalaena australis*, is comparable to that described for other cetacean species. As found in bowhead whales, *Balaena mysticetus*, of the same family, southern right whales possess an acanthotic epidermis and a notably thick hypodermis. Epidermal rods and extensive papillomatosis support these unique characteristics. A “fat-free” reticular dermis makes the integument of southern right whales more like that of odontocetes than that described for balaenopterids. Skin samples taken in South African and Antarctic waters showed evidence of superficial moulting throughout the austral winter and in mid-summer. Unidentified “microflora” and fungal microbes were detected on the skin of whales sampled in both South African and Antarctic waters. The predominance of “microfloral”

aggregations on cows and calves in October/November suggests that these micro-organisms are acquired in coastal waters. A *Candida*-like invasive fungal infestation of the skin of a stranded neonate was recorded for the first time in this species and may be related to the demise of this animal. The film-forming diatom, *Bennettella* [*Cocconeis*] *ceticola*, was not detected on any skin samples. This may imply that southern right whales exhibit high cellular proliferation rates, which prevent diatomaceous films from forming. Neonatal southern right whales undergo a spectacular form of ecdysis approximately 6-7 days after birth. Histologically, “rough-skinned” neonates possess a distinct “fault line” above the distal tips of the dermal papillae, that becomes characterised by intercellular oedema, which causes all the cell layers above the plane to separate from those below it. The fatty acid composition of the dermal and hypodermal layers provides indications of prey species consumed as well as reflecting physiological processes within the digestive system of the southern right whale. Total lipid values in the blubber of late season cows and calves are reported for the first time. A new hand-held biopsy system for collecting deep-core integument samples from free-swimming balaenids is described. It is a practical and cheaper alternative to projectile systems and the head design allows for the collection of samples that can be used for multidisciplinary research on right whales (e.g. histology, toxicology and blubber composition studies).

**Keywords:** Southern right whale, integument, histology, ecdysis, microbial aggregations, *Candida* sp., blubber, fatty acid composition, total fatty acid, deep-core biopsy.

## ACKNOWLEDGEMENTS

Besides the acquisition of invaluable academic knowledge I gained while researching my Ph.D., the assistance I received from so many wonderful people is the one facet of my study that has left an everlasting impression on me. So much so, that I could not wait to get to this part of my thesis - my time to put down on paper how I feel, for everyone to see. With this in mind, I never could have imagined that I would have such difficulty in actually doing it and saying my “thank yous”. I could never have achieved this dream without the help I received, how does a person use words to express this kind of gratitude?

So although I thought the “thesis” challenge was over and that all in all I am satisfied that I applied myself and did my best, if the people who helped and supported me so tremendously can know how truly grateful I am, then I will really have accomplished my goal.

Bob Pitman, Lars Kleivane and the crews on the 1998/1999 IWC/SOWER Circumpolar Cruise for collecting samples from the Antarctic and to Hideyoshi Yoshida from the National Research Institute of Far Seas Fisheries, Japan for organising the necessary CITES export permit.

Mike Paterson from Marine and Coastal Management for his skilled construction of the hand-held biopsy system.

Carolyn Miller and Michael Moore from Wood’s Hole Oceanographic Institute, Massachusetts, for assisting with sampling and funding a portion of the field work.

Yolanda Davies, Helen Ilsley, Dr Maureen Duffield, Mary Wolfe, Sharon Marshall, Heather McLeod, Dr Dirk Lang, Liz Van Der Merwe and Prof Sue Kidson from the Departments of Anatomy and Anatomical Pathology, University of Cape Town, Groote Schuur Hospital.

Dr Rachel Alexander, Michelle van der Merwe, Liz Hoenson, Aubrey Byron, Rina Krynauw, Vicky McCrae, Jackie Truman-Baker, Brenda Commins, Cedric Hunter,

Cedric Goliath and James Bolton from the South African Museum who helped in so many ways, from acquiring literature, processing of SEM photographs, computer glitches, illustrations to general motivation and support. I know how busy you all are, thank you for making time to help me.

Dr Alf Botha and Owen Rhode from the Department of Microbiology, University of Stellenbosch for assisting with the preparation of the microbial culturing and general advice on the topic.

Dr Sara Iverson from Dalhousie University, Canada; Prof J. D. Buck (ex University of Connecticut, USA); Prof Roberta Fulthorpe from the University of Toronto, Canada; Prof C. von Holt and Dr J. de A. Rodrigues from the University of Cape Town; Dr Derek Du Preez from the University of Port Elizabeth and Prof Richard Pienaar from the University of the Witwatersrand, for their guidance and advice.

All the staff at the Department of Animal and Wildlife Sciences, University of Pretoria, especially my co-supervisor Dr Eddie Webb, Mr Bertus Spreeth, Karen Steenkamp, Christine Jansen van Rensburg and Adri O'Neill.

Hannetjie Boshoff and Gerda Ehlers at Academic Information Services, University of Pretoria.

Dr Paul van Jaarsveld, De Wet and Martelle Marais and Dr Marius Smit at the Medical Research Council, Cape Town.

Dane Gernecke and Miranda Waldron at the Electron Microscopy Unit, University of Cape Town.

Prof. Johan T. Du Toit, Martin Haupt and Elmarie Cronje from the Mammal Research Institute, University of Pretoria.

Rudy Cloete-Hughes, Derek Kemp and Mark Addison for skippering during my field work. Steve Stafford and Susan and Basie Uys for providing accommodation in Gansbaai and Witsand.

All the staff at the South African Museum who make every day special, especially, Danita, Danie, Karim, Olga and Ilana.

The love and support that I have always received from my dearest mom, dad, sisters, brother, aunts, uncles, grannies, “brotherS-in-law”, cousins, niece and nephews, has always been unconditional and the very spark that keeps me going. Together with the love and support from my “angel network”, Dani and Gill, Berny, Gavin and Payton, Carolyn, Yin, the Orwin, Friedman & Sebba families, Leonie, Meredith and André, Marc, Stuart, Simon and Maggi Best.

My precious Zeider, thank you for always being with me, for being a continual source of inspiration and for loving me from where you are.

I have to single out the person who had to deal with all my moods, my tears, my laughter, my moans and groans and general “Ph.D-ness” every single day, Dov. Koeks, I hope you always get your “glape jouws”! Thank you for helping me on this journey.

To all the people who were kind enough to share their time, be it 5 minutes or 5 hours, a smile or a kind thought - it all made the world of difference to me, thank you all so very much.

Saving the “best for last”, my supervisor, Dr Peter B. Best, who is without a doubt one of the finest whale biologists that ever sailed the seas. Thank you for being a mentor and friend. Your supervision has equipped me with a solid foundation for my future career. A career that I hope includes many more hours of shared “sea time”.

And of course, this list would not be complete without thanking the precious creatures that this study is based on - the southern right whales. May they always grace us with their presence.

This study was made possible by funding provided by the National Research Foundation, with grateful thanks.

## LIST OF CONTENTS

	Page
Abstract	ii
Acknowledgements	iv
List of Contents	vii
List of Tables	xi
List of Plates	xiii
List of Figures	xxi
Chapter 1: Introduction	1
Chapter 2: Structure of the integument of southern right whales, <i>Eubalaena australis</i> .	6
2.1 Introduction	6
2.1.1 Definitions	10
2.1.2 Taxonomy	11
2.2 Materials and Methods	12
2.2.1 Study area	12
2.2.2 Sample collection	12
2.2.2.1 Biopsies	12
2.2.2.2 Stranded animals	15
2.2.3 Histological preparations	18
2.2.3 Statistical analyses	18
2.3 Results	19
2.3.1 General characteristics of southern right whale skin	19
2.3.2 Microscopic characteristics of southern right whale skin	24
2.3.2.1 Superficial epidermal features	24
2.3.2.2 Histological and ultrastructural epidermal features	31
2.3.2.3 Histological and ultrastructural dermal and hypodermal features	40
2.3.2.4 Histological structure of hair follicles and callosity “stalks”	43
2.3.3 Blubber thickness	43
2.4 Discussion	47
2.4.1 General characteristics of southern right whale skin	47
2.4.2 Microscopic characteristics of southern right whale skin	50
2.4.2.1 Superficial epidermal features	50



2.4.2.2	Histological and ultrastructural epidermal features	51
2.4.3	Blubber thickness	54
2.5	Conclusion	56
Chapter 3: Post-natal ecdysis in southern right whales, <i>Eubalaena australis</i> .		57
3.1	Introduction	57
3.2	Materials and Methods	59
3.2.1	Study area	59
3.2.2	Sample collection	59
3.2.2.1	Biopsies	59
3.2.2.2	Stranded animals	60
3.2.3	Aerial and boat survey data used to describe skin condition: determination of an ecdysal time scale	60
3.2.4	Histological preparations	61
3.3	Results	62
3.3.1	Macroscopic appearance of neonatal southern right whale skin	62
3.3.2	Microscopic appearance of neonatal southern right whale skin	65
3.4	Discussion	72
3.5	Conclusion	77
Chapter 4: Observations of microbial associations on the skin of southern right whales, <i>Eubalaena australis</i> .		78
4.1	Introduction	78
4.2	Materials and Methods	80
4.2.1	Sample collection	80
4.2.1.1	Study area	80
4.2.1.2	Sampling	81
4.2.1.2.1	Biopsies	81
4.2.1.2.2	Stranded animals	83
4.2.1.2.3	Scanning Electron Microscopy (SEM)	83
4.2.2	Determination of viable microorganisms	84
4.2.2.1	Sampling of skin	84
4.2.2.2	Culture techniques	86
4.3	Results	86
4.3.1	Microbial populations on the skin samples as revealed by SEM	86
4.3.2	Viable microbial populations as revealed by culturing	97
4.4	Discussion	100

4.1	Conclusion	105
Chapter 5:	Fatty acid composition of the blubber in southern right whales, <i>Eubalaena australis</i> .	106
5.1	Introduction	106
5.2	Materials and Methods	110
5.2.1	Study area	110
5.2.2	Sample collection	110
5.2.2.1	Biopsies	113
5.2.2.2	Stranded animals	113
5.2.3	Lipid analysis	114
5.2.3.1	Preparation of fatty acid methyl esters (FAMES) for composition analysis	117
5.2.3.2	Settings and specifications of the gas chromatograph (G.C.) column for composition analysis	118
5.2.3.3	Standard for composition analysis	118
5.2.3.4	Preparation of fatty acid methyl esters (FAMES) for quantitative analysis	119
5.2.3.5	Settings and specifications of the gas chromatograph column for quantitative analysis	119
5.2.4	Data analysis	120
5.2.5	Statistical analysis	120
5.2.6	Proximate analysis on faecal sample (AOAC, 1984)	120
5.2.6.1	Determination of crude fat (ether extract)	122
5.2.6.2	Determination of crude protein (Macro Kjeldahl method)	122
5.2.6.3	Determination of dry matter	123
5.2.6.4	Ash determination	123
5.1	Results	124
5.3.1	Fatty acid composition of southern right whale blubber	124
5.3.1.1	Effect of position on body	124
5.3.1.2	Effect of layer in blubber	135
5.3.1.3	Age and seasonal effects on the proportions of fatty acids	138
5.3.1.4	Seasonal trends in lipid composition between different age groups	140
5.3.2	A comparison between the fatty acid composition of North Pacific and southern right whales	143
5.3.3	Quantitative fatty acid analysis	145
5.3.4	Proximate analysis of faecal sample	146
5.4	Discussion	146
5.4.1	Fatty acid composition of southern right whale blubber	146
5.4.2	Influence of prey on fatty acid composition of North Pacific and southern right whale blubber	149
5.4.3	Quantitative lipid values of southern right whale blubber	154
5.4.4	Microbial fermentation in southern right whales	156



5.5	Conclusion	158
Chapter 6:	A biopsy system for deep-core sampling of the blubber of southern right whales, <i>Eubalaena australis</i> .	159
6.1	Introduction	159
6.2	Materials and Methods	160
6.3	Results	163
6.4	Discussion	165
6.5	Conclusion	166
	Summary	167
	References	172

## LIST OF TABLES

	Page
Table 1: Total lengths, girths and skin and blubber thicknesses of southern right whales stranded along the Cape coast of South Africa 1998-2000.	16
Table 2: Details of stranded southern right whales sampled for histological analysis.	18
Table 3: Lengths of biopsied blubber samples retrieved from southern right whale cows* and calves, Ec = early season calves, Ea = early season cows, Lc = late season calves, La = late season cows.	49
Table 4: Skin condition of calves seen at sea during biopsy sampling.	61
Table 5: Details of southern right whales sampled for an electron microscopic study of the skin.	82
Table 6: Description of stranded southern right whales sampled for viable micro-organisms on the skin.	84
Table 7: List of samples from southern right whales on which "microfloral" organisms and bacterial <sup>b</sup> growths were found on the skin, using SEM.	87
Table 8: Samples from southern right whales on which fungal and bacterial <sup>b</sup> growths were found on the skin using SEM.	95
Table 9: Viable micro-organisms cultured from different skin sections, as well as from skin washings, compared to those detected in the same samples using SEM.	97
Table 10: Details of southern right whales biopsied along the South African coastline for lipid analysis.	111

Table 11: Details of southern right whales that stranded along the South African coastline and that were sampled for lipid analysis.	112
Table 12: List of fatty acids in standard mixture used for qualitative analysis (University of Pretoria).	119
Table 13: List of fatty acids in standard mixture used for quantitative analysis (MRC).	121
Table 14: Mean proportions of fatty acids in seasonal and age groups, Neo = neonates, "Ec" = early season calves, "Ea" = early season adults, "Lc" = late season calves, "La" = late season adults (Mean % $\pm$ S.E.).	139
Table 15: Mean proportions of lipid classes in seasonal and age groups (Mean % $\pm$ S.E.).	143
Table 16: Fatty acid composition of blubber from a North Pacific right whale and southern right whales (average weight percent of total fatty acids).	144
Table 17: Total fatty acid values from late season southern right whale cows and calves, biopsied along the South African coast cows and calves (AOAC, 1984).	145
Table 18: Fatty acid composition of TAGs in various mysticete species (mean % values).	153
Table 19: Total lipid values (% w/w, expressed as mean $\pm$ S.E.) obtained from various samples from different age and sex classes of some non-stranded mysticetes.	155
Table 20: Outside dimensions of stainless steel needles used in biopsy heads for calves and adults.	160
Table 21: Summary of integumentary sampling of southern right whale cows and calves, using hand-held deep-core biopsy system.	163

## LIST OF PLATES

	Page
Plate 1: Map of sampling areas along the South African coastline.	13
Plate 2: Biopsy pole (arrow) was inserted perpendicularly into the whale and immediately retracted. Note dorsally-located white and grey patches.	14
Plate 3: Sampling positions (Pos 1-5) along the bodies of stranded southern right whales. Dorso-lateral (DL) and mid-dorsal (MD) planes (lateral and mid-ventral planes are not indicated, but were sampled when possible).	14
Plate 4: Raised areas of skin (arrows) on the rostrum and mandible of an adult southern right whale. Note white patch on the mid-dorsal surface used for individual identification.	20
Plate 5: Barnacles (a) and cyamids (b) on the bonnet callosity of a southern right whale. Scale bar = 1.5 cm.	20
Plate 6: A partially albinistic southern right whale calf that has become grey with age.	22
Plate 7: Grey patches (arrows) caused by sloughing of the superficial stratum corneum on the head of an adult southern right whale.	22
Plate 8: A core sample taken through the integument of a neonatal southern right whale. The epidermal layers (E) are heavily pigmented and noticeably thick. Dermal layer (D), hypodermal layer (H), superficial fascia (Sf) are shown.	23
Plate 9: Longitudinal section through the fluke tip of a southern right whale calf. Note the thicker dorsal epidermis (D) compared to the ventral epidermis (V) and extensive collagen fibres (F), coloured light pink, ramifying through core of the fluke. (H/E, Mag 8X).	23
Plate 10: Longitudinal section through the fluke of a southern right whale calf (99/05). Note the unusual, corrugated appearance of the dorsal (d) and ventral (v) epidermis (arrows).	25

- Plate 11: Longitudinal section through the epidermis of a southern right whale calf indicates the presence of flattened stratum spinosum cells (s) and the absence of the stratum corneum. Dermal layer (D). (H/E, Mag 10X). 25
- Plate 12: SEM showing the flaking of superficial squamosal keratinocytes of a late season southern right whale calf. (Mag 75X). 26
- Plate 13: SEM showing the flaking of superficial squamosal keratinocytes of an adult southern right whale sampled in Antarctic waters. (Mag 100X). 26
- Plate 14: SEM of superficial keratinocytes with distinct pentagonally-shaped cell junctions (j) forming deep surface ridges in a honeycomb-like pattern (arrow). A, individual epidermal cells in the process of sloughing; B, cell boundaries formed by epidermal cells that have already sloughed. (Mag 750X). 27
- Plate 15: SEM showing the uniformly pitted appearance of the superficial epidermis exposing the disconnected and freed intercellular boundaries (arrow), after sloughing has occurred. (Mag 3 500X). 28
- Plate 16: SEM exposing the multi-layered superficial epidermal moult of a subadult southern right whale. (Mag 50X ). 28
- Plate 17: Southern right whale cow and “smooth-skinned” calf. Note the smooth, dark skin of the calf. 29
- Plate 18: Southern right whale cow and “rough-skinned” calf. Note the light grey colour and rough, broken appearance of the calf’s skin. 29
- Plate 19: SEM of the skin of an early season, smooth-skinned calf. Note the patches of smooth skin (s) with no honeycomb patterns visible which give way to the exposed, pitted surface of recently sloughed areas (p). (Mag 3 500X). 30
- Plate 20: “Dots” on the surface of the skin of a southern right whale sampled in the Antarctic (a) and a brindle-coloured southern right whale calf (b) showing the distinct dark ring (d) around the “dots”. 30

- Plate 21: SEM showing the irregular nature of the superficial epidermis of a “rough-skinned” southern right whale calf. Note the exposed keratinocyte rosettes around and superficial to the dermal papillae (arrows). (Mag 100x). 32
- Plate 22: SEM of exposed keratinocyte rosettes around and superficial to the dermal papillae (arrow) of the skin of a stranded adult southern right whale (89/30). Decomposed dermal papillae (d). Absence of stratum corneum, probably due to decomposition. (Mag 100x). 32
- Plate 23a: Longitudinal section through the integument of a juvenile southern right whale (00/11), killed by a boat collision. Epidermis (E), stratum corneum (sc), stratum spinosum (ss), stratum basale (sb), reticular dermis (rd), hypodermis (H) infiltrated with collagen fibres (pink lines) and adipocytes (white spaces), superficial fascia (Sf). Note increase in the concentration of adipocytes in a proximal direction. (H/E, whole mount). 33
- Plate 23b: Longitudinal section through the integument of a neonatal southern right whale (00/09). Epidermis (E), stratum corneum (sc), stratum spinosum (ss), stratum basale (sb), reticular dermis (rd), hypodermis (H) infiltrated with collagen fibres (pink lines) and adipocytes (white spaces), superficial fascia (Sf). Note the lower concentration of adipocytes compared to Plate 23a. (H/E, whole mount). 34
- Plate 24: Structure of the integument of rorquals (A) and toothed cetacea (B). Legend: 1 = epidermis, 2 = dermal papillae, 3 = dermis, 4 = hypodermis, 5 = subcutaneous musculature, 6 = bundles of collagen fibres, 7 = bundles of elastin fibres, 8 = adipocytes (from V. Sokolov, 1955). 35
- Plate 25: Stratum corneum (sc) and stratum spinosum (ss) layers of the Epidermis of an adult southern right whale. Note melanin granules stained black (arrow). (H/E, Mag 200X). 35
- Plate 26: A dermal papilla (DP) protruding into the stratum spinosum of a juvenile southern right whale. Note flattened stratum spinosum cells along the sides and tip of the papilla (arrows), melanin granules (m) stained black and stratum basale (sb). (H/E, Mag 200x). 37



- Plate 27: TEM showing the presence of melanin granules (m - black dots) around the nuclei of stratum spinosum cells. Note the thick cell boundaries formed by inter-folding cell membranes (i), nucleolus (n). (Mag 12 000X). 37
- Plate 28: TEM showing the extensive interfolding of stratum spinosum cell membranes (i) connected by desmosomes (d). Tonofilaments (t) are present in parallel bundles within these cells, melanin granules (m) are also present. A = Mag 4 500X, B = Mag 5 000X). 38
- Plate 29: TEM showing large groups of glycogen granules (arrow) in the cytoplasm of spinosum cells. Tonofilaments (t). (Mag 6 000X). 39
- Plate 30: The stratum basale of the epidermis consisted of a layer of variably shaped keratinocytes (k) which interdigitate with the basal lamina (arrows) separating the epidermis (E) and the dermis (D). Melanin granules (m), nucleolus (n), interconnecting cell membranes (i), collagen fibres (c). ( Mag 7 500X). 39
- Plate 31: Stratum spinosum and stratum corneum cells of the epidermis of a “rough-skinned” southern right whale calf. Note reduced concentrations of melanin granules (arrows) compared to Plate 25. (H/E, Mag 100X). 41
- Plate 32: Dermal papillae (p) reach from the base of the papillary dermis (PD) into the epidermis (E) and epidermal rete (r) interdigitate with the dermal papillae. The reticular dermis (RD) consists of dense collagen fibres (dark blue) with blood vessels (b) coursing through both layers. (Ayoub-Shklar, Mag 25X). 41
- Plate 33: Blood vessels (b) extending from the papillary dermis into dermal papillae (p) and between epidermal rete (e) (H/E, Mag 100X). 42
- Plate 34: The reticular dermis consists of tightly packed collagen bundles (arrows) forming a “fat-free” zone. Blood vessels (b), shown in irregular cross-section, course through this layer. Epidermis (E). (H/E, Mag 25X). 42
- Plate 35: A nerve (n) extending through a collagen fibre bundle (c), surrounded by adipocytes (a), within the hypodermis. (H/E, Mag 100X). 44
- Plate 36: Vascularisation (b) is evident within collagen bundles (c) of the hypodermis. Note the various orientations of the collagen bundles. Only remnants of adipocytes are visible (arrow) due to autolysis. (H/E, Mag 25X). 44

- Plate 37: Longitudinal section through the bonnet callosity (callosity on the anterior tip of the upper jaw) of a stranded neonate revealing a hair follicle (f), deep to the epidermis (E). (H/E, Mag 8X). 45
- Plate 38: Photomicrograph of the base of the hair follicle (f) in Plate 37 showing the blood sinus (s) appendage between the inner (i) and outer dermal (o) connective tissue sheaths. (H/E, Mag 25X). 45
- Plate 39: A longitudinal section through an epidermal “stalk”, from the head of a stranded juvenile shows this structure consisting of viable, nucleated stratum spinosum cells (n). (H/E, Mag 200X). 46
- Plate 40: Longitudinal section through the mid-dorsal integument of a stranded southern right whale calf (98/09) showing a separate epidermal region (A) above the epidermis (E) and the distinct plane separating these regions (arrows). Note stratum corneum (sc) cells tearing away from the rest of the integument, dermal papillae (d), epidermal/dermal junction (j). (H/E, whole mount). 66
- Plate 41: Longitudinal section through the integument of a “smooth-skinned” southern right whale calf. Note the absence of a second epidermal layer as well as the absence of a distinctive plane (arrows) above the dorsal tips of the dermal papillae (d). Epidermal/dermal junction (j), stratum corneum (sc). (H/E, 12.3X). 67
- Plate 42: Longitudinal section through the integument of an adult southern right whale sampled in Antarctic waters. Note the absence of a second epidermal layer as well as the absence of a distinctive plane (arrows) above the dorsal tips of the dermal papillae (d). Epidermal/dermal junction (j), stratum corneum (sc). (H/E, 9X). 68
- Plate 43: Longitudinal section through the integumentary layers between two rostral callosities from a stranded southern right whale calf (98/09). Note the thickness of the outer epidermal layer (B) between the callosities (c), separation of the “baby skin” along the “plane” (p), epidermis (E), dermis (D). (H/E, whole mount). 69
- Plate 44: Longitudinal section through the epidermis of a mid-dorsal sample (Pos 4) from a stranded southern right whale calf (98/09). Note the stratum corneum cells (arrow) within the stratum spinosum (ss), intercellular oedema (i), outer epidermal layer (B) and cyto-keratin bodies (stained red). The plane (p) occurs superficial to the tips of the dermal papillae (d). (Ayoub-Shklar, Mag 100X). 69

- Plate 45: Longitudinal section through the integumentary layers of mid-dorsal samples from Pos 1 (A) and Pos 4 (B) along the body of a stranded southern right whale calf (98/09). Note the conspicuously porous plane (arrows) in B compared to A. Dermal papillae (d), intercellular oedema (i), “baby skin” (b), epidermis (E), dermis (D). (Ayoub-Shklar, Mag A 9X, Mag B 7X). 70
- Plate 46: A (rotated) longitudinal section through the stratum spinosum of a mid-dorsal sample (Pos 1) taken from a stranded southern right whale calf (98/09), showing necrotic cells (n) at the distal tips of the dermal papillae (p). (Ayoub-Shklar, Mag 100X). 71
- Plate 47: A neonatal southern right whale (34°2745S, 20°4212 E) with distinctly grey-coloured, “roughened” skin. 71
- Plate 48: A piece of sloughed skin recovered at sea from an apparently abandoned neonatal southern right whale. 73
- Plate 49: Longitudinal section through a piece of sloughed skin recovered at sea from a neonatal southern right whale. Note the spindle-shaped spinosal cells possessing only ghost nuclei (arrows). (H/E, Mag 200X). 73
- Plate 50: A stranded neonatal southern right whale (98/09). The dark skin colour and smooth appearance of the skin initially defined this animal as “smooth-skinned”, but it possessed an outer epidermal layer and “plane”, refer to Plates 43-45). 74
- Plate 51: Longitudinal section through the upper epidermal layers of an apparently “rough-skinned” southern right whale calf (00/09). Note the flattened stratum spinosal cells (f) replacing a true stratum corneum and the absence of an ecdysal plane at the distal tips of the dermal papillae (d). (H/E, Mag 100X). 74
- Plate 52: SEMs showing microbial aggregations on the skin (s) of a stranded neonatal southern right whale (99/05) taken at the University of Cape Town’s Microscopy Unit during random trial inspections. (Mag A 250X, Mag B 3 000X). 85
- Plate 53: SEM of an undetermined species of cyanobacteria possibly forming crypts in the skin of a late season calf (# 90). (Mag 3 500X). 88

Plate 54:	SEMs of “stonelike” micro-organisms deeply seated in the skin of a stranded neonatal southern right whale (99/05) (Mag 350X).	88
Plate 55:	SEM of a spore with prosthecate appendages (arrow) found on the skin of a stranded neonatal southern right whale (99/05). (Mag 10 000X).	90
Plate 56:	SEM of a spherical, smooth spore found on the skin of a late season southern right whale calf (# 61). (Mag 750X). Insert: SEM of smooth spore found on the skin of a stranded juvenile southern right whale (00/11) (Mag 750X).	90
Plate 57:	SEM of a unique spore, with corrugated edges, found on the exfoliated skin surface (s) of a late season southern right whale calf (# 84). Mag (3 500X).	91
Plate 58:	SEM showing a “spiky” spore (arrow) found on late season cows and calves, an early season calf and two non-calves sampled in the Antarctic. Bacterial cocci (b) and fungal mycelia (f). (Mag 3 500X).	91
Plate 59:	SEM showing yeast colonies on the surface of the skin of a late season southern right whale calf (# 73). (Mag 750X).	92
Plate 60:	SEM showing actively dividing yeast cells (arrows) on the skin from a late season southern right whale calf (# 45). (Mag 2 000X).	92
Plate 61:	SEM showing the presence of bacterial cocci distributed on the exfoliated skin of a non-calf southern right whale (# 140S) sampled in Antarctic waters. (Mag 5 000X).	93
Plate 62:	SEM showing the mycelia of different fungal species (a + b) on the skin of a non-calf southern right whale (# 146S) sampled in Antarctic waters. (Mag 500X).	93
Plate 63:	SEM showing the fungal aggregations on the sides (s) of a skin sample taken from a non-calf southern right whale (# 149S) in Antarctic waters. Epidermis (E). (Mag 200X).	94
Plate 64:	SEM of fungal mycelia (f) congregating around degenerating skin (g) of a stranded juvenile southern right whale (# 00/11). (Mag 750X).	94

Plate 65:	SEM of the skin of a late season calf (# 73) showing encrypted spores (s) in association with fungal mycelia (f). (Mag 1 000X).	96
Plate 66:	SEM of the skin of a stranded neonate southern right whale (99/05) showing invasive fungal growth. (Mag 750X).	96
Plate 67:	SEMs of yeast cell formations found on the surface of the skin of a Stranded neonatal southern right whale (99/05). A: stalks (arrow), B: clumps and C: budding (b) yeast cells. Blastospore (o) (Mag A, 5 000X; Mag B + C, 3 500X).	98
Plate 68:	SEM showing small, spherical spore-like structures nestled within the epidermal tissue (arrows) of a stranded neonatal southern right whale (99/05). (Mag 350X).	99
Plate 69:	The integument of a neonatal southern right whale. The separation of the layers for lipid analysis is possible on gross inspection of the integument, dermal layer (D), intermediary fibrous/fatty layer (I), fatty hypodermal layer (H), superficial fascia (Sf), epidermis (E).	107
Plate 70:	A maximally expanded minke whale ( <i>Balaenoptera acutorostrata</i> ) stomach and proximal duodenum, showing the forestomach (fs), the fundic chamber (fu), the pyloric chamber (p) and the duodenal ampulla (da). The connecting channel (cc) is situated between the fundic and the pyloric chamber. Scale bar = 30 cm. (from Olsen et al., 1994).	107
Plate 71:	Sketches of the hand-held biopsy system and tools. Rubber bush (A) fitted with a female brass coupling and nylon cord; male brass coupling (B) and stainless steel needle (note bevelled tip of the needle); spring-steel tool for attaching the biopsy head (C); brass coupling at the base of the biopsy needle (D) showing indentations for tightening and a hole at the base of the head for air movement; side view of the biopsy head (E) exposing the spring-steel and trap-door barbs (F); tool for setting the spring-steel barb (G).	161
Plate 72:	Integument of a southern right whale calf (arrow) and the biopsy head (b) used for sampling (11 cm x 0.8 cm x 0.4 cm). Epidermis (E).	164

LIST OF FIGURES	Page
Figure 1: Blubber thickness measurements on the mid-dorsal plane along the body of neonatal southern right whales.	48
Figure 2: Blubber thickness measurements on the lateral plane along the body of neonatal southern right whales.	48
Figure 3: Blubber thickness measurements on the ventral plane along the body of neonatal southern right whales.	48
Figure 4: Frequency of different skin conditions seen in southern right whale calves during biopsy sampling and aerial surveys, South Africa 1988-1999.	63
Figure 5: Percentage of smooth-skinned calves observed in boat-based and aerial surveys, South Africa 1988-1999 as a function of the number of days from 1 June. Solid vertical line represents the mean day at which 50% of the calves are smooth-skinned, broken lines indicate S.E.	64
Figure 6: Chromatograms showing the fatty acid profile from the blubber of a southern right whale calf (# 87), indicating the major fatty acids as well as unidentified peaks, detected using gas chromatography (MRC).	115
Figure 7: Chromatograms showing the fatty acid profile from the blubber of a southern right whale mother (# 86), indicating the major fatty acids as well as unidentified peaks, detected using gas chromatography (MRC).	116
Figure 8: Chromatograms showing the fatty acid profile from the blubber of a southern right whale calf (# 30, top) and mother (# 29, bottom) pair indicating the 13 major fatty acids detected using gas chromatography.	125
Figure 9: Proportions of fatty acids in positions 1-5 on the mid-dorsal plane along the bodies of neonatal southern right whales (mean $\pm$ S.E.).	127
Figure 10: Proportions of fatty acids on the mid-dorsal plane along the body of a male neonatal southern right whale.	128
Figure 11: Proportions of fatty acids in positions 2-5 the lateral plane along the body of a male neonatal southern right whale.	129
Figure 12: Proportions of fatty acids on the mid-ventral plane along the body of a male neonatal southern right whale.	128

Figure 13: Proportions of fatty acids in positions 2-5 along the lateral plane of a male neonatal southern right whale.	130
Figure 14: Proportions of fatty acids on the lateral plane along the body of a male neonatal southern right whale.	128
Figure 15: Proportions of fatty acids in positions 1-5 along the lateral plane of a juvenile southern right whale.	132
Figure 16: Proportions of fatty acids on the lateral plane along the body of a juvenile male southern right whale.	133
Figure 17: Proportions of fatty acids in positions 1-5 along the dorso-lateral plane of a subadult southern right whale.	134
Figure 18: Proportions of fatty acids on the dorso-lateral plane along the body of a subadult male southern right whale.	133
Figure 19: Average proportions of fatty acids in the layers of mid-dorsal position 3 samples from 4 neonatal southern right whales.	133
Figure 20: Average proportions of fatty acids in the layers of lateral positions 1-5 from a juvenile female southern right whale.	136
Figure 21: Average proportions of fatty acids in the layers of dorso-lateral positions 1-5 from a subadult male southern right whale.	136
Figure 22: Proportions of fatty acids in the layers of a mid-dorsal position 3 sample from an adult male southern right whale.	136
Figure 23: Proportions of saturated (SFA), Monounsaturated (MUFA) and Polyunsaturated (PUFA) fatty acids in various age and seasonal groups.	141
Figure 24: Proportions of fatty acids from different seasonal and age classes of southern right whales (mean $\pm$ S.E.).	142