Part I:

The Musician's Hand: An Organ of Exquisite Finesse! *

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Introduction:

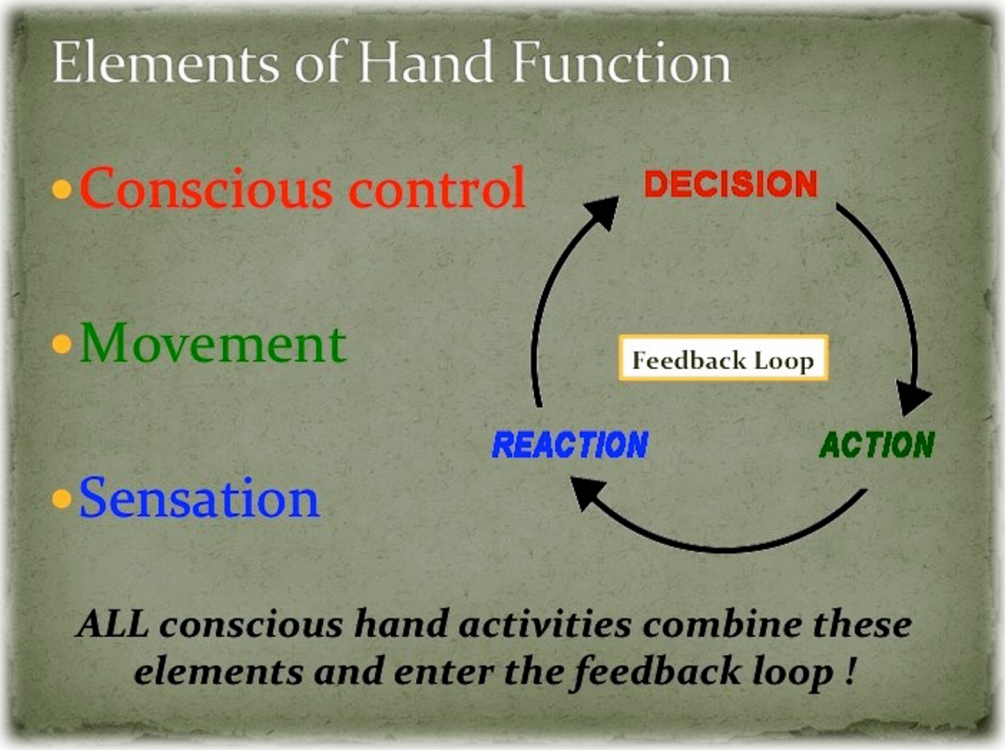
We all take our hands for granted until the day when we have pain or sustain an injury that prevents us from accomplishing a task that we have done effortlessly a thousand times before. Time and again over three decades as a hand surgeon I heard patients earnestly say to me: "*You know, Doctor, I'm not like everybody else. I **REALLY** need my hands!*" I would usually reply: "*Yes, I know exactly what you mean*" rather than: "*Yes, you really **ARE** like everybody else!*"

If we sit down and think about what we do with our hands we begin to realize that the answer is: *"Just about everything"*. The shorter list would be the things we **don't** do with our hands! Not only do they serve as universal tools that allow us to manipulate every aspect of our environment ("*manipulate*" is from the Latin for "*handful")* but they also allow us to touch and feel the many shapes and textures that are so much a part of our daily lives. We have no difficulty reaching into a purse or a pocket and discerning its contents. We can pick up a contact lens and place it gently into the eye or swing a sledgehammer with impressive power. We can feel the roughness of sandpaper as well as the smooth soft texture of a baby's skin!

As high-level or professional musicians you have taken these nuances a step further, to a level that goes **far** beyond the skills of the other 99.98% of the population. You have spent thousands of hours developing and maintaining the very unique and demanding skills required to play your instruments with extreme proficiency and endurance. The musician's hand is indeed an organ of exquisite finesse and if anyone needs to take a good long look at their hands and give them some serious thought, it's you!

In this first section our goal is to look at some important general concepts that govern the functions of the hand, wrist and forearm and to discuss the nature of pain in order to establish a basis for later discussions on how to avoid or manage problems that may interfere with your career in the years to come. Some of it may seem complicated (it is!) but it isn't necessary to memorize any terms, only to try to understand these basic concepts and their relevance to your own body when you play your instrument. The next sections are the most tedious and difficult to read but still explain physiological principles that may interest you at a later date. **If you find yourself falling asleep**, just do the demonstrations then skip ahead to ***"Sensation: The Nature of Pain***".

Elements of Hand Function: Conscious control, movement and sensation



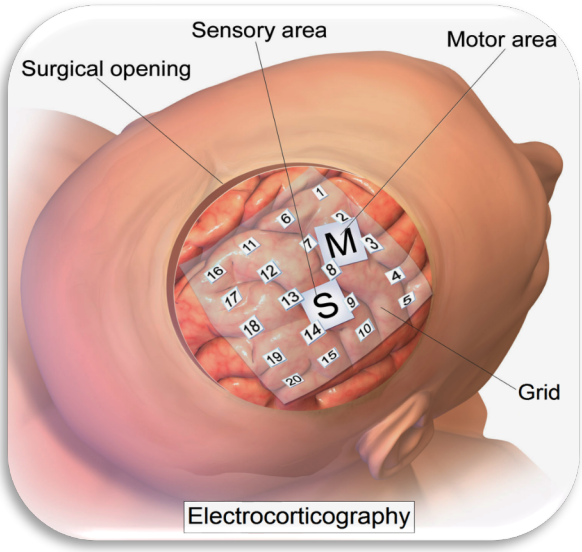
A. Brain and Hands

1. Conscious Control: The intellectual "niche" – our place in the animal kingdom
   a) For millennia early humans were mediocre predators surpassed in individual physical traits by many other animals
   b) Upright posture freed their upper limbs for other uses even when running
   c) Opposable thumbs gave them the potential for very fine manipulation of objects with their hands
   d) Social behavior, especially language, first spoken then written, helped them to pass on knowledge (including music!) to future generations
   e) But mainly, **superior brains** allowed them to solve problems, become toolmakers and progressively overcome essentially **all** of their physical shortcomings (some of their sophisticated tools were musical instruments for their own diversion!)
   f) Thus, even as mediocre predators, we became the masters of the planet with near absolute power over the other species (we still have some problems with viruses & bacteria!)

2. Brain development
   a) An infant's brain is about 25% of its adult size and weight at birth but its whole body is only about 5% of its adult weight – its brain will grow to 75% of its adult size by age 2 and 90% by age 6

b) The brain is a work in progress with basic modules present even before birth but most of its connections must still be formed (maturation) for normal function as it learns how to understand and control the body that surrounds it
c) Brain growth is rapid until the end of adolescence but continues very slowly until it peaks about age 40 then begins to get smaller ("*atrophy*")
d) Brain maturity is reached around age 25 but varies among individuals
e) The mature brain (more specifically the cerebral cortex or "*new brain*"- the outer covering of the brain like the "bark of a tree"- found only in mammals and a few reptiles) contains over 100 billion neurons that can each make over 1,000 connections with other neurons for an average total of approximately 60 trillion connections
f) The brain can monitor and control every organ in the body **except itself**, having no internal sensory nerve endings. Hence, it cannot sense touch, pressure, temperature, local chemical changes etc. and does not usually interpret pain as coming from within itself ("headache" rather than "brainache")

3. The cerebral cortex: **What are our brain's priorities?**
   a) How can we find out?
      1) Surgical treatment of uncontrollable epilepsy in the 1940's and 50's required detailed mapping of the cortical (outer) surface of the human brain
      2) Since the brain feels nothing, the cortical surface could be painlessly stimulated with electrodes in conscious patients awakened during surgery
      3) If motion occurred with stimulation, the site was classified as a "*motor*" area. If sensation was felt by the patient it was localized to a specific region and classified as "*sensory*"
      4) The surface area of the cortex devoted to a specific body region was then mapped showing how much of the brain controlled each particular area



5) This process (called "electrocorticography") was repeated in many different patients and even though minor variations were present, the map was found to be generally consistent and reproducible

b) The results: The "***Homunculus***" – meaning "*little human*"- is a model of a person that depicts the size of **each body part as proportional** to the surface area of the cortex that is devoted to it – the larger the part the more attention it receives from the brain. More recent studies have shown complex and extensive interconnections between these brain areas making this diagram simplistic but still indicative of the brain's priorities.

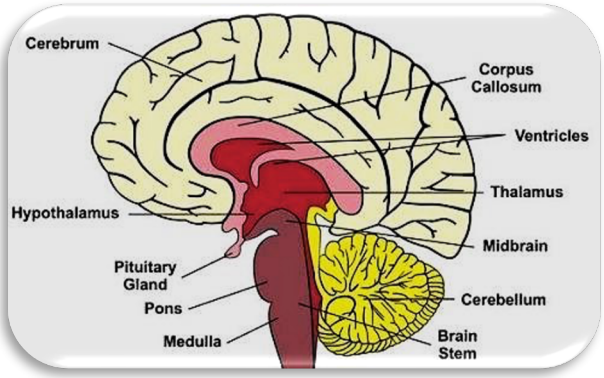
1) Conscious control of the hands and mouth (and the face for expressions) overshadows **every** other cortical occupation
2) Today we know that as elite musicians **you,** on average, develop the highest level of hand and/or mouth control (finesse) of any humans on the planet!
3) As such, you are the favorite subjects of neurophysiologists!
4) So, the homunculus can be summarized by: ***"hands and mouth"!*** The very thing musicians use most! **It's also no coincidence** that they are favored in nearly all other human activities!

It's no surprise that musicians communicate using their hands and mouths!

The most effective way of getting massive amounts of information into the cortex!

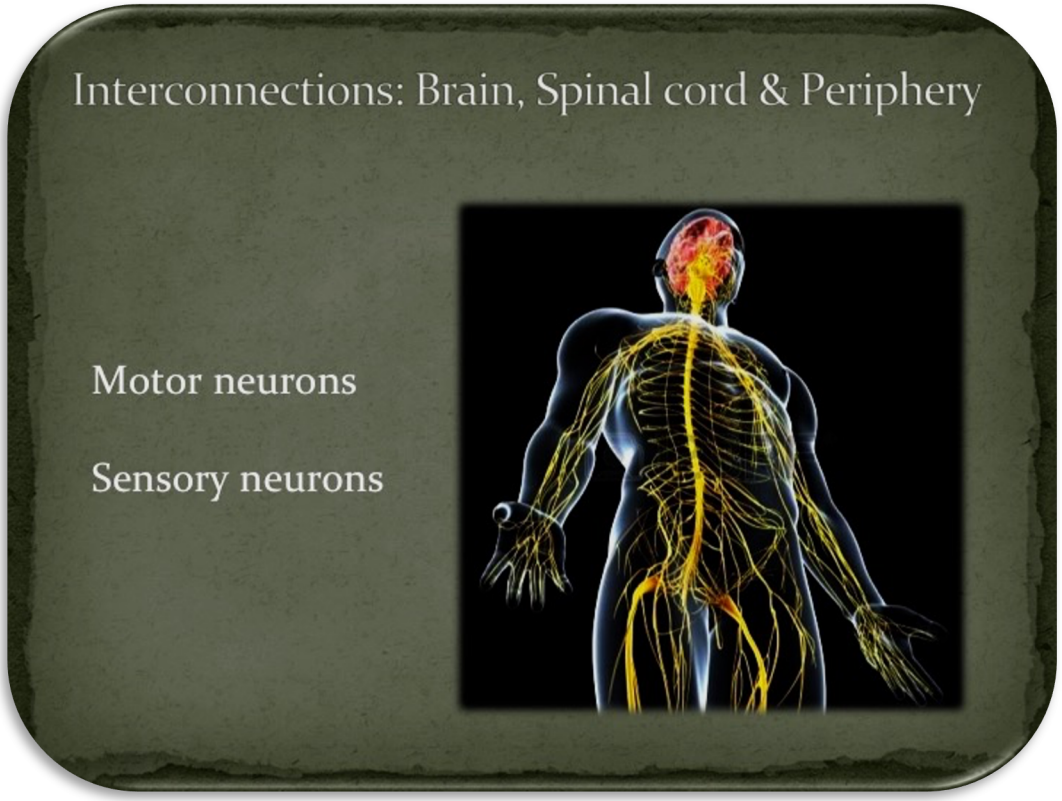
Humans use their hands and mouths to communicate their thoughts and feelings!

4. Unconscious control – some hand functions are controlled elsewhere in the brain and spinal cord (the "*old brain*")
    a) Vasoconstriction/dilatation
        1) Skin warmth
        2) Skin coloration
    b) Sweating
    c) Sebaceous secretions (skin oils)
    d) Trembling



5. Interconnections: getting signals to and from the body – the spinal cord and peripheral nerves
    a) The brain must communicate with the body (the "*periphery*") through nerve fibers ("*neurons*") traveling in **both** directions
    b) Motor neurons travel away from the brain sending signals to the spinal cord and the muscles
    c) Sensory neurons travel towards the spinal cord and brain sending feedback signals for analysis and comparison to the "*ideal*" outcome
    d) A **single nerve cell** to and from the limbs may be several **feet** long (its "*axon*") and an injury separates part of the cell from its nucleus causing cell death beyond the injury site ("*Wallerian degeneration*") – this is why it takes so long for an

injured nerve to regenerate (see "*Digital Nerve Compression*" in **Part III**) and why in some cases more severely damaged nerves cannot recover (This is an interesting topic but beyond the scope of our discussion.)

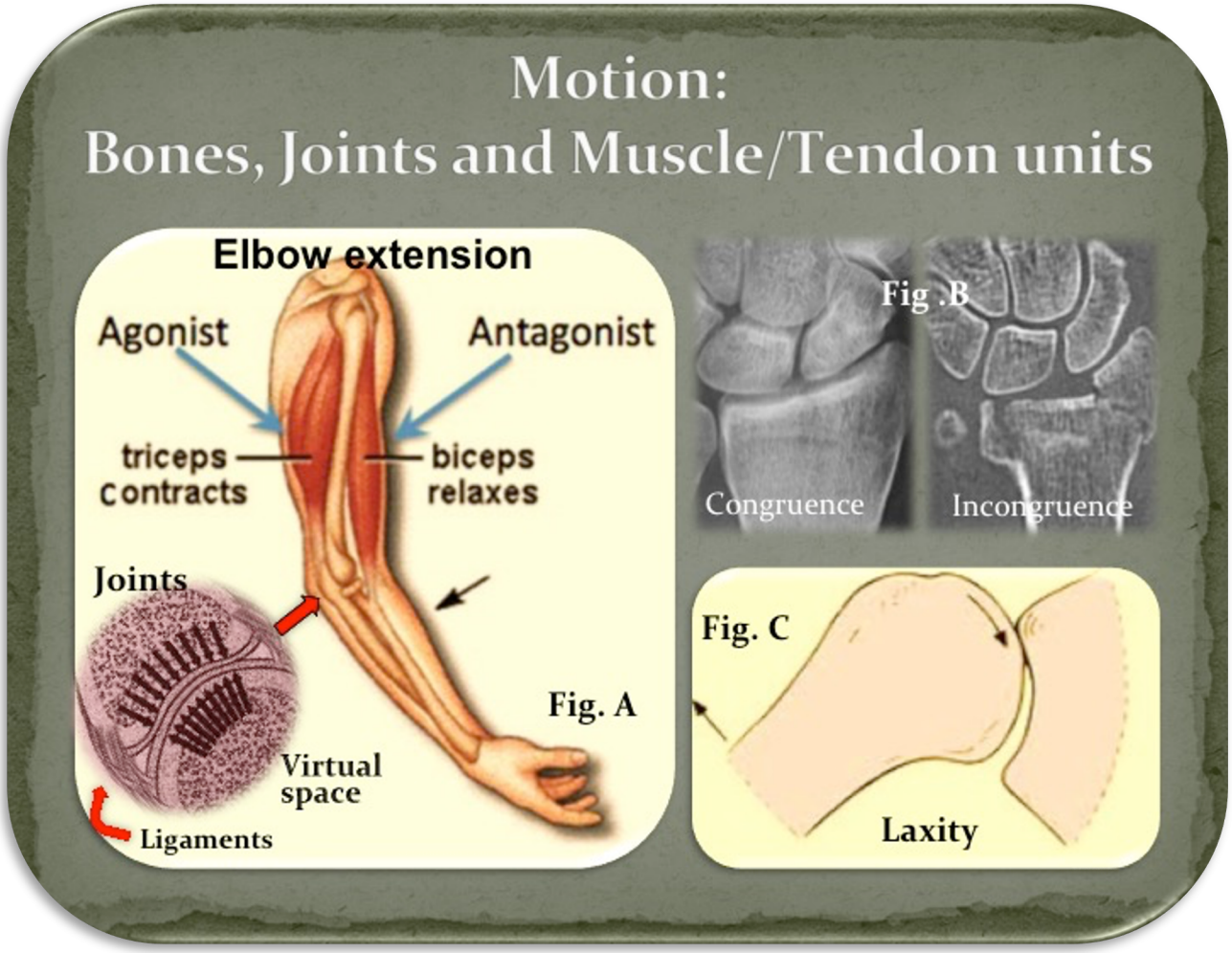


B. Movement – motor function

1. Bones form a solid base for muscle (and other tissue) attachments and provide a lever arm for motion. They give your body its form, shape and rigidity

2. Joints between bones have smooth gliding surfaces (cartilage) that allow for motion in **specific directions and amounts defined by their individual anatomy** (motion of your elbow allows you only to bend and straighten but your wrist and shoulder allow you to move in every direction but only by a specific amount)
   a) The two cartilage surfaces of a joint match **perfectly** creating a "*congruent*" surface (see Fig. A below). This is crucial to prevent wear damage as we'll see
   b) They interface so perfectly that they are separated only by a "*virtual*" space
   c) Motion helps create that precise interface so when a pregnant mother-to-be feels movement inside her uterus, her baby is fine-tuning the formation of the cartilage surfaces of the joints so they will be perfectly congruent at birth and form that virtual space.
   d) When you "*pop*" your knuckles you force open that space, like pulling a suction cup away from a piece of glass. The surfaces gradually come back into intimate

contact reforming the virtual space after a few minutes. No, contrary to what your mother said, popping your knuckles causes no long-term problems with your hands! In fact, popping joints is what you **pay** the chiropractor to do for you.



e) It is this "***congruence***" that allows our joints to move smoothly and without resistance by distributing the forces **equally over a large surface area** (Fig. A)
f) Any direct damage to the joint surface (like a fracture - Fig. B above) leads to areas of **localized** pressure that cause abrasive cartilage damage.

3. Ligaments hold the joints together providing stability and preventing **abnormal** motion. If a ligament is damaged or congenitally "*loose*" the two surfaces are no longer perfectly aligned (see "Laxity" – Fig. 3 above and the demonstration below) and the congruence is lost, again causing areas of localized pressure and subsequent abrasive damage

4. Demonstration: (Joint congruence)

a) Take three spoons from your silverware drawer and align the handles so they fit perfectly inside each other (Fig. 1 & 2)

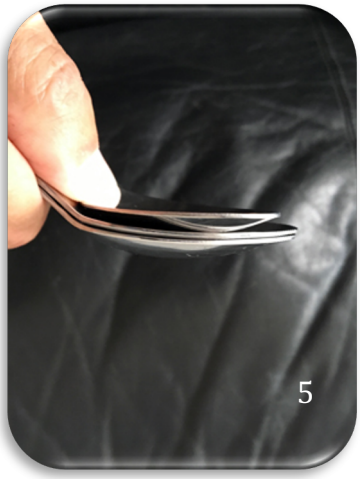
b) Rotate each spoon slightly relative to its neighbors keeping the handles aligned in exactly the same plane (Fig. 3)

c) Notice how the spoons glide and maintain contact over a large surface area (congruence) – this is similar to joints moving within their anatomically defined planes of motion

d) Imagine that a very strong but slightly elastic structure allows this rotating motion but will not allow the handles to change alignment (analogous to ligaments)

e) If you now "tear" or "*stretch*" the "ligaments" and misalign the handle of the top spoon a few degrees (Fig. 4 & 5) you will note that the surfaces are no longer "*congruent*". The top spoon is now elevated above the 2nd spoon and the two surfaces only touch at the edges (**localized** pressure)

f) Compare this to the relationship of the 2nd and 3rd spoons (Fig. 5) that still fit perfectly



g) If we move the spoons with the same motion shown in Fig. 3, the contact surfaces are now much smaller between spoon 1 & 2 and they will rapidly become "scratched" and worn ("*arthritic*")

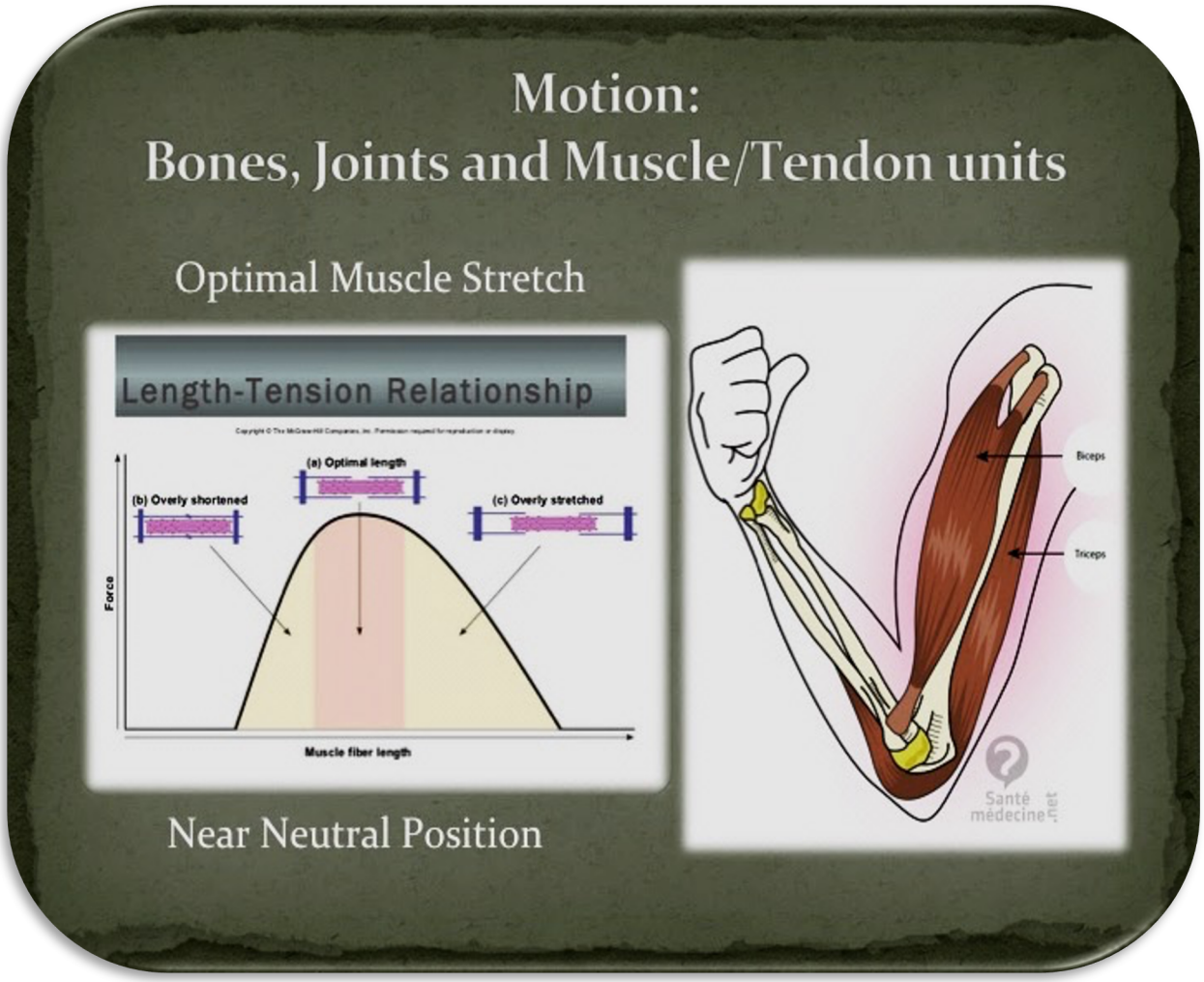
h) This illustrates the basic concept of degenerative arthritis caused by ligament damage or laxity

i) Thus, **ANY** process that damages the congruence of a joint will also cause it to "wear out" with usage. These "*pathological*" conditions fall into the general category of "arthritis" and they will be discussed in **Part III**

5. Muscles span joints and when they contract (shorten) they generate motion. Each muscle must have an origin on one bone and an insertion on another with a joint in between in order to effectively cause different "*kinds*" of motion in both direction and amount: (these terms below are for reference, not necessary to memorize!)
    1) Flexion – decreases the angle between the 2 bones
    2) Extension – increases the angle between the 2 bones
    3) Abduction – moves away from the midline of the body
    4) Adduction – moves toward the midline of the body
    5) Rotation – moves around an axis i.e., in the forearm: pronation = rotation with the palm down, supination = rotation with the palm up
    6) Distal – farthest away from the center of the body
    7) Proximal – closest to the center of the body

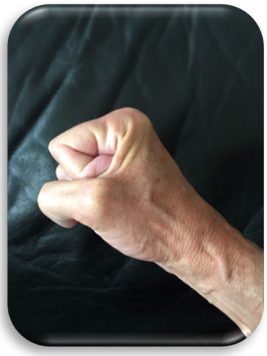
6. **Optimal muscle stretch (the musician's MOST important concept!)**
    a) Muscles that cause opposing motions are called **antagonists** – at extremes one of the pair is contracted and shortened while the other is relaxed and lengthened
    b) They never completely relax when the limb is suspended in the air because they must constantly work to counteract the force of gravity
    c) Smooth **precise** motion requires antagonists to contract simultaneously **against** each other and to coordinate their contractions in a "*give and take*" fashion
        1) This takes more energy (see the demonstration below)
        2) Uses "*eccentric*" contractions, that is:
            a) Muscle fibers are **forced to lengthen** as they actively contract
            b) Muscles are more easily strained under these conditions
            c) **These motions are routine for musicians**
        3) **Demonstration**: (Precision requires more energy)
            a) Gently touch the pulp surface (the skin at the tip) of your thumb to the same surface of your little finger and separate them again. Repeat this several times paying close attention to the force required in the muscles of the forearm and hand
            b) Now, touch the tip of the fingernail of the thumb to the top surface of the fingernail of your little finger without touching any skin surface together at any point (if you touch skin to skin anywhere, you played the wrong note!) Compare the tension on your muscles and the energy required to accomplish these two gestures. Precision requires more energy to apply the same force. You can mitigate this effect with "*efficiency*" (see **Part II**)

d) A muscle is strongest, is less prone to injury, uses energy most efficiently **and** has greater **endurance without pain and fatigue** when its fibers are stretched to a medium length (**optimal muscle stretch**)



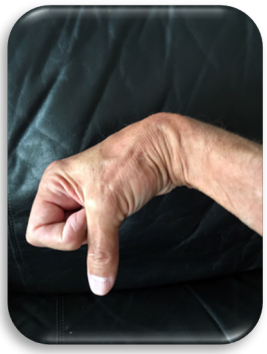
Demonstration: optimal muscle stretch

a) Hold your wrist straight in a comfortable position and make a **very tight** fist as if you were crushing something in your hand or trying to squeeze out every drop of water from a wet sponge (if you have long fingernails, put something soft in your hand so they don't dig into your skin). Hold this fist as forcefully as you can and keep track of how long it takes for you to feel either fatigue or any pain **in the forearm** (if you're still feeling great after a minute, you can stop)



b) Now rest for a minute then bend the same wrist as far as it will go towards your body. Holding it in that

position (use your other hand to help if you need to), make the same **very forceful fist** as if you were squeezing something and time how long it takes to feel pain or fatigue as you did above. Are you able to generate as much power? Were you able to hold it as long? Probably not. Why not? Do you **<u>Recognize this pain?</u>**



e) This optimal length is usually attained for both antagonists near the **middle range** of possible joint motion or the "*neutral position*". This range is quite narrow. It can vary somewhat from one individual to another so because your colleague is fine doesn't mean you will be!

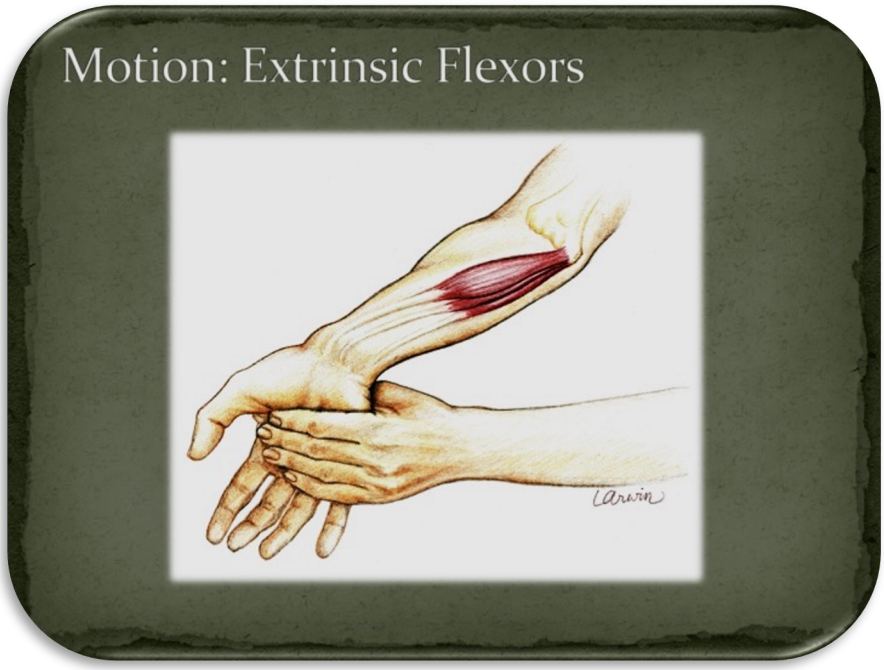
f) Extreme positions (laxity or overstretch) will make the muscle weaker, more prone to strain, rapidly fatigued, and **painful**. **This is "*physiological pain*"** (We will discuss this in some detail in **Part II**) and it can occur in the muscles that control **any joint** in your body (approximately 450 of them!). It becomes most important in **sustained** or **repetitive** activities (musicians!).

g) For a musician, this translates directly into technique and posture. **Failure to achieve near optimal muscle stretch will reliably cause chronic pain** and could end your career prematurely (this is the primary focus of **Part II**).

h) Modifying muscle stretch until the optimal is reached in **so many** joints is the most subtle and elusive thing that a musician can achieve, yet it is the **single most effective way** to prevent, reduce or treat physiological pain!

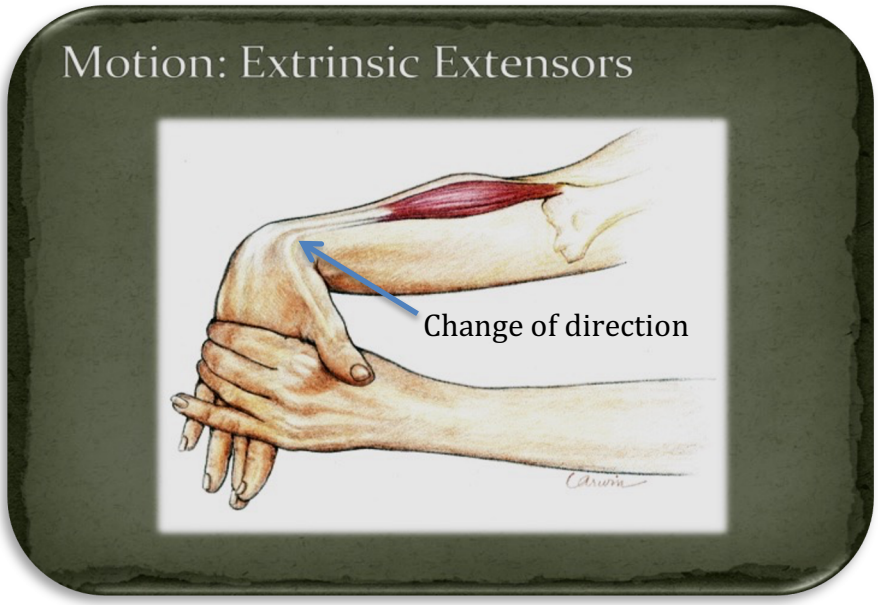
7. **"*Extrinsic*"** muscles and tendons:

a) Those whose muscle bellies originate in the forearm, **outside** the hand (thus



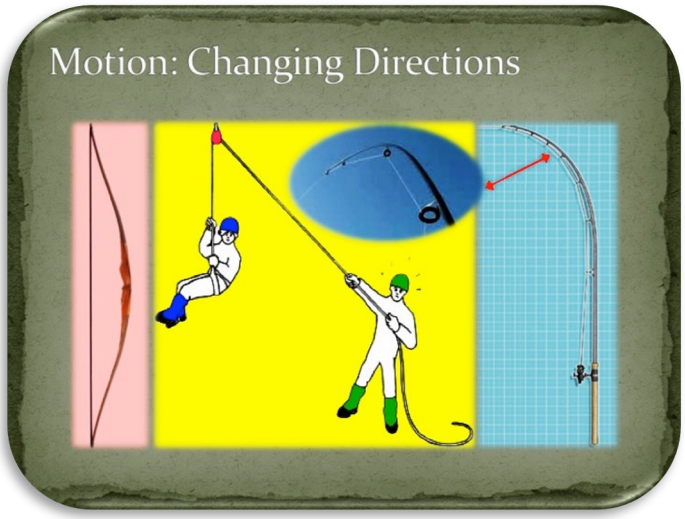
"***ex**trinsic*"), but are connected with fibrous tendons (like ropes) that insert somewhere on the hand or wrist. Thus, they control the hand **from a distance**

b) The size (volume) of a muscle determines its strength – if we had these large bulky muscles in our hands instead of our forearms, there would be no room left to hold or manipulate objects – **extrinsic** muscle-tendon units allow us to generate tremendous **power without obstructing** our grasp

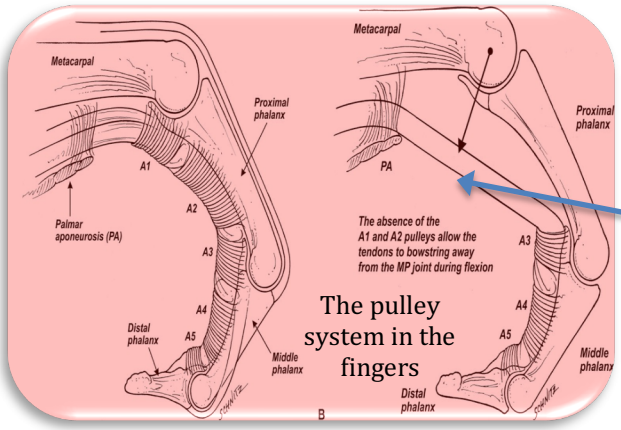


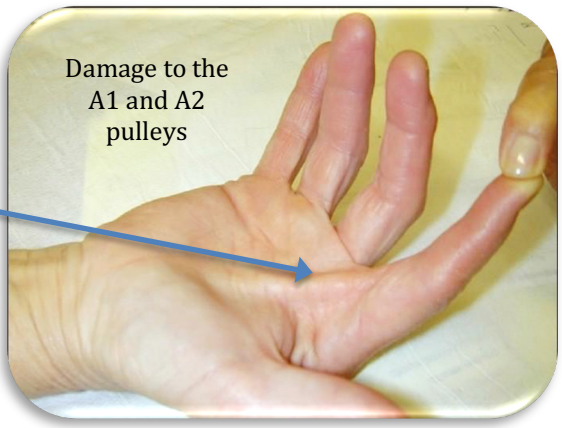
c) These units are responsible for most movements of flexion and extension of the wrists and fingers

d) Muscles pull (shorten) from fixed locations but tendons must **change directions** as joints move through **different positions**



e) A tendon behaves like a rope under stretch and will **always** pull in a straight line ("*bowstringing*") away from the flexion side of a joint **unless** there are one or more **pulleys** to hold it in place – compare the bow to the fishing rod above where the eyelets ("*pulleys*") hold the line against the pole – bowstringing is now in short segments allowing for a smooth change in directions keeping the tendon close to the bone, again making more space in the hand to hold objects





f) Tendons must glide freely through these pulleys

g) Since they have very large "*excursions*" (glide long distances) they cannot have blood vessels penetrating directly into them except at their insertions – as living tissues however, they must have nourishment

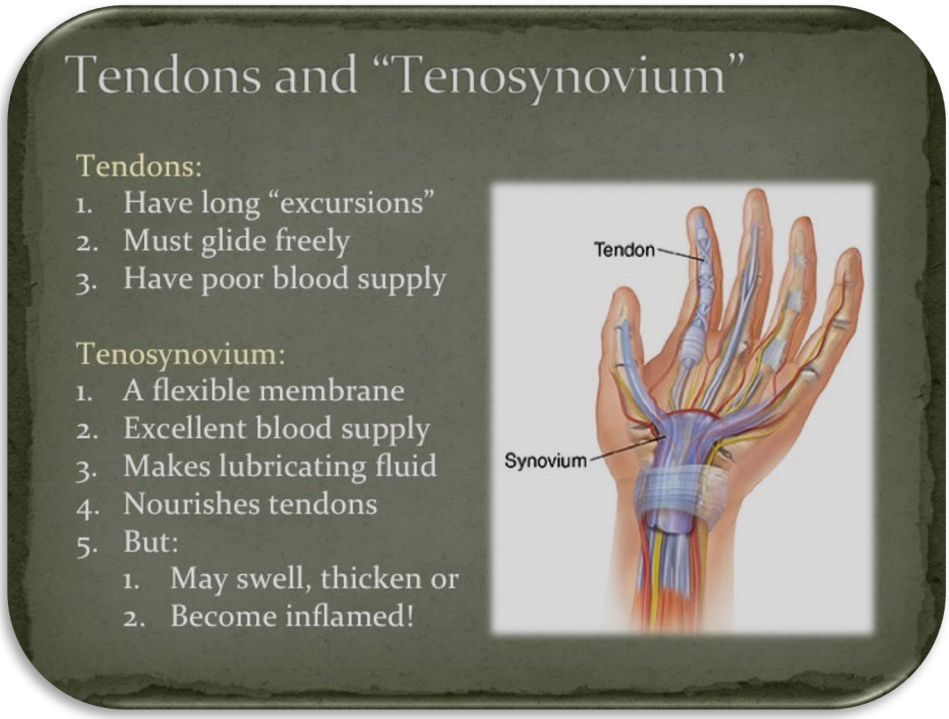
h) A membrane called the "tenosynovium" surrounds them and moves short distances with them

i) The tenosynovium has many blood vessels and provides nourishment to the tendons by direct exchange due to its proximity

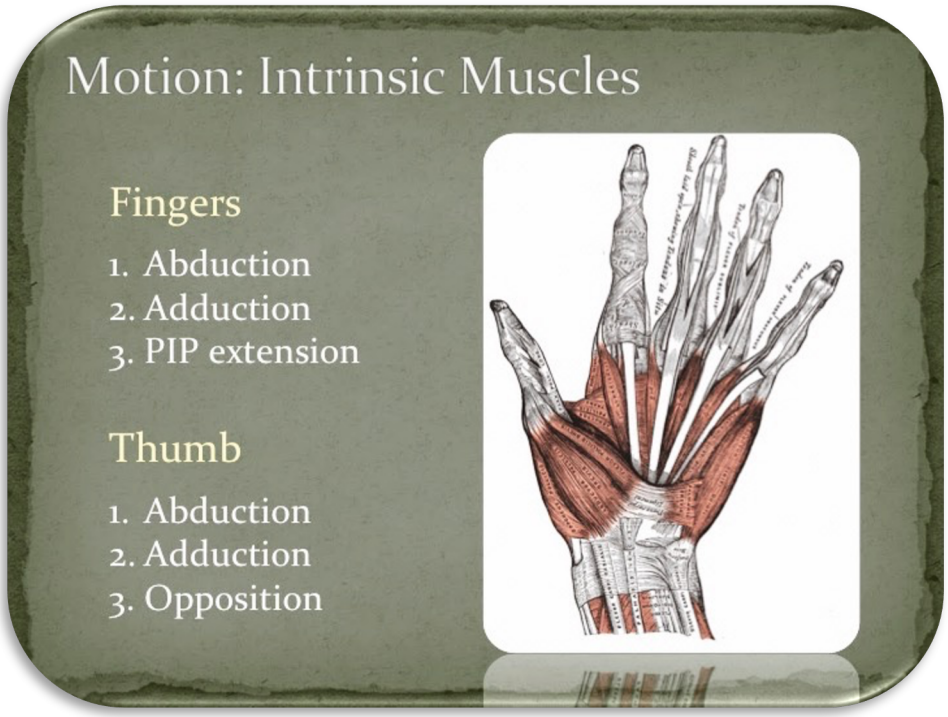
j) It also creates a lubricant for the tendons called "*synovial fluid*" (like oil)

k) Understanding these concepts is necessary to understand why we experience "*tendinitis*". This is discussed in **Part III**

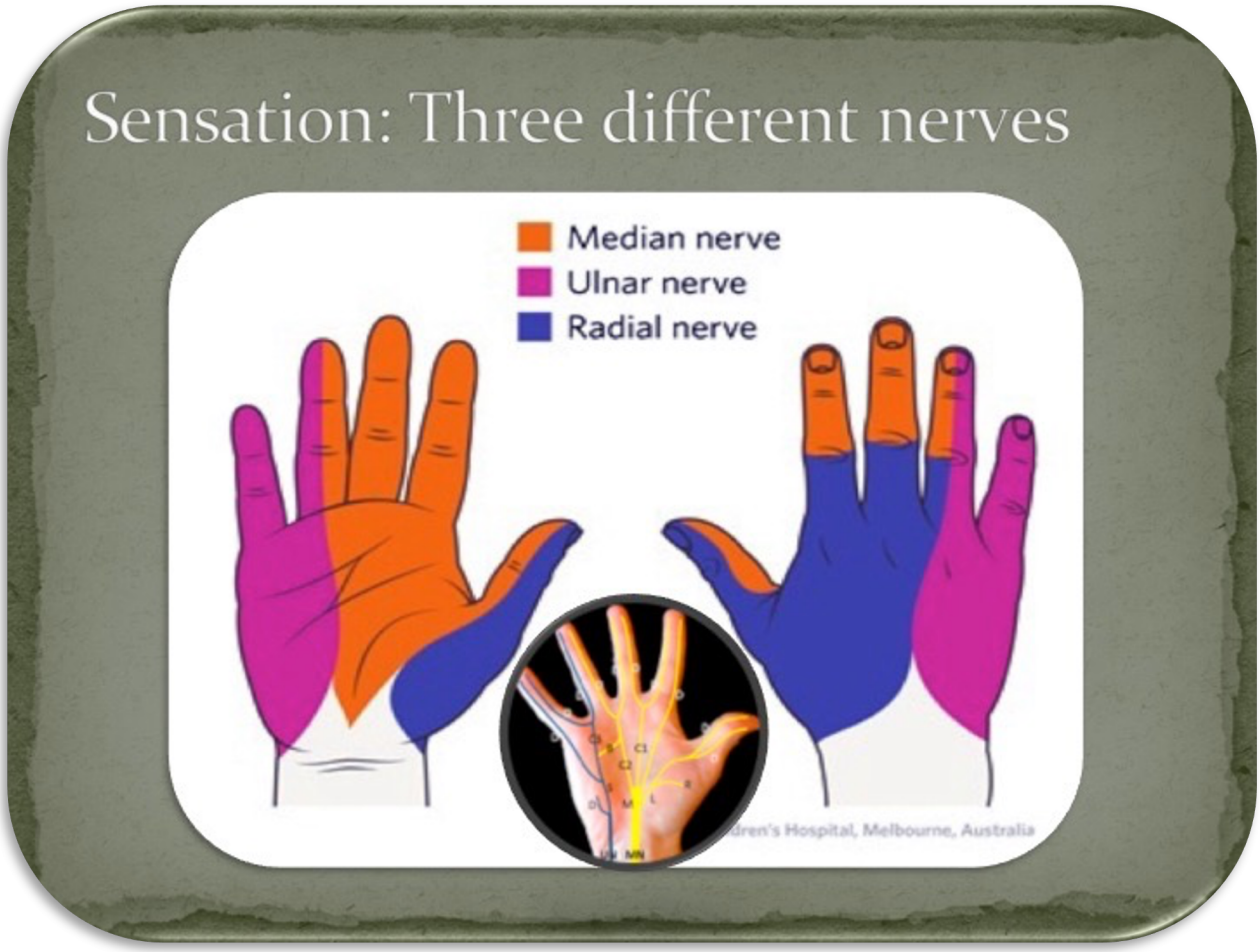
l) In summary:



8. **"*Intrinsic*"** muscles:
   a) Those whose muscle bellies are located **inside** ("***in****trinsic*" to) **the hand** itself
   b) Small, much weaker muscles, capable of **incredibly fine, precise motions**
   c) Responsible for spreading the fingers apart (abduction) and pulling them together (adduction) as well as straightening (extending) the middle joint of each finger – **these muscles are extremely well developed in most musicians**
   d) Very short tendons with straight-line pull and **<u>no need for pulleys</u>**
   e) Responsible for our "*opposable thumb*" – opposition means:
      1) Pulling the thumb away from the fingers on the palm side of the hand **and**
      2) Rotating the thumb so the pad (pulp) faces directly the pads of the other digits (in other words, turning the thumb tip toward the fingertips)
      3) Form a big "*C*" with your left hand. That's opposition!



C. Sensation – sensory function creates feedback!

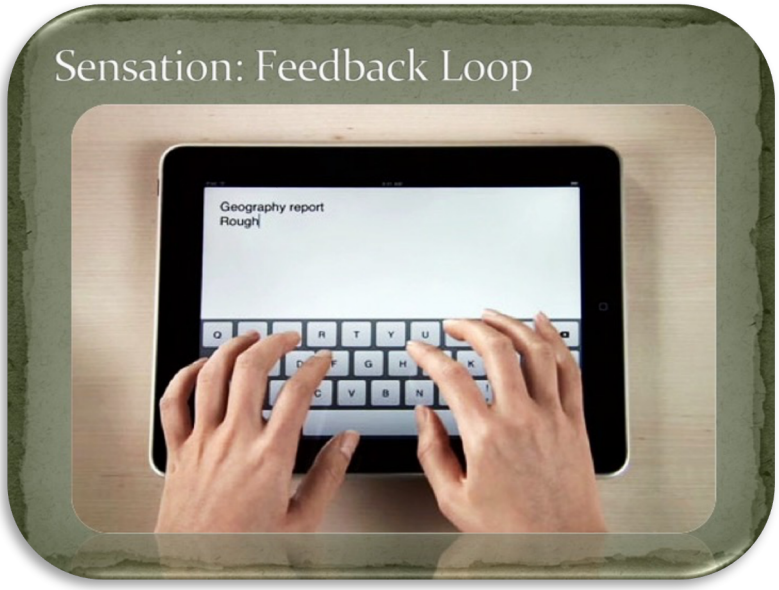


1. Three different nerves give the skin **touch** and **pressure** sensations in the hand. This is called "*tactile*" sensation (they also sense heat, cold etc.)
   a) Median nerve (orange above) – surfaces that are used for fine manipulation – the tips ("*pulp surfaces*") of the thumb, index, long, and ring fingers (**very important for you!**) This is the nerve that is compromised in **carpal tunnel syndrome**
   b) Ulnar nerve (purple above) - border of the hand, little and ring finger side, pulp surfaces of the little finger and half of the ring finger. This sensation is important for most musicians (the same nerve is critical for nearly ALL musicians because it also controls the intrinsic muscles!). This is the nerve that is compromised in **cubital tunnel syndrome** (pathological conditions will be discussed in **Part III**)
   c) Radial nerve (blue above) – sensation from this nerve is less crucial for musicians since it does not go to the fingertips. It gives sensation to areas that usually are not in contact with your instruments

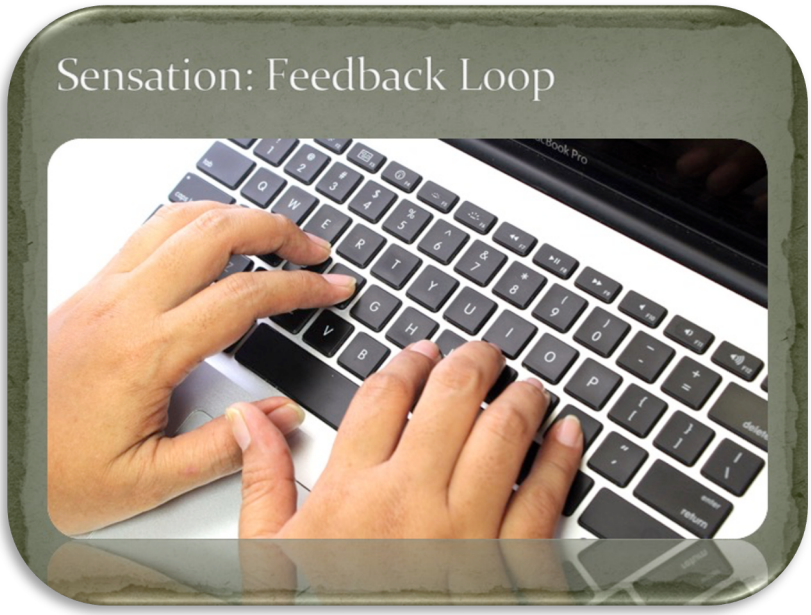
2. Common digital nerves (see insert above) control sensation to ½ of 2 fingers rather than 1 whole finger – if injured in the palm not all sensation is lost in an entire finger

3. Signals create a feedback loop of tactile sensation allowing the brain to judge the effects of its motor signals. Imagine what it would be like if you couldn't **feel** the shape, position, motion, resistance etc. of the keys or strings of your instrument!

4. In addition to tactile cues, the brain uses visual and auditory information in the feedback cycle to make fine adjustments.



Which of these devices do you find more comfortable when writing a long text and why?



Musicians and the blind share the most sensory finesse of anyone on the planet!

Sensation - The Nature of Pain:

Everyone agrees that acute pain is an unpleasant experience that helps protect us from injury. It has almost certainly been crucial to our survival as a species. Because we evolved in an environment where we were surrounded by dangerous objects and predators, we needed a hair-trigger warning system to protect us from injury, making it appropriate to "*freak out*" at certain stimuli in preparation for rapid "*fight*" or "*flight*". We were **built** to err on the side of **fear**, but what is the relationship between fear, pain and injury?

Today, most people live in much safer environments and most of the pain we feel has a more subtle meaning. Our instincts however, are also products of our evolution and we have some difficulty interpreting pain in this more recent context. Pain continues to be a significant problem that becomes even more complex and elusive as we witness dramatic improvements in the standard of living and the level of safety in many societies around the world. Why? Shouldn't it be the opposite?

A. **Classical concepts and the vicious circle of pain**:

1. <u>"Nociceptors":</u> In the early 1900's researchers discovered specialized nerve endings that fired **only** when exposed to potentially harmful stimuli (**extreme** pressure, temperature, chemical changes, etc.) and these were very logically thought to be the **origin and source** of our sensations of pain. They were called "*nociceptors*" which means "*harm sensors*" – pain finally had an "***<u>objective</u>***" source and a straight-forward, intuitively satisfying "*explanation*" in the avoidance of injury

2. <u>An "Obvious" Conclusion:</u> It seemed logical then to assume that pain was a direct indicator of impending tissue damage and that if it persisted or became chronic that it **must** be associated with some ongoing or continuing **injury** to our bodies

3. <u>The Interjection of Fear:</u> This widespread assumption generated **fear** that "untreated" or persistent (chronic) pain would necessarily lead to some long-term or irreversible physical damage. This belief, accepted and propagated by the medical community in modern societies, makes it impossible to distinguish between **"*hurt*" and "*harm*"** since by definition in this context, pain indicates harm

4. <u>Sensory Adaptation:</u> Our nervous system however, constantly "***adapts***" our sensitivity to adjust for the intensity of stimuli around us so that when the stimulation level is **low**, we become **more** sensitive and vice versa. Sitting in a dark room for example, we become much more sensitive to light and attentive to its presence. We can see shadows and pinpoints of light we couldn't possibly see when we first entered the dark. Then, when we encounter bright sunlight, we are initially painfully blinded by the intensity of light stimulation, but our eyes and brain **adapt** by gradually decreasing our sensitivity and we can then see details again. This almost exponential "sensory adaptation" gives us a much wider and more effective range of perception, markedly improving our ability to protect ourselves. This is an essential part of our **normal physiology** – it involves **all** of our senses, including those that mediate pain, and is **<u>inescapable</u>**. In certain circumstances however, this process can work against us

5. <u>Fear of Pain:</u> When we have pain, **if** we are **afraid** that it is an indication of **ongoing or additional injury,** we become highly protective **avoiding ALL** stimulation. We are even often prescribed complete rest and immobilization to "***reduce***" our pain but with this decreased stimulation level, sensory adaptation makes us **much more attentive** and **much more sensitive** to the pain. This causes even more fear, more pain and more stress, making us even more protective and less active with no natural end in sight, creating a **vicious circle** that is called "*hypersensitivity*" (see

also *"Swelling (Edema)"* in **Part II**). In fearful individuals this can maintain and increase pain exponentially and sometimes cause it to persist indefinitely

a) Let's create a hypothetical situation to illustrate this using the light sensitivity we mentioned above.
   1) You've been sitting in a dark room say watching an afternoon movie for 2 hours and you walk out the exit door directly into bright sunlight. It is so bright that it hurts your eyes. Imagine that you learned (and truly believed!) that pain is a direct indicator of tissue damage and you **become afraid** that if you allow the pain to persist you will become blind!
   2) So, you turn quickly around, go back into the dark room and close the door to protect your eyes, thinking: "*I'll wait until the sunlight doesn't hurt my eyes and go out again*". You try it again in 10 minutes but now it seems even worse so you quickly close the door again and wait longer. When will you have waited "*long enough*" in the dark room that bright sunlight will not hurt ("*harm*"!) your eyes? The answer of course is: "Never". The longer you wait in the dark, the more sensitive your eyes become to the light. This is the vicious circle of hypersensitivity. The **fear** turns it into an **impossible dilemma**

b) We have enough experience with this type of "*pain*" on an almost daily basis that no one could convince us that we are at risk of going blind if we just "*tough it out*" for a while and adapt to the bright sunlight. We easily make the distinction between "*hurt*" and "*harm*"

c) In our modern and safe societies however, we have very little personal experience with injury and illness and must rely on prevailing opinions in others and in the medical community for advice and guidance

6. Pain as a Disease: Over time this vicious circle of hypersensitivity can become **so intense** that the **pain itself becomes a "*debilitating disease*"** (called "*Complex Regional Pain Syndrome*" – CRPS) not just a symptom of some process asking for the brain's attention. In this tragic but now common scenario, rest, immobilization and narcotic pain medications are routinely prescribed and are rapidly and deeply addictive. Only mind-altering drugs such as opioids, alcohol and marijuana can give victims temporary relief by reducing their **fear**, but these drugs **only** reduce the fear of pain ("*injury*") **while they are being taken.** Unless the fear itself can be addressed and activity levels ("*stimulation*") can be significantly increased, the cycle continues while the effects of the drug wear off. Thus, they cannot be stopped, leading to unending drug dependence, chronic fear and stress, and gradual self-destruction. The **injuries themselves heal because our physiology will not allow otherwise,** but the pain and fear persist causing immense suffering with no end in sight

7. Misplaced Fear: In other animals and in primitive human societies fear is also present but it is **fear of injury and not fear of pain**. Once the threat and the perceived source of injury are gone, other animals and people **stimulate** their wounds by continuing their activities of daily living or they would die of dehydration or would be eaten by predators. They **do not have the option** of complete rest or immobilization and so rarely suffer from this vicious circle. Those familiar with domestic animals know that they will often lick their wounds and whimper with pain but appear to have instinctively understood that **stimulation reduces sensitivity**. They often survive devastating injuries without veterinary intervention

8. A Deadly Mistake: This modern **misinterpretation** of the nature of pain has become one of the most pressing problems in our sophisticated societies, especially in the United States where the current "*opioid epidemic*" is now (prior to some brief periods during the COVID-19 pandemic) the **leading cause of death** in people under the age of 50! In some cases, people who don't die from overdosing but whose chronic opioid prescriptions are withdrawn without addressing their fear of pain (for them "ongoing injury"), choose suicide as their "*only option"*!

9. Something Must be Wrong: Under this classical interpretation of the nature of pain, **how do we account for the following?**

This woman discovered a healing scratch on her skin but doesn't recall how she injured herself. She experienced no pain and was surprised when someone pointed it out to her. Has this ever happened to you? But this could only occur with minor injuries, right?

Many soldiers *during wartime have reported only realizing that they were suddenly and severely injured* ***after*** *they looked down* ***and saw that they were missing an arm or leg.*** *Their nociceptors should have given them instant and intense pain. Why didn't they?*

This construction worker jumped down from a ladder landing on a 6" screw protruding from an object on the ground. It pierced his boot just in front of the steel toe pushing all the way through and out the top. He experienced ***excruciating pain*** *and was taken to an emergency room where* ***he required sedation*** *to remove the screw and the boot.*

The emergency room staff found that the screw had passed between his toes and was only pressing against his skin. There was no actual injury to his foot. Does this mean that he didn't "really" have pain and was only faking it? Think about it!

B. **Our current understanding of pain**:

1. Background: Pain is the sensation that urgently commands our attention. Consider for a moment that **if tissue injury** were truly the **only source** of our pain, it would always occur **too late** to allow us to **avoid** injury. It could only allow us to **respond** to injury. It could help us to reduce the severity but, only if we could react quickly enough to remove or escape the source. This is indeed an important mechanism in pre-mammalian species (i.e., before there was a cortex) and is certainly still important in humans in certain circumstances (i.e., stepping on a thorn) but remember that we owe our tremendous success in dominating the Earth to our intellectual abilities. **Only responding** to injury and not avoiding it does not accurately describe the pain behavior of humans or other mammals. They **prevent** injury, and so **must** be able to **predict** and feel pain **before** injury actually occurs!

2. Prediction: Our cerebral cortex is a **prediction generator** that learns recurrent pattern sequences from the world around us and uses them to predict what will happen next, down to the smallest detail in touch, pressure, body position, smell, taste etc., as well as what we will see and hear – this is possible **only** because the laws of physics dictate changes in our world in **highly** reproducible ways (how surprised are you when you inadvertently step off a curb?)

a) The cortex appears to use a similar algorithm (process) to analyze **all** the signals that can be sent through the nervous system **regardless of the source** i.e., vision, hearing, touch etc. This allows for the adaptability ("*plasticity*") of cortical regions – for example: blind people often use the region of the cortex usually reserved for vision to improve their sense of touch or hearing

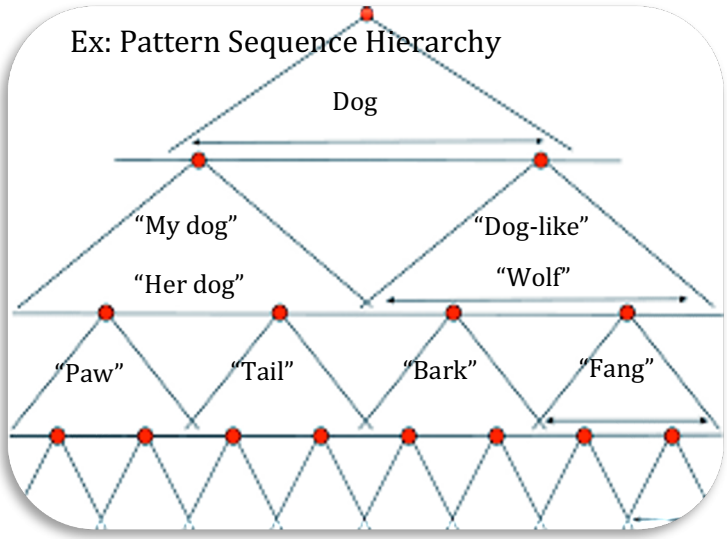
b) When a pattern is recognized, it is given an "*identity*" and passed up the hierarchy allowing us to "*understand*" it without the need to pay attention to the components that are important lower in the hierarchy - for **Example**:

1) Individual letters and sounds are crucial to learning words which are patterns of these elements in a particular order ("*temporal sequence*") but once they are learned and passed up the hierarchy, they are recognized **independently** and higher "*contextual*" patterns (phrases, concepts etc.) are formed allowing one to predict the next word with only minor cues making speed reading possible

2) *"Aoccdrnig to rscheearch at Cmabrigde Uinervtisy, it deosn't mttaer in waht oredr the ltteers in a wrod are wirtten as lnog as the frist and lsat ltteer are in the rghit pclae. The rset can be a total mses and you can sitll raed it wouthit a porbelm. Tihs is bcuseae we do not raed ervey lteter by istlef but the wrod as a wlohe. Amzanig, huh?"*

3) Musical phrases are learned in the same way by converting patterns of notes into intervals and sequences allowing you to recognize a melody regardless of the key it is played in, whether it is played by a tuba or a piccolo or hummed by a friend – even if you have never previously heard that rendition

c) **ALL** learning appears to proceed in this way no matter how abstract it is and higher level concepts are formed by patterns of lower level concepts that **occur together** i.e. you can easily recognize a generic "*dog*" even though it may be a different breed from any dog you have ever seen before – you can also as easily recognize concepts such as "*my dog*", "*her dog*", a "*white dog*" and a "*dog-like*" creature, say a wolf, in addition to its patterns lower in the hierarchy such as a "*paw*", a "*tail*", a "*fang*", a "*bark*", the smell of a "*wet dog*" etc.



d) This process of pattern recognition begins in the brain almost certainly before birth and continues progressively throughout our lives with ever increasing complexity, allowing the cortex to make templates ("**invariant representations"**) of **ALL** the objects, forces, sensations, concepts etc., that make up our daily lives, freeing up our brain to concentrate on and "***fill in***" **ONLY** the missing and unique information in a given context. ***What does any of this have to do with pain?***

3. Twenty-first Century Data: Current research suggests that the sensation of pain is **entirely** constructed in the brain based on nerve signals interpreted within a **context** (that hierarchical series of recognized patterns that allows us to constantly situate ourselves in time, space and the circumstances that surround us) using combined information from our senses (feedback) **but mostly** from our **past experiences** (called "feed forward") – if we measure neuron "*traffic volume*", feed forward data outweighs feedback data **10 to 1**!
   a) Signals from the nociceptors are sent **before** any tissue damage actually occurs and several fractions of a second pass before our brain interprets their significance and **tells us** (predicts) what we **should** feel. Thus, when no pain is predicted, the brain may not initially interpret nociceptor signals as painful – does this mean our nociceptors don't work? Not at all! It means that their significance must be learned and interpreted, the same as all of our other senses! **They are not "*objective*" sources of pain**
   b) Essentially, **any** nerve signals that are unusual enough to deserve the brain's sudden attention in a particular context may generate a full range of responses from pleasure to intense excruciating pain depending on the brain's **expectation** or prediction of pain or danger
   c) The slightest touch to your skin or even to a single hair on your skin in complete darkness when you believe yourself to be alone, vulnerable and stalked by a mortally dangerous predator **can be** one of the most intense and painful experiences imaginable without the necessity of **any** actual injury!
   d) Thus, **ALL pain is REAL pain!** Regardless of the reason or the source, it is as **REAL** as anything we can experience in life, in spite of the **fact** that **ALL pain is "*in our heads*"!** These concepts have always been deemed contradictory (and generate intense defensive reactions!) but they are not!

C. **What are the implications**?
   1. Judgements: Pain can **only** be judged as exaggerated or inappropriate by an observer, **never** by the person experiencing it. Thus, any judgment on the appropriateness or "*objectiveness*" of another person's pain usually reflects a misunderstanding of pain itself

2. Reliability: Can the brain be fooled? **Absolutely!**

> ***[Article from: MDedge® Internal Medicine News, April 8, 2021]***
>
> ***"Something's wrong, but I can't put my finger on it"***
>
> *"Mixed martial arts is not a sport for the faint of heart. However, we doubt fans who were watching the Khetag Pliev/Devin Goodale fight on April 1 were prepared for the announcement that a search was commencing for a missing finger. Not broken, in case you think that was a misprint. Completely 100% removed from the rest of the hand".*
>
> *"One would think that pinpointing the exact moment when the finger, belonging to Mr. Pliev, was severed would be easy, but the video evidence is unclear, with the best guess being that a kick in the first round broke the finger and a grapple in the second severed it completely. Mr. Pliev was not helpful in clearing up the matter; not only did he fail to immediately notice the fact that his finger had been broken or severed, he tried to keep the fight going after the second round when the referee noticed some blood where his left ring finger should have been. He thought he was winning. Unfortunately, the doctor on hand, who was clearly a complete drag, felt differently, ending the fight and awarding it to Mr. Goodale in a technical knockout."....*

("*But these things can **only** happen to other people, **never** to me. **Right?**"*)

3. Current Pain Concepts: Our classical pain concepts are simply **WRONG** yet they continue to be widely accepted, taught and propagated, even in our medical schools! All of the recent research indicates that **pain is not an objective indicator** of impending injury but rather a request for the brain's attention! Until we better understand and spread this knowledge, countless people will continue to suffer needlessly

D. So now what?

1. "*So, you're saying that I should ignore pain because it is unreliable and just my imagination*?" **Absolutely not!** (If this was your reaction, you are feeling defensive and should re-read the above section!)
   a) By our best scientific description, **ALL** pain deserves the brain's attention and you couldn't consciously ignore it any case, even if you wanted to! (If you ignored it, it would have been unconscious and would never have been interpreted as pain in the first place, just like the person with the healing scratch!)
   b) Controlling the panic, paying **closer attention** to pain's nuances **without fear,** and using a more detailed and more objective analysis than the one the brain can accomplish in just a few milliseconds, becomes important exactly **because** it's "*all in our heads*"!
   c) Be **constantly aware** of our natural tendency to initially **overestimate** pain signals in the context of our evolutionary history. Fractions of a second could and can still be the difference between life and death. "*React first – think later*"! That's completely normal, but it doesn't mean: "*Just react - don't think*"!

2. **Once the source of pain is understood**, (or the source of "*danger*" is eliminated), conscious and **deliberate stimulation** of a painful site (**desensitization**) breaks the cycle and is **BY FAR** the most effective and safest pain treatment available!
    a) It stands to reason that if our interpretation of a stimulus can make it **more painful** (some of you felt pain and distress just **looking at** the image of the screw sticking through the boot!) it can also make it **less painful!**
    b) If we are confident that a stimulus cannot harm us in any way, the signals, **including those from the nociceptors**, that we may initially have interpreted as a source of extreme pain or discomfort can instead be re-interpreted as touch, pressure or whatever sensation we consider "*appropriate*" – this is called "*sensory re-education*"
    c) **Example:** As a hand surgeon, I treated about 300 patients with traumatic fingertip amputations over 30 years (bloody stumps including some degree of bone and fingernail loss - a "*frightening*" injury)
        1) Those who could understand and adopt these concepts when explained to them, overcame their fear and immediately began desensitization by using the finger normally, could be treated with Band-Aids, and had **NO pain** within **days** of their injury. They regenerated excellent quality tissue with normal or near normal sensation, had no "*phantom pain*" (feeling pain in a missing part of your body) and full function. Most returned to their normal work and activities almost immediately and did not feel handicapped by their injury
        2) Those who could not get over their **fear** that the pain they felt would cause additional injury or prevent healing **avoided contact** with the stump at all costs, developed abnormal hand postures and had to modify **all** of their activities to decrease stimulation. They suffered terribly, had phantom pain and poor sensation at the stump. Their pain became chronic and they felt that they had experienced a **"*permanent injury*"** and were now handicapped. Indeed, **all** aspects of their lives were affected. Their suffering was **very real!**
    d) Our brains and our bodies are **extremely** adaptable yet we often do not take advantage of this capacity because of our misinterpretation of the nature of pain (another simple example: Do you enjoy roller coasters? If you do, it is because you are confident that you are safe, **can put aside your fear**, and are therefore able to transform the instinctively terrifying sensation of free fall, normally followed by inevitable severe injury or death, into an exciting and pleasurable experience! Can you doubt your brain's adaptability?)
    e) You can verify the effects of desensitization yourself quite easily the next time you sustain a minor but very painful injury. If you bump your shin, stub your toe, etc.:

1) **Immediately** massage and stimulate the **most** painful site aggressively and forcefully (fortunately, **many** people do this instinctively – they are **not** usually the ones who suffer from chronic pain!)
2) The first contact will be **very** painful but if you swallow your fear and stay with it, your pain will subside **within seconds**
3) It will gradually return when you stop stimulating (local tissue damage and inflammation will occur and be present over the next 7-10 days – see Part II) but if you stimulate the site frequently – touch it, massage it and pursue your normal activities, your pain will become rapidly tolerable and will quickly subside

f) ***"But won't all that stimulation prevent me from healing?" Shouldn't I wait for my wounds to heal before I try to get back to my activities?***
1) **Absolutely NOT!** Your body is made to heal itself **while it continues to function** (or your ancestors **could not** have survived and you would not be here!) The fatality of an injury was indeed **determined** by the body's ability to continue functioning (self-defense, hydration, nourishment, shelter etc.) **during** the healing process and was favored in our evolution!
2) **In fact**, our bodies **rely** on our activities to guide the formation of scar tissue
   (a) Our tissues move relative to each other when we move (i.e., muscles shorten, tendons glide, skin slides over tissues beneath it etc.)
   (b) Scar "heals" wounds by sticking tissues together and contracting
   (c) It relies on our needs (our activities!) to determine which tissues should be stuck together and which should be allowed to move
   (d) Scar has a long "*maturation*" process (see Part II) that allows us to fine-tune the compromise between stability (stuck in scar) and mobility (gliding motion)
   (e) Once it is mature however, scar tissue is **very** strong and **will no longer allow** gliding tissues to regain their motion
   (f) So, if we change our needs completely by "*waiting*" for an injury to heal before we move and use our limbs, we **interfere** with this intricate and valuable process – and **pay the price** with drastically **increased pain and adhesive scarring** (loss of motion)!

g) None of this should be interpreted as condemning modern medicine or surgery. They have reduced the fatality of illnesses and injuries dramatically and improved our quality of life

h) Of course, with certain severe injuries, **sometimes** rest and immobilization can help us to attain a **better** result, but it is **always** a compromise and the benefits **should outweigh** the **predictable negative effects** of these treatments!

i) It is not an accident or a coincidence that in recent decades a steadily increasing number of surgeries are done on an outpatient basis. Instead of

hospitalizing and keeping patients on bed rest from the day before their surgeries and for days or weeks afterwards, they are now sent home and asked to get up and move around. It has reduced the number of problems and complications dramatically

j) Unfortunately, especially in the upper extremities, older protocols requiring rest and immobilization at home are often still followed without question because that is the way we were taught. With our current knowledge however, these issues should no longer be ignored

k) We as physicians couldn't start by knowing everything up front. We have to learn as we go just like everyone else. Changing established concepts and protocols however, in this case our notions of the nature of pain and tissue healing, is a long slow process

E. In Summary

1. Finally, in the 21st century, we have the knowledge available to allow us to better understand, manipulate, and control our pain

2. Our instincts however, based on our evolution, naturally generate **fear of injury**

3. Unfortunately, flawed assumptions in the 20th century have turned this tendency into **fear of pain** making it impossible for some people to distinguish "*hurt*" from "*harm*"

4. **Pain is not automatically dangerous**. **It is only painful!** Fearfully trying to eliminate pain by avoiding all stimulation has the opposite effect, **increasing pain** by creating a vicious circle of hypersensitivity and adhesive scarring. It can be likened to placing frightened, desperate people in a very dark room and telling them to wait until the bright sunlight does not hurt their eyes before they go out and get back to normal life. With injuries it is even worse, since remaining immobile causes tissues to stick together with scar that must then be stretched or torn (generating even more pain and anxiety!) before they can regain normal motion. Until we understand and embrace this new knowledge, countless people will continue to suffer with chronic pain and disability for decades to come – hopefully, **you** will not be one of them

5. This classic approach to pain is so fully entrenched in modern societies that even with mounting evidence of its flaws many physicians will continue to prescribe rest, immobilization and narcotics to treat pain in the foreseeable future in spite of **predictably poor results**. If they prescribed stimulation and rapid return to

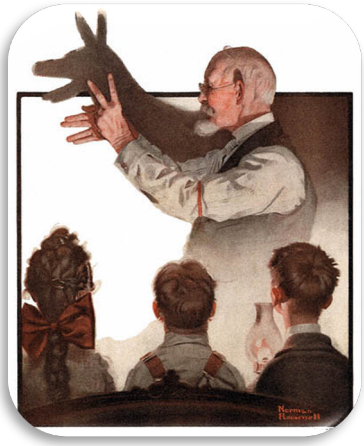
activity without fully understanding and explaining these concepts, they would be branded incompetent by both patients and colleagues!

6. Knowledge is power but a little knowledge is dangerous! **If you believe everything you read on the Internet without making the effort to learn about your own physiology, you will suffer throughout your career**

7. Learning can allow you to distinguish evidence from speculation, which you can **only** do if you understand the concepts. The "*prevailing opinion*" always lags behind our current knowledge. You will need to know enough about your own physiology to make reasoned judgments about the pain **you will** experience in the years to come

8. Our most objective assessment of any alert signal comes when we are not charged with emotion. If you are already visualizing the end of your career every time you feel pain, you're in trouble! Most pain in musicians is physiological ("*normal pain*" – see **Part II**) and does not require medical attention though it does **require YOUR careful attention and activity modification!**

9. **Musicians take careful note**: If you cannot get past your fears that pain will automatically lead to irreversible injury and you try to be "*extra safe*", you will **paradoxically increase** your likelihood of experiencing a career-ending event



10. **Your understanding and your response to pain are in YOUR hands**!