Book Report

The Biology of Skin

Alice Maceo

Las Vegas Metropolitan Police Department

Reference: *The Biology of Skin*; Freinkel, R. K.; Woodley, D., Eds.; Parthenon Publishing Group: New York, 2001.

Preface: The science associated with the latent print profession is often hard to put a finger on because the science is spread out over so many disciplines. It's amazing how many subtle, yet significant, details you find looking in different places (biology, chemistry, vision studies, pattern formation, chaos theory, scientific method, etc.). Even if you studied one of these areas as a student, it's enlightening to go back and discover the relevance of the topic to the latent print discipline. From my own perspective, as a student, I desperately memorized as much as possible for a final and had no practical application for the knowledge. Consequently, much of the knowledge was filed away in some irretrievable area of grey matter. Reviewing these topics in a more leisurely manner from the perspective of a latent print examiner has been tremendously rewarding because the material now has relevance to a profession.

This article will be the first in a series published in the JFI that introduces the latent print community to sources available in the scientific disciplines foundational to the practical application of latent print examination. The bibliographical information of the source and a summary of the information that the latent print community may find useful will be presented.

Introduction

The Biology of Skin provides a review of the current understanding of how the skin functions. Reading the book from the perspective of a latent print examiner, the sections describ-

ing how the skin maintains itself are most intriguing. These sections explain how ridge detail maintains itself, and – viola! – permanence. This epiphany is important. When discussing the structure of the skin, the following question almost always arises: How can the skin be permanent, when the cells are always flaking off the surface?

The following sections summarize information that lends itself to a greater understanding of the concept of permanence (of all the levels of ridge detail). The information is not presented in the order the book presents the information. Rather, the relevant information from different chapters of the book is correlated in a manner that hopes to illustrate its usefulness to the latent print community. The information from *The Biology of Skin* is supplemented with explanations from *Principles of Anatomy and Physiology*, 7th ed., edited by Gerard J. Tortora and Sandra Grabowski, published by HarperCollins College Publishers, New York, 1993. The supplemented explanations include the discussion under the section entitled "Homeostasis" and the subsection "What is a Cell Cycle?" under the section entitled "A Closer Look at Proliferation".

The Bottom Line

The conclusion section of Chapter 12, "Epidermal kinetics and regulation of cell proliferation", says it so succinctly . . .

> … the rate of epidermal proliferation is orchestrated by a complex interplay of positive and negative regulators. Positive regulators, such as growth factors and oncogenes, are balanced by the activity of tumor suppresser gene products and inhibitory proteins. In the normal epidermis, these regulatory factors interact in a balanced fashion to maintain homeostasis between cell proliferation and death. Page 206

But what does this mean?

Homeostasis

Homeostasis Defined

Homeostasis refers to the relatively constant chemical and physical conditions that are maintained within the internal environment of the body. Although the body strives to maintain constant conditions, it is not static. The body is constantly assessing the environment and making adjustments as necessary. The body must maintain this dynamic steady state in order for its cells to survive and function efficiently.

Methods of Homeostasis: Feedback Systems

In a dynamic steady state, there must be a mechanism in place to monitor the "state" of the organism and initiate changes if the "state" is not within tolerance. This mechanism is referred to as a feedback system. The terminology involved with feedback mechanisms is as follows:

Controlled system – a system whose activity is regulated to maintain the appropriate level of a particular variable.

Set point – a reference that calls for or indicates the level at which the variable is to be maintained (e.g., the minimum or maximum concentration of a protein).

Receptor – monitors the variable and transmits information (feedback) to the processing center.

Processing center - evaluates the information from the *receptor* about the actual level of the variable and increases or decreases the activity of the *control system* in order to re-establish the *set point.*

Negative Feedback – When the activity of the control system reverses the level of the variable, it is called a negative feedback system. When the level of the variable becomes too high, the processing center signals the control system to slow or halt production of the variable. If the variable becomes too low, the processing center signals the control system to increase or resume production.

Positive Feedback – When the activity of the control system enhances the level of the variable, it is called a positive feedback system. The presence or increase in level of a variable stimulates the control system to produce more of the variable. The decrease in the level of a variable signals the control system to further reduce the level of the variable.

Overview of the Epidermis

The epidermis is a stratified, continually renewing epithelium that exhibits progressive differentiation as the cells move from the basal layer to the surface. In other words, the epidermis is layered because the cells (termed keratinocytes) are undergoing changes as they move from the bottom of the epidermis to the top of the epidermis. These changes, generically termed differentiation, may be referred to as keratinization or cornification. Keratinization refers to the biochemical activity inside the cell which causes the cell to become filled with the protein keratin. Cornification refers to the physical hardening of the cell as it fills with keratin.

The cells are pushed upward from the bottom of the epidermis because the basal layer of epidermal cells is always multiplying, forcing older cells upward. Skin thickness varies across the surface of the body, with the thickest on the volar surfaces. Maintenance of the skin thickness (the number of cells from the basal layer to the surface) depends on the balance between cell proliferation (how fast the basal cells multiply) and cell differentiation (how fast the cells are committed to moving upward). Homeostasis of the skin is maintained by the interaction of the keratinocytes (primary cells in the epidermis which comprise 90 to 95% of epidermal cells) with immigrant cells of the epidermis (melanocytes, Langerhans cells, Merkel cells), the adhesion of the keratinocytes to each other and to the basement membrane, and the interaction of the epidermis with the dermis.

The process of differentiation (keratinization) is a genetically controlled, tightly regulated series of morphological and metabolic events which involves: "(1) the loss of the ability to proliferate; (2) an increase in cell size and cell flattening; (3) the formation of new organelles together with structural reorganization of existing organelles, and eventual loss of organelles;

(4) synthesis of new proteins and lipids; (5) changes in plasma membrane properties, cell surfaced antigens and receptors; (6) dehydration" Page 21. The end point of the keratinization process is a terminally-differentiated, dead cell that contains filamentous and free (nonfilamentous) keratin and a protein-reinforced plasma membrane with associated lipids. The keratin inside the cells and protein-reinforced cell membranes impart durability while the lipids between the cells act as intercellular grout.

A Closer Look at the Layers of the Epidermis: Opportunities for Regulation

Basal Layer

The basal keratinocytes are structurally and functionally associated with components of the underlying basement membrane zone via hemidesmosomes. Hemidesmosomes are plaques on the bottom side of the basal keratinocytes that adhere the basal keratinocytes to the basement membrane and provide a channel for communication with the rest of the body. The hemidesmosome imparts structural integrity to the epidermis and provides a physical pathway for signals from the circulatory system that regulate keratinocyte proliferation, migration (necessary for wound healing), and differentiation. *Hemidesmosomes assist in the homeostasis of the skin by providing structural support and a communication system between the epidermis and the rest of the body. The keratinocytes are constantly evaluating the greater system and being evaluated by the greater system to maintain the appropriate chemical and physical state.*

Basal cells are also connected to each other by desmosomes. *The desmosomes provide structural support and a mechanism for cell-to-cell communication. Basal keratinocytes that are not close to the capillaries in the dermal papillae rely on cell-to-cell communication to pass on signals from the system.*

Basal keratinocytes are not all the same. They can be subdivided into three groups depending on their potential to proliferate (divide). Ten percent of basal keratinocytes are stem cells, long-lived cells capable of continuous self-renewal. When stem cells divide, they produce two daughter cells: one remains in the basal layer as a stem cell, the other is destined to differentiate. The daughter cell destined to differentiate is termed a transient-amplifying cell and will undergo a few rounds of

division in the basal and first suprabasal layer before committing to differentiation. Fifty percent of the basal keratinocytes are transient-amplifying cells. Transient-amplifying cells are more concentrated in the primary ridges than the secondary ridges of the epidermis. The remaining 40% of cells in the basal layer are cells that have passed through the transient-amplifying stage and are committed to terminal differentiation. *Homeostasis of the epidermis can be regulated by controlling (1) the rate of proliferation of the basal keratinocytes and (2) the commitment of the transient-amplifying cells to terminal differentiation (control of cell birth and cell death).*

Spinous Layer

Once committed to differentiation, the cells (keratinocytes) immediately begin to change structurally and may be referred to as spinous cells. The spinous cells have abundant cellular junctions (desmosomes) that were established in the basal layer during cell division. These junctions cause the cells to look spiny in histological preparations, hence their name. The spinous cells are polyhedral (whereas the basal cells are columnar and the upper layer cells are more flattened). Spinous cells contain large bundles of keratin filaments organized concentrically around the nucleus and inserted peripherally into desmosomes. *The organization of the keratin filaments around the nucleus and into desmosomes, which link each cell to its neighboring cell, provides a complex web of durable filaments that lock the cells in place and maintain cell communications. Structural changes are regulated by gene activity induced by signals internal and external to the epidermis.*

Granular Layer

As cells enter the upper limits of the spinous layer and progress into the granular layer, two new organelles develop: keratohyalin granules and lamellar granules. Keratohyalin granules contain the precursors of keratin and other proteins necessary for the structural reinforcement of the interior of the cell and cell membrane. Lamellar granules are small secretory organelles that excrete precursors of the lipids associated with the stratum corneum into the intercellular space. As cells progress into the stratum corneum, the intercellular lipids are remodeled to aid intercellular adhesion and to repel water. This adhesion and hydrophobia imparts the epidermis with its impermeability. As the cells reach the upper layers of the stratum

corneum, the lipids are remodeled again to allow for hydration and desquamation (loss of the cells at the surface). *The genesis of new organelles and release of lipids into the intercellular space are initiated and regulated by gene activity induced by signals internal and external to the epidermis. Products secreted by the lamellar granules also provide signals for regulation and differentiation of epidermal cells, maintaining homeostasis by relating cell birth and cell death.*

The Transitional Layer (Stratum Lucidum)

There is an abrupt transition from the granular cell to a terminally cornified cell. The granular cell not only synthesizes the structural proteins involved in keratinization, it also participates in its own-programmed destruction. Destruction is driven by degradative enzymes generated in the granular cells and involves the destruction of the cells organelles, including the nucleus. *As with all changes in the keratinocyte, genesis of degradative enzymes is regulated by gene activity triggered inside the cell.*

The Stratum Corneum

The stratum corneum is a complex of protein-rich, terminally-differentiated keratinocytes (corneocytes) surrounded by a lipid matrix. The corneocyte is the largest of the keratinocytes and is a flattened, polyhedral shape. The shape and features of the corneocyte are adapted to maintain the integrity of the stratum corneum, yet allow for desquamation. Changes in the structure, composition, and function of the corneocytes occur as they move toward the outer surface. Cells of the deeper layer of the stratum corneum are thicker and have more densely packed parallel arrays of keratin, have a more fragile cornified cell envelope (membrane), and have a greater variety of desmosomes for cell-to-cell attachment. Cells of the outermost corneum have a rigid cornified cell membrane and undergo degradation of the desmosomes to allow for desquamation.

A Closer Look at Proliferation

What is a Cell Cycle?

Cell cycle refers to the stages of a mitotic cell. A mitotic cell is one that replicates its DNA and divides to create another cell. Basal keratinocytes and transient-amplifying cells are mitotic. The stages of the cell cycle are as follows:

G1 - gap (resting phase) after the completion of mitosis and prior to the beginning of DNA replication

R Point – restriction point where the cell monitors signals and determines if conditions are favorable for DNA replication

S Phase – DNA replication (the cell makes a duplicate copy of its DNA)

G2 – gap (resting phase) between DNA synthesis and mitosis

R Point – restriction point where the cell monitors the results of DNA replication before the cell enters mitosis (cell division)

Mitosis – the cell divides, generating two daughter cells.

After mitosis, each daughter cell can either enter G1 and start another cycle (e.g., stem cell or transient amplifying cell) or terminally differentiate (e.g., committed keratinocyte after completing a few rounds of division as a transient amplifying cell).

Regulation of Cell Cycle

Growth stimulatory signals originate from outside the cell. The growth factor may originate far from the cell in an endocrine gland (transported by the circulatory system to the capillaries of the dermis where it is passed through the basement membrane zone to the basal keratinocytes), may be secreted by neighboring cells (via cellular junctions or the interstitial fluid), or may be secreted by and act on the same cell. Cellular proliferation often depends on specific combinations of growth factors rather than a single factor. Growth factors act via receptors on the cell surface.

When the cell surface receptor binds a growth stimulatory signal, a cascade of reactions occurs inside the cell to initiate cell proliferation. Initiation of cellular proliferation means activation of proto-oncogenes. Proto-oncogenes are the genes whose protein products participate in cellular proliferation. The proto-oncogenes produce the components necessary to replicate the DNA and divide the cell, in addition to the regulatory proteins that control the cell cycle. These regulatory proteins mediate actions necessary for progression through the cell cycle during the G1 or G2 phase of the cell cycle.

In the steady state of the mature epidermis, the number of new cells produced is balanced by the number of cells leaving the proliferative pool (committed to terminal differentiation). The normal products of cells undergoing terminal differentiation act to "feedback inhibit" cell proliferation. If too many cells are differentiating, proliferation of the basal layer will be suppressed in order to maintain the appropriate thickness of the epidermis.

Growth inhibitory signals can also be received from outside the cell. A growth inhibitory protein binds to a receptor and activates anti-oncogenes. Anti-oncogenes (tumor suppressant genes) are the genes whose products prohibit cellular proliferation.

In Plain English: So What Do I Tell the Jury?

If you are having a really rough day in court and the question comes up, what are you going to say? Regulation is the key to understanding why the ridges (first and second level detail) and the surface contour of the ridges (third level detail) remain consistent despite cells leaving the surface. The body continually strives to keep all its systems in balance. Certainly the skin is an important organ to maintain because it is our shield from the outside world and serves many vital functions. The body is engineered to keep the rate of cellular proliferation and terminal differentiation (cell birth and cell death) in balance (homeostasis of the skin). There are many pathways in place to provide regulation and act as a fail-safe in the event one pathway of regulation becomes disrupted. If the body cannot rectify an imbalance in the rate of cellular proliferation or terminal differentiation, then a diseased state is present (e.g., melanoma).

Large groups of cells on the basal layer of the epidermis are responsible for generating and maintaining the surface ridges. Even small features of a surface ridge (e.g., bumps and grooves) are continually reproduced as new cells are pushed upward to replace cells lost at the surface. As latent print examiners, impressions of the surface ridges are studied. These impressions, however, are not studied at the cellular layer. The impressions are studied for those very features that are reproduced over the lifetime of the individual because of the body's inherent drive to maintain itself.

Comments

The Biology of Skin has much more detail to offer than is presented here and has an extensive bibliography for each chapter. Other suitable references certainly exist and should be sought. The Internet and local libraries are great places to find sources.

> "You can know the name of a bird in all the languages of the world, but when you're finished, you'll know absolutely nothing whatever about the bird . . . So let's look at the bird and see what it is doing – that's what counts. I learned very early the difference between knowing the name of something and knowing something."
>
> – Richard Feynman (1918 – 1988), US educator and physicist.

Acknowledgments

I would like to thank John Vanderkolk (Indiana State Police Lab) for his reading recommendations, input, and encouragement. I would like to thank Alan McRoberts, editor of the JFI, for giving the JFI the flexibility to publish the information in this format. And last, but certainly not least, I would like to thank the Las Vegas Metropolitan Police Department Forensic Laboratory for their unwavering support of independent inquiry.

Alice V. Maceo, CLPE
Las Vegas Metropolitan Police Department
Forensic Laboratory
6765 West Charleston Blvd.
Las Vegas, NV 89146
(702) 229-3938
a7828m@lvmpd.com

[Editor's note: This is the first of what the staff hopes will be many special "Book Reports" on topics related to our various disciplines. It should be noted that this is a "Book Report", not a "Book Review". It is a critical summary of pertinent information presented from the book versus a critical review of the book's presentation of information.]