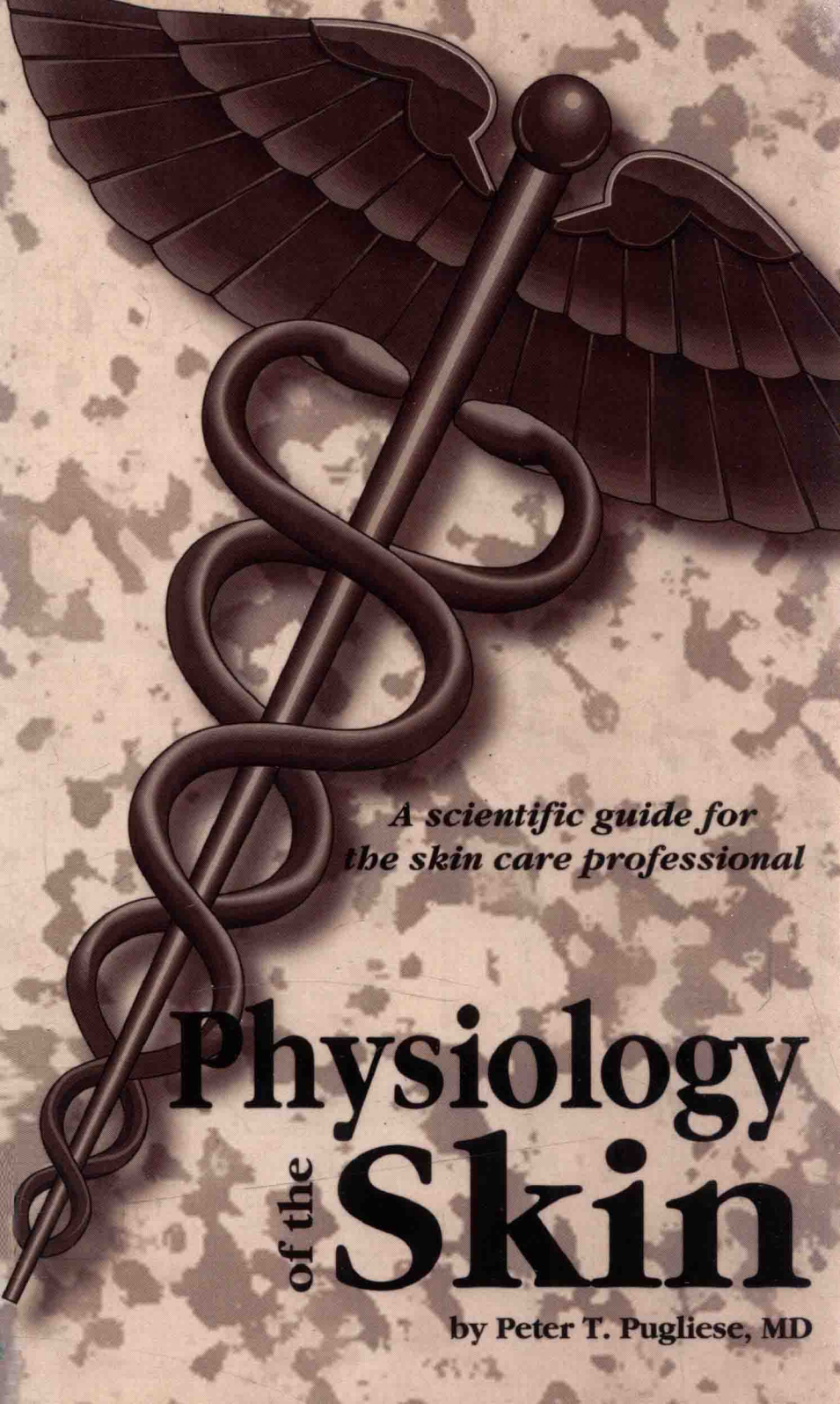

A scientific guide for the skin care professional

Physiology of the Skin

by Peter T. Pugliese, MD

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About the Author ...

Peter T. Pugliese, MD, was in private practice for 15 years before founding Milmark Research, Inc. in Reading, Pennsylvania. He is president of Peter T. Pugliese, MD & Associates, and a biomedical consultant to the cosmetics and pharmaceutical industries. His major research interest is normal skin physiology and mechanisms of aging.

Since 1978, Dr. Pugliese's efforts have been dedicated to the development of ethical skin care products and public education through skin care professionals. Over the past 20 years, more than 50 papers on skin physiology have either been published or presented by Dr. Pugliese, and he has written and published a text book titled ***Advanced Professional Skin Care***.

Dr. Pugliese has written for ***Skin Inc***. magazine since its launch in 1988 and has contributed a series of articles throughout the years covering various subjects related to physiology of the skin.

He received his medical degree from the University of Pennsylvania School of Medicine in 1957. Dr. Pugliese did graduate work at Oak Ridge Institute of Nuclear Studies in Oak Ridge, Tennessee, in 1955, and did post-graduate research in biophysics on a part-time basis from 1964 to 1967 for the Johnson Foundation at the University of Pennsylvania.

Dr. Pugliese is a member of various industry organizations, including the Society of Cosmetic Chemists, the American Academy of Dermatologists, the Society of Bioengineering and the Skin, the Society of Investigative Dermatology and the Skin Pharmacology Society.

Dr. Pugliese and Joanne, his wife since 1949, have four children and reside in Pennsylvania.

INTRODUCTION

This book represents a collection of scientific articles written for the skin care professional and published throughout the past several years in ***Skin Inc***. magazine. Now these articles have been organized, updated and put into book form to produce a convenient, educational source and a ready reference for the serious practitioner. Skin care is an evolving art based on an even more rapidly evolving science. While human anatomy has not changed in the last ten years, the knowledge in skin physiology and treatment modalities has grown enormously.

How to Use This Book

An apparent shortcoming of our educational system is that students aren't taught how to study, how to use their textbooks or how to organize study time effectively. Education should be based on incremental information that finally builds into a coherent whole. One cannot master algebra without a basic knowledge of arithmetic, yet tough courses often are tackled without understanding the fundamentals of the subject. A mechanic can repair a car without a knowledge of engineering, but a surgeon cannot operate without a knowledge of anatomy and physiology of the body. This knowledge separates the technician from the professional.

This book is written for the professional skin care specialist. The very fact that you purchased this book indicates that you are serious about continuing your education. The writer assumes that the reader has a certain level of training and expertise with each topic, so some basic concepts are not covered, though references are supplied to help fill in those areas. The organization of the text starts with basic science topics and builds up to clinical topics. The first step is to

page through the book, looking at the table of contents and then peruse one or two chapters. This will give you a "feeling" for the information in the book and help you to decide if it will serve as a reference, as a continuing education tool or both.

Once you have made this decision you can pace yourself in reading. Making notes helps, but most of the key information is outlined in each chapter for ease of learning the essential material. After you read a chapter, file a few key words in your memory and recall them as necessary. At this point, go back to the text and refresh your knowledge. It is not necessary to keep all these facts in your head. Knowing where to find the information is as valuable as having it memorized, but less laborious. So start with **Chapter 1—"Behavior of Normal Skin,"** for you cannot appreciate the abnormal states until you know about the normal state. Learn all the key words in this chapter since they are repeated throughout the book.

Chapter 2—"The Appendages," builds further on the structure of the skin and prepares for a more detailed look at acne and other disorders of the appendages. In **Chapter 3—"The Lymphatic System,"** structure intimately is woven with function so that the true nature and importance of the lymphatic system becomes very clear. **Chapter 4—"Pigmentation,"** covers both the basics of melanin formation and disorders of pigmentation, and then leads us into the clinical areas of these topics.

In preparation for this journey, the critical immune system, must be discussed and is done so in **Chapter 5—"Immunology and the Skin Care Specialist."** Wrinkles are discussed from a clinical point of view and from a basic science viewpoint in **Chapter 6—"How Wrinkles Develop."** Here the discussion of aging begins.

Our next clinical topic is the most common condition in skin care—acne. Again, we build on our knowledge of the skin and add to it. In **Chapter 7—"Biology of Acneic Skin,"** a rational basis for treatment is provided. In **Chapter 8—"Sun's Effects on the Skin,"** the study of the sun begins, and then this information expands with practical application in **Chapter 9—"Sun-Related Skin Disorders."** In **Chapter 10—"Systemic Lupus Erythematosus,"** this topic continues with a detailed discussion of the disorder which is related to a combination of immune dysfunction and sun exposure. Lupus occurs mainly in females, so the differences between males and females are discussed in **Chapter 11—"Males and Females: Physi-**

ological Differences." This topic naturally leads into a discussion of menopause, which is covered in **Chapter 12—"Menopausal Skin."** The basic mechanisms in free radical disorders of the skin are covered in **Chapter 13—"Free Radicals and the Skin."** It is an important concept directly relating to antioxidant use and the slowing down of the aging process.

The last two chapters are essential to skin care practice. A detailed account of the many sterilization methods available are discussed in **Chapter 14—"Principles and Practice of Sterilization."** A complex subject is presented in **Chapter 15—"Phytotherapy."** It is presented in a manner that supplies the basic science needed, while at the same time providing practical everyday information with suggested formulae.

Skin care is advancing rapidly and, as I predicated ten years ago, professional esthetics is moving closer to medicine. More estheticians are working in the offices of plastic surgeons and dermatologists than ever before. This association demands greater educational effort on the part of both the estheticians and the physicians, but I think the esthetician is taking the lead.

There is an exciting new field opening in the total care of the mature adult, with skin being one of the most exciting areas. New developments will tax our efforts to keep abreast, to weigh and evaluate new skin care methods and new skin care products. This new knowledge will help you to be a more effective skin care specialist as well as a more critical judge. It will require a lot of knowledge in many fields to be able to judge what is good, or not so good. The topics covered in this book will provide you with a good foundation to appraise what currently is available and what may be coming down the pike in the next few years. I hope that you enjoy reading this book as much as I enjoyed writing it for you.

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1

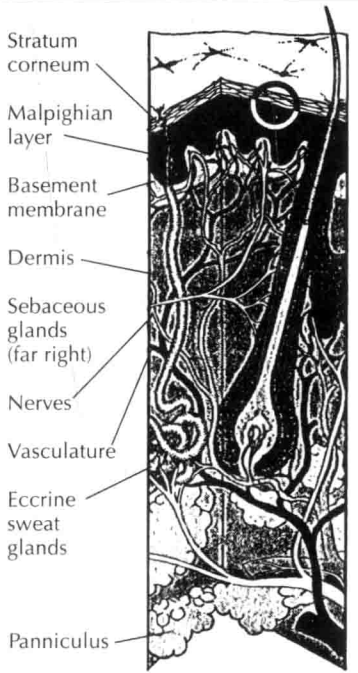
Behavior of Normal Skin

The smooth, soft, supple skin of a human female face—free of any blemishes—is highly attractive to the human male, as is a smooth male face to the female. This skin is a result of many biochemical and physical factors. Unfortunately these factors are subject to changes both internally and externally. Sun, smoking, stress, disease and aging alter the structure of the skin over time, making it sag, lose its luster and suppleness. The purpose of professional skin care is to maintain skin in its most attractive and healthy state. The aim of this chapter is to provide an understanding of normal skin behavior in relation to its structure and function.

Structure of the Skin

Every book on skin describes its two basic layers: The *epidermis* and the *dermis*. This is correct, of course, but these two layers are really one system. One layer cannot be affected without some effect on the other layer. This is an extremely important concept to understand as both the function and structure of these two layers are explored. (See **Figure 1–1**.)[1-2]

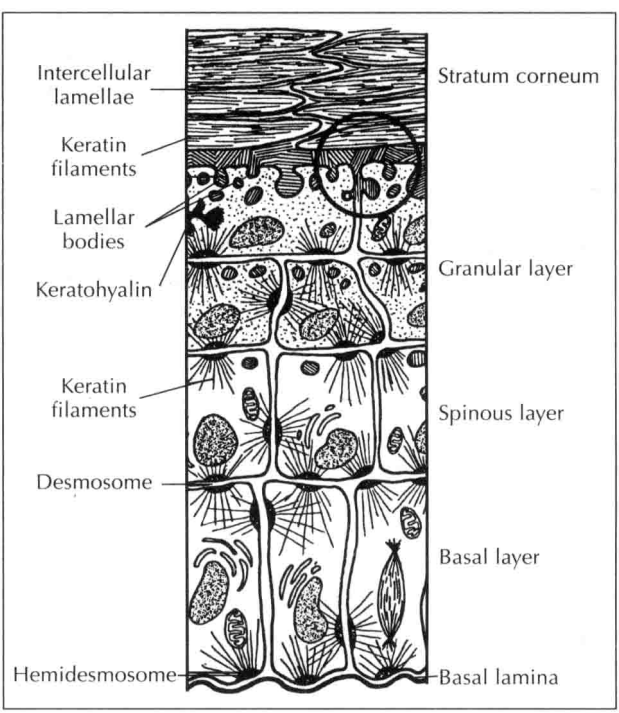
The epidermis serves as a barrier to the outside world, keeping



Epidermis—Stratum corneum. Dried flattened keratinocytes; a multicellular membrane.	*Protective layer, permeability barrier: it impedes the entrance of micro-organisms, UV radiation, electric current and toxic substances; it retains water, electrolytes and soluble substances*
Epidermis—Malpighian layer. Highly cellular; no blood vessels or nerves. Keratinocytes, 80%	*Synthesis of keratin precursors and cell envelope; transformation of living to cornified cells* *Synthesis of keratin, intermediate filaments, membrane-coating granules, keratohyalin, ETAF, lipids, vitamin D, prostaglandins and others*
Dermis—Loose connective tissue, consisting of: Fibrous portion: Collagen, Reticulin, Elastin. Ground substance cells: Fibroblasts, Macrophages, Mast cells, Lymphocytes	*Mechhanical protection; main support structure of skin: passively protects against trauma and maintains the body's integrity by virtue of its strong and flexible composite materials, i.e., collagen and ground substance.* *Water binding, wound repair, reservoir and diffusion medium for regulating the distribution of water, salts, horomones and other substances; contains essential elements (cells, mediators) for tissue homeostasis and to generate an inflammatory response*

***Figure 1–1**. Overview of the structure of the skin. The circled area on this figure indicates the cross section of the enlargement in **Figure 1-2**.*

out water, sunlight, insects, germs, heat and cold, dirt and gases. It keeps in fluids such as water and blood, minerals, vitamins, hormones, proteins and heat. With the dermis, it provides for heat regulation for the entire body by controlling sweat evaporation and dermal blood flow. It provides a system that allows replacement of the outer cells lost to the environment. It provides a waterproof outer layer, yet permits water to carry nutrients to the outermost living cells. It provides a tough outer layer to resist friction, abrasion and pressure. It provides a system of controlling and regulating these functions. Finally, it serves as a vast waste disposal system, ridding the body of many toxic substances. (See **Figure 1–2**.)



Scientific Basis of Dermatology, Thody and Friedmann, eds, Longman Group UK Ltd, 1986, p 7

***Figure 1–2**. Diagram of the four layers of the epidermis. Note the various structures within the cells and the change from oblong, vertical cells in the basal layer to flat, horizontal cells in the stratum corneum. The circled area indicates the cross section of the enlargement in **Figure 1-3**.*

THE STRATUM CORNEUM

The outermost layer of the skin is the *stratum corneum*, or "horn layer." Consider that the whole epidermis is only 0.04–1.5 mm (millimeters) thick, the stratum corneum (SC) is only 75–150 microns thick.[1] To put that into perspective, the paper on which this is written is 70 microns thick. A micron is 1/1000 of a millimeter; a millimeter is 0.039 inches. The SC is 0.0030 inches thick. That is thinner than a human hair. Most of human life hangs upon this thin structure, for without a SC the epidermis would perish. Here is why the SC is so tough.

Keratin proteins make up the bulk of the SC. Keratin is a helical or coil-shaped fibrous protein made up of a series of polypeptides. Polypeptides are, in turn, made up of amino acid basic units. These polypeptides vary in different parts of the body so that the skin is not homogeneous, but rather heterogeneous. The protein is resistant to water and many chemicals. It is this complex structure that provides part of the protection from the outside. Manufacturing proteins is one of the major functions of the skin. These proteins are formed with the other important component of the SC—the lipids.

Lipids are water-insoluble, oily substances. They can be classified by their electrical charge and by their structure. The two major groups of lipids are *polar lipids* which have an electrical charge. Examples of this type of lipid are phospholipids, glycolipids and cholesterol. *Non-polar lipids* have no electrical charge. Triglycerides, squalene and waxes are examples of this group.

The six major structural groups of lipids are: *triglycerides*, the most abundant lipids in the body, which function as energy storage compounds and make up between 12–25% of the lipids in the SC; *fatty acids*, which give the oily feel and make up between 12–20% of the lipids in the SC; *waxes*, which make up 6% of the lipids in the SC; and *cholesterol, sphingolipids* and *ceramides*, which make up between 14–25% of lipids in the SC.

MAKING OF THE BARRIER

Here are the mechanisms, outlined briefly, that make up the final SC cell. The cells are called *keratinocytes* until they are finally cornified at which time they are called *corneocytes*.

The basal layer, or bottom layer, is the active, growing, dividing layer of the epidermis. Each cell divides under control of a very sophisticated biochemical system. As these cells divide, a series of biochemical reactions, or pathways, are set into motion. Two of these pathways are protein or keratin synthesis, and lipid synthesis. All of the biochemical action in these two pathways is designed to produce a tough, protective SC.

Step 1: Formation of keratin fibrils and early lipids. Keratin fibrils are formed from keratin filaments in the basal cells. They are part of the inner cell, the cytoplasm, which changes as the cell moves upward to the next layer.

The lipids of the basal cell differ from those in the SC in that there are more polar lipids and less free fatty acids, and almost no sphingolipids. They are mostly phospholipids and neutral lipids.

Step 2: The spiny layer and early differentiate. The keratin fibrils now become more plentiful and begin to change shape. A process of cross-linking takes place and the keratin is seen more easily in microscopic examination of the skin.

The lipids in the spiny layer are not much different than those in the basal layer.

Step 3: The granular layer—the zone of transition. The keratin proteins in the granular layer are visible as dark aggregates and begin to almost completely fill the cell interior. They now are longer than they were in the spiny layer.

The first signs of lipid changes now occur. Free sterols are increased, ceramides and glycolipids now are seen and cholesterol sulfate is detected.[3] The lamellar body makes its appearance at this stage and the drama of the SC begins.

Step 4: Cornification—making the barrier. At this stage the keratinocyte has lost most of its enzyme functions, but not all. It hovers between life and death, but has reached its destiny and must become inanimate to serve its purpose. These cells are mostly protein, flat, very thin and hardy, and are stacked in layers. The outer layer easily sloughs off with mild force and new cells move up to replace it.

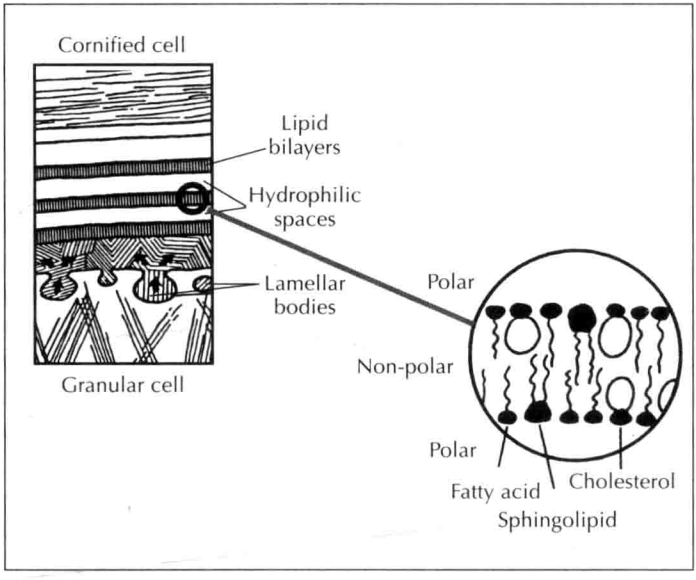
Between the cells, in the intercorneocyte space, a dramatic

process occurs. Small, complex structures called lamellar bodies are scattered within the spaces between the corneocytes and appear to secrete free sterols, sphingolipids and other compounds such as glycoproteins. This arrangement permits both hydrophilic and hydrophobic materials to pass through the intercorneal space. (See **Figure 1–3**.)[3]

Remember that the SC must permit the passage of water (hydrophilic material) through the skin, as well as allow gases and oils (hydrophobic material) generated in the tissue, to escape. At the same time it must keep out undesirable environmental elements.

CONTROL OF EPIDERMAL GROWTH AND DIFFERENTIATION

Much is being learned about the intricacies of growth control and the associated feedback mechanisms involved. The epidermis is a very active tissue, both anatomically and metabolically, being able



***Scientific Basis of Dermatology**, Thody and Friedmann, eds. Longman Group UK Ltd, 1986, p 28*

***Figure 1–3**. Left, diagram of intercellular substances showing lamellar bodies and neutral lipids. Note the circular enlarged area at right, showing the polar and non-polar lipids.*

to replace itself completely in 45–74 days. The SC in the young can be fully replaced in about 14 days, while individuals over 50 may require as long as 37 days to replace the SC.

Changes in the SC send messages to the basal layer to produce cells at different rates. For instance, where there is pressure, such as on the sole of the foot, more cells are produced to make a thicker SC—a callus.

The skin care specialist should be aware of the various disorders of the skin that are associated with a high growth rate of the epidermis. These skin diseases are called *proliferative disorders* and are treated by dermatologists. Psoriasis and certain ichthyoses (scaling conditions) are two examples of this disorder. The underlying cause of proliferative disorders is either a lack of control mechanism in the epidermis or in the dermis. This may be either an over-response reaction or lack of some inhibitory chemical. In any case, it demonstrates the interdependent relationship between the dermis and the epidermis.

The Dermis

The dermis accounts for more than 90% of the skin mass and for the greatest part of its physical strength. The major divisions of the dermis are the *papillary* layer and the *reticular* layer.

The papillary dermis is the most outer part of the dermis in direct contact with the epidermis. It is thin, contains small and loose elastin and collagen fibers, and the lymphatic and blood vessels. In addition, there are connective tissue cells and interfibrillar gel in the papillary dermis.

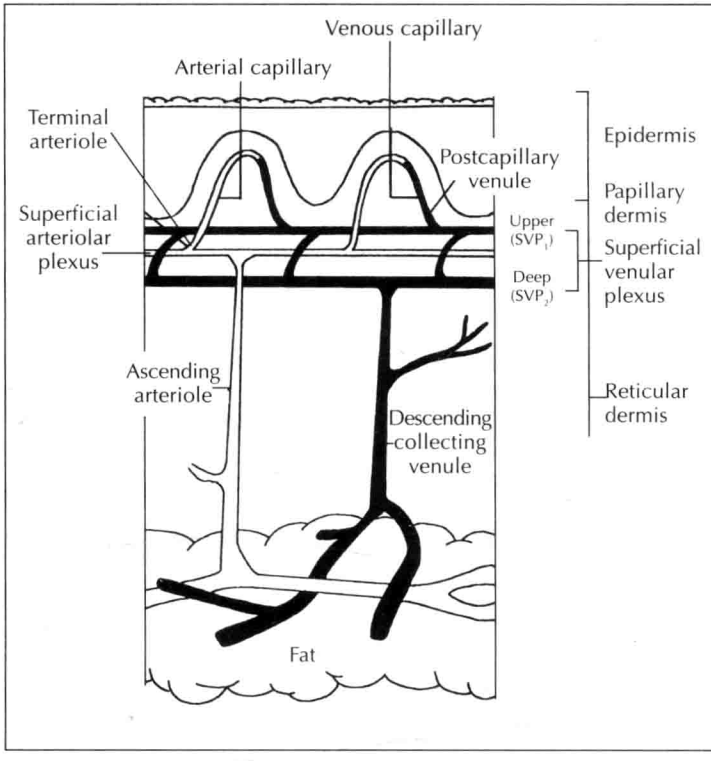
The reticular dermis is under the papillary dermis and is found to have fewer cells, relatively few blood vessels, dense collagen bundles and coarse elastin fibers. This is the area which carries most of the physical stress of the skin.

Blood Vessels in the Dermis

The blood supply to the skin and the sweat glands, along with heat receptors and the central and sympathetic nervous system, are the chief players in the skin's role as a heat control organ. At this point the focus mainly is in the blood vessels of the skin.

The peripheral blood vessel system is a three-dimensional maze of both large and small arterial and venous vessels. Starting with the cutaneous arteries, a number of smaller arterioles are given off to form the subcutaneous vascular bed. At the top of this system the fine capillaries of the papillary dermis serve to nourish the epidermis. (See **Figure 1–4**.) The vertical vessels connecting these two plexuses are the major skin blood vessels employed in heat control. The capillary is the key structure in the skin for our purpose and this small vessel needs to be understood in detail.

Capillaries develop in the embryo about the fourth month of gestation. By the fifth month new vessels form from existing vessels



Dermatology in General Medicine. Third Edition, Fitzpatrick et al, eds, McGraw-Hill, New York, 1987, p 358

***Figure 1–4**. Diagram of the blood circulation of the skin showing the arterioles, venules and the capillary loops. The vessels are not drawn to scale but are excellent graphic representations of the blood vessel system in the skin.*

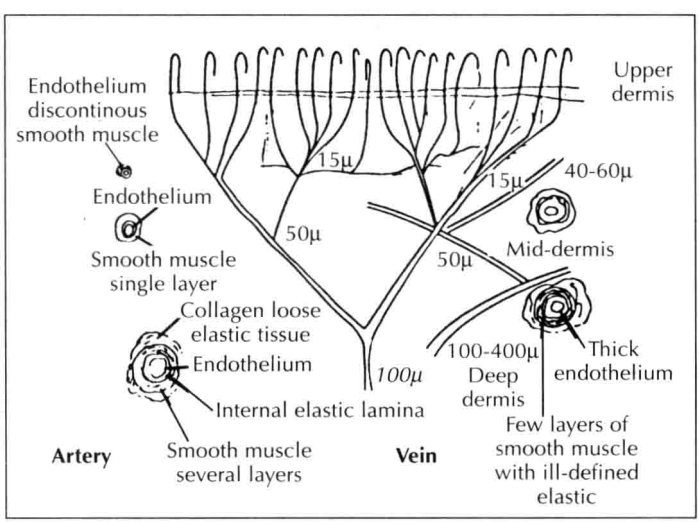
by budding. In a fetus at this stage the skin is very thin, only a few cells thick, but it now increases rapidly and there is active and rapid blood vessel proliferation. The tiny capillaries now form into arterioles and venules, developing muscular coats and spreading the underlying tissue. These vessels will be the adult subcutaneous blood vessels. The ability of skin to repair itself after injury lies in this primitive ability to grow new vessels from capillaries.

Visualize the capillary network as a series of loops that arise from arteries which become smaller and smaller until they form tiny vessels of a few microns (u) then loop over and become tiny venules that reverse the direction and grow larger as they return to the dermis. (See **Figure 1–5**.)

In one square mm of skin on the face, there is on an average 150 loops, 38 on the ears, 100+ on the neck, 45 on the arms, 60 on the hands, 20 on the fingers and 40 on the legs and the feet.

THE CUTANEOUS NERVES

The skin is the largest sensory organ in the body. It must be able to detect many sensations such as pain, pressure or touch, itch, heat,



The Physiology and Pathophysiology of the Skin, Volume 2, Jarret, ed, Academic Press, New York, 1973 p 620

***Figure 1–5**. Schematic diagram of the blood supply to the skin showing the various sizes and vessel wall structures.*