A central component of an anti-cellulite aesthetic program is the use of devices that deliver physical energy to deeper skin layers. While many options exist, they share a common capability: activating physiologic processes that reduce SAT volume. At the same time, superficial skin layers are either unaffected or only minimally disrupted, thereby substantially lowering the risk. Unlike injectable procedures, these approaches can treat larger areas without allergic reactions or other adverse effects associated with injected substances. And unlike cosmetic products that mainly act on the surface, physical energy can reach deeper tissues.

Depending on the primary mechanism, these approaches can be grouped into five categories:

1. Mechanical
2. Electrical
3. Light
4. Sound
5. Temperature

Combined technologies also exist and incorporate more than one mechanism. For example, RF microneedling creates multiple skin punctures with needle electrodes while delivering alternating RF current. Other combinations are also used and are discussed in the relevant sections.

Chapter 1
Mechanical technologies

One of the oldest and most accessible ways to influence the body is massage. In general, massage involves mechanical action on the skin using hands or dedicated tools. Techniques vary and may include:

- Pressure (static at a point or dynamic across multiple areas)
- Tapping
- Vibration
- Compression and decompression
- Stretching
- Kneading
- Stroking

Massage techniques have evolved over centuries, based on observations and practical experience passed down through generations. It was not until the 20th century, with advances in medical engineering, that massage progressed substantially. New devices improved control over applied force and exposure time and enabled the combination of mechanical action with other inputs, such as light and temperature.

A dedicated field, **skin mechanobiology**, has since emerged. It focuses on the biomechanical properties of dermal tissues and how cells respond to external mechanical forces. This research has reshaped how we think about the skin's role in massage: the skin is not merely a passive conduit relaying signals to deeper, damaged tissues. It actively participates and can undergo structural change. This opens additional opportunities to use massage for skin rejuvenation and to address a range of aesthetic concerns, including body contouring.

Today, massage techniques are an essential component of aesthetic care aimed at improving skin structure and function. However, to achieve durable, clinically meaningful results, dedicated tools are often needed to reliably reach different depths and address multiple targets simultaneously. To emphasize these clinical capabilities, massage performed with devices is increasingly referred to as **mechanotherapy**.

1.1. Mechanotherapy: molecular and cellular mechanisms

External mechanical forces can deform the skin, altering its three-dimensional structure (**Fig. IV-1-1**). Both the extracellular matrix and the cells themselves undergo deformation. This triggers cellular processes that affect function and lead to tissue-level structural remodeling.

Fig. IV-1-1. Skin deformation during massage

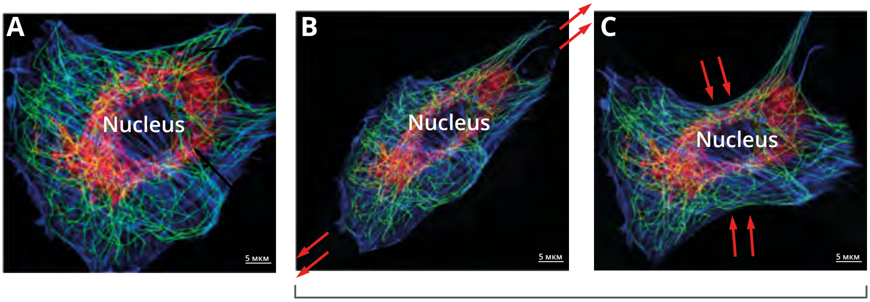

Fig. IV-1-2. Fibroblast cytoskeleton (fluorescence micrograph): microtubules (green), intermediate filaments (red).
A — fibroblast at rest; B, C — cytoskeletal and shape changes in the fibroblast under external deforming forces (adapted from Pollard T.D., Goldman R.D., 2018)

1.1.1. Cell cytoskeleton and extracellular matrix

Every living cell contains a protein framework known as the cytoskeleton (**Fig. IV-1-2**) (Pollard T.D., Goldman R.D., 2018). The cytoskeleton maintains cell shape at rest and is essential for movement, whether the entire cell migrates or parts of the cell capture and release substances from the surrounding environment (Pollard T.D., 2016). When the external environment changes mechanically, the cytoskeleton deforms: the cell may stretch globally, or specific regions may distort.

Cytoskeletal changes activate biochemical pathways that help the cell adapt to its environment. When fibroblasts undergo prolonged stretching, they increase fibrillar protein synthesis, forming a three-dimensional network. The fibroblast attaches to this fiber network and senses changes in tension because its internal cytoskeleton also shifts configuration (**Fig. IV-1-3**). To improve the skin's resistance to stretch, fibroblasts reinforce the tissue by producing new structural proteins, including collagen. This is one way skin adapts to increased mechanical load (Humphrey J.D. et al., 2014).

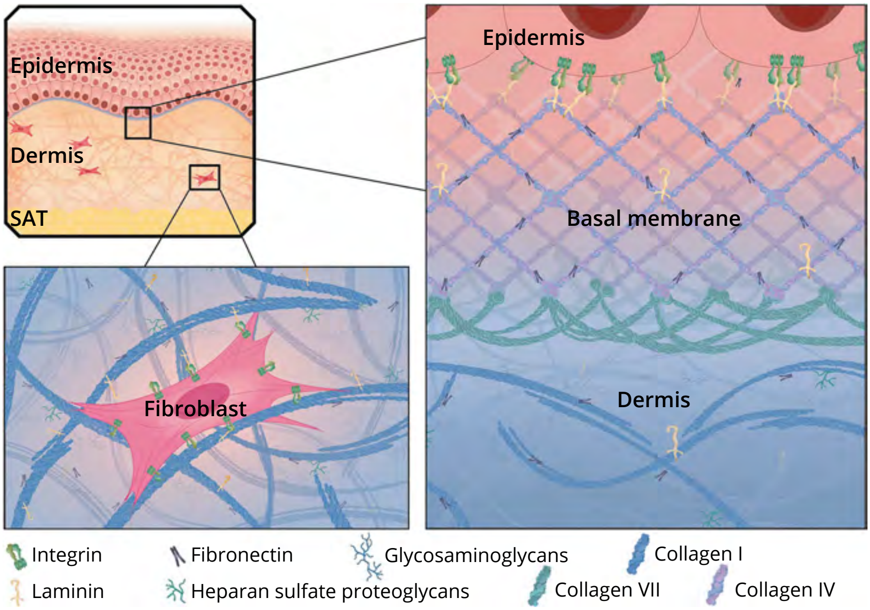

Fig. IV-1-3. Major structural molecules of the skin extracellular matrix (adapted from Pfisterer K. et al., 2021)

1.1.2. PIEZO channels: cellular mechanoreceptors

Dr. Ardem Patapoutian

Beyond the cytoskeleton, the cell's outer layer — the cell membrane — can also participate in mechanosensing. The membrane is a lipid bilayer, a thin, flexible film. Under mechanical load, it bends, and its lateral tension changes. Even small changes can be enough to alter the conformation of proteins embedded in the membrane. For many proteins, this has no functional impact. However, some cells contain specialized proteins that are highly sensitive to membrane deformation.

These proteins form ion channels. They were described in 2010 by American molecular biologist and neuroscientist Ardem Patapoutian, who named them PIEZO, from the Greek word πιέζω (piezo), meaning "press" or "compression." For this discovery, Dr. Patapoutian received

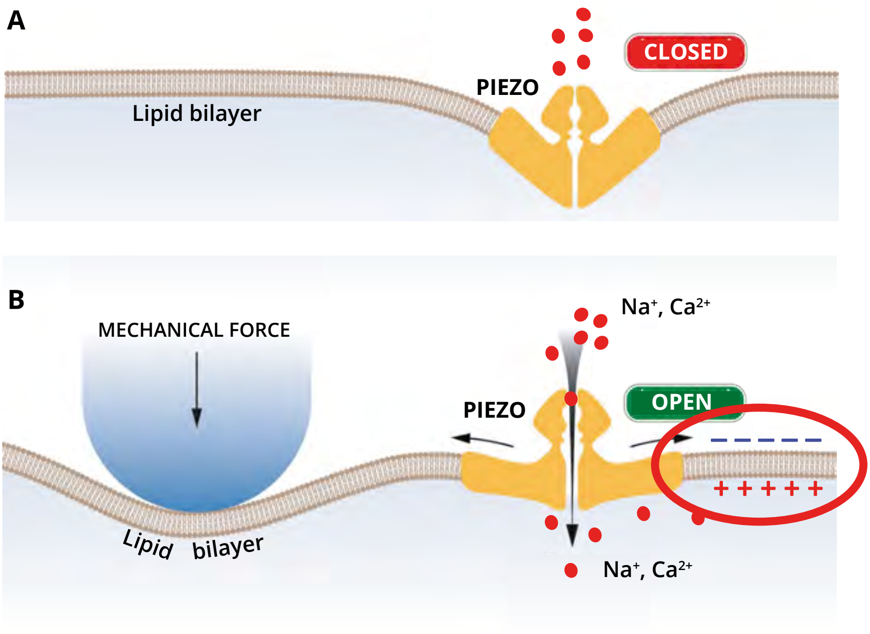

Fig. IV-1-4. PIEZO channels: mechanically gated ion channels

the 2021 Nobel Prize in Physiology or Medicine (Kefauver J.M. et al., 2020).

Typically, PIEZO channels are closed; hence, they are also called mechanically gated or stretch-activated channels (**Fig. IV-1-4**). When the membrane near one of these proteins is stretched by external force, the protein deforms, and the channel opens (Parpaite T., Coste B., 2017).

1.1.3. Tactile receptors: mechanoreceptors of the skin

PIEZO channels are present in endings of sensory (afferent) nerve fibers that respond to mechanical stimuli such as touch, pressure, and stretch. These specialized sensors are collectively called mechanoreceptors.

Mechanoreceptors in different organs are typically named for their function. Baroreceptors in vessel walls, the heart, and the bladder detect fluid pressure. Proprioceptors in muscles and joints respond to stretch and help coordinate movement. Vestibular receptors detect head motion and are critical for spatial orientation. Tactile receptors mediate skin sensitivity (Abraira V.E., Ginty D.D., 2013).

Although mechanoreceptors differ in structure across tissues, the core principles of detection and signal transmission are similar. The sequence can be represented as follows:

1. When the membrane is mechanically deformed, a PIEZO channel opens, allowing positively charged ions (such as Ca^{2+} and Na^{+}) to enter the cell (**Fig. IV-1-4B**).
2. On the inner side of the membrane, where negative ions predominate at rest, incoming positive ions reverse the local charge from "–" to "+". At rest, the membrane is negative inside and positive outside. When channels open and positive ions flow inward, polarity briefly shifts — this phenomenon called membrane depolarization (Ridone P. et al., 2019).
3. The depolarized region becomes the origin of a depolarization wave — a nerve impulse — that propagates. In a sensory neuron, the impulse travels from the mechanoreceptor along the axon. Eventually, excitation reaches the next neuron and the signal is relayed onward (**Fig. IV-1-5**).
4. The impulse ultimately reaches the brain (**Fig. IV-1-6**), where information is processed, and an appropriate response is selected. Commands then travel down motor neurons to their terminals. This triggers the release of signaling molecules that affect other skin cells, including immunocytes, endotheliocytes, keratinocytes, fibroblasts, and adipocytes. Each cell type responds to specific signals in a cell-specific way.

This is a broad, simplified outline of how external mechanical forces can influence skin structure, where **"deformation" is the key concept**.

- **Deformation of the extracellular matrix** affects the cytoskeleton and initiates biochemical processes within the cell; fibroblasts provide a clear example of direct detection.
- **Deformation of the cell membrane** can open PIEZO channels in tactile receptors, activating them and sending signals to

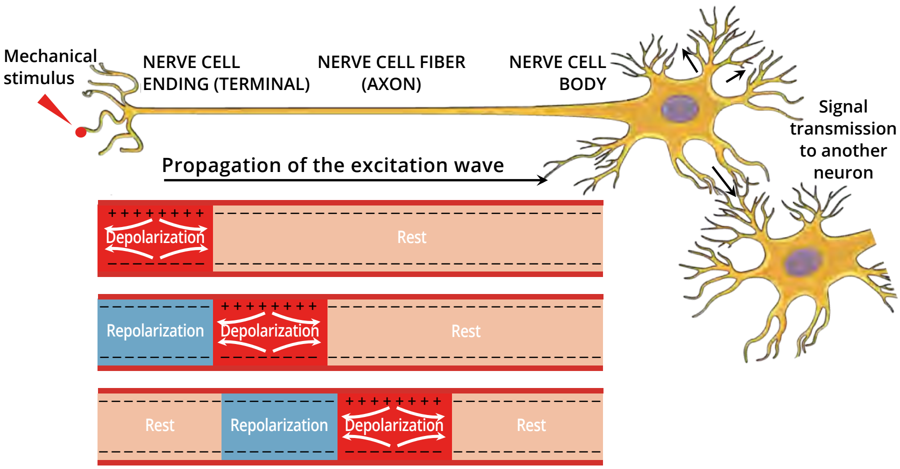

Fig. IV-1-5. Propagation of an excitation wave (impulse) along a nerve fiber

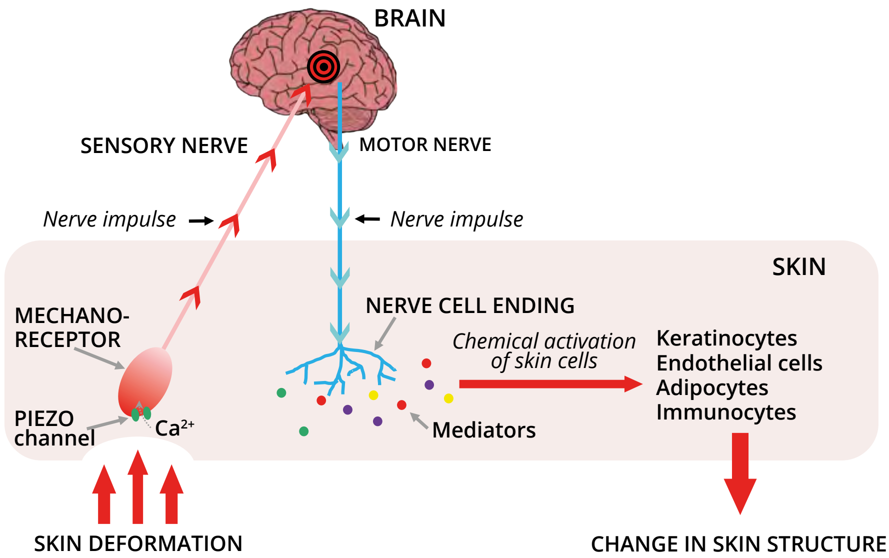

Fig. IV-1-6. Principles of skin mechanosensitivity the CNS via sensory nerve fibers. Commands are then returned to skin cells via chemical mediators released at motor nerve terminals. This pathway is referred to as indirect sensitivity.

Ultimately, all skin cells participate — directly or indirectly — in the response to mechanical forces and contribute to structural reorganization. The specific nature of the reaction depends on mechanical parameters such as force, duration, and direction (perpendicular to the skin vs. parallel to the surface).

1.2. Mechanotherapy technologies: variants and effects

Mechanical effects on the skin can be **constant** (often referred to as mechanical stress) or **variable**, such as those produced by mechanical vibrations (vibration therapy).

Mechanical stresses can also be classified by whether pressure is applied **above atmospheric pressure** (pressotherapy) or **below** it (vacuum therapy).

1.2.1. Manual massage

Manual massage is the simplest and most widely used form of mechanotherapy. Its effectiveness largely depends on the practitioner's skill and the techniques applied.

The clinical benefits of manual massage are commonly attributed to several mechanisms:

- Release of physiologically active, histamine-like substances with vasodilatory effects. Their action is relatively prolonged and can extend into deeper layers, influencing muscle tissue and improving soft-tissue nutrition.
- Improved lymphatic flow, supporting restoration of cutaneous homeostasis.
- Increased muscle tone contributes to smoother, firmer-looking skin.