Neuro-Plasticity & Permanency

Growing and Refining

during adolescent years

As a neuro-physiologist I emphasize what is common knowledge ...
but often ignored with slow strength & endurance training,
players become what they repeat.

Chuck Grillo (Gringo) one of the great coaches of our sport at all levels says it this way: "Show me a great team, and I'll show you great practices."

Overview: Implications of Neuro-plasticity & permanency

I offer this overview early, because the neuroscience might get a little heavy.

• **Specificity: The more your training looks and feels like the desired outcome, the more likely it will accomplish the goal. Specificity has been validated from decades of research, but new technology lets us actually 'see' the structural (anatomical) modifications from training.**

• **Speed of movement is just as important as Range of motion in developmental training of young athletes. Much of our dryland speed training should be as fast as skating. Hip Abduction-Rotation-Xtension is a high priority – but it must ultimately be fast.**

• **Permanency: After the CNS and peripheral nerves are modified by repetitions, these circuits are more difficult to change. We become what we repeat most often, so it takes a major effort to un-do bad habits. The tradition of SLOW endurance conditioning on the ice – with poor technique from fatigue – does not help a team play faster. Nor does it help young players improve skating fundamentals. Repetitions build relatively permanent habits.** !

• **Windows of Opportunity are not closed (at least into young adulthood) for most athletic attributes, including many that have incorrectly been called 'untrainable' after certain ages. These bogus claims were never based on evidence; train-ability was not investigated. Training for speed, quickness, and agility must never be left out of a long term program at ANY age – young or old – because this would invite slowness to be programmed into the CNS.**

• **Mirror Neurons will become an important learning tool. Stay abreast of this and other research in Neuroscience. What is written in any book – including this one – might change.**

In case the name 'mirror neurons' sounds a little like science fiction, remember there was a time when creative thinkers were told the earth was flat. Experiment creatively.

Developmental training is based on plasticity of the Peripheral and Central Nervous Systems, it's not just building big, strong muscles:



This 2° decline is about the maximum for Overspeed downhill sprints

Emphasis at a young age is:

1) Basic Athleticism, appropriate for any sport: Speed, Agility, Quickness, Reactivity, Coordination, Dynamic balance, and Core synergy with muscles that move limbs.

2) Build efficient quick skating habits from the first day you put skates on, or increased athleticism has little chance to make you a great skater

3) Quality. Young athletes become what they repeat most often, so training must feature quality, not quantity training at all times. Don't allow fatigue to ruin the development of athleticism.

4) High intensity interval training, HIIT, is the only way that Hockey endurance makes sense. After all the dumb things we have done on the ice to build endurance it looks like we are preparing for slow competition, instead of super fast playoff games.
HIIT on the ice is Overspeed practice



Photo by Pete Salutous
shutterstock.com

At first glance

It's tempting to think the reason for all the hard work is the ripped, muscular body

But, muscle size and structure are a small part of the story.

The other major factor is 'plasticity' of the nervous system

Neuroplasticity: *nerves, not just muscles, change with training*

1) *Changes to the nervous system are specific:*

Training is most effective when it LOOKS and FEELS like the desired outcome.

Nerves that are seldom used are 'pruned' away during adolescence, while new connections (called synapses) are added. So, nerve growth and refinement are observable with modern technology.

2) *Changes to nerves are relatively permanent:*

To form good habits QUALITY training is more important than QUANTITY.

***Neuroplasticity*: the changes associated with learning**

We've all heard the advice: "Practice the way you want to play." With the assistance of computerized scanning and other technologies, we can *'see'* inside the brain to validate this advice.

Neuroplasticity refers to *two* things:

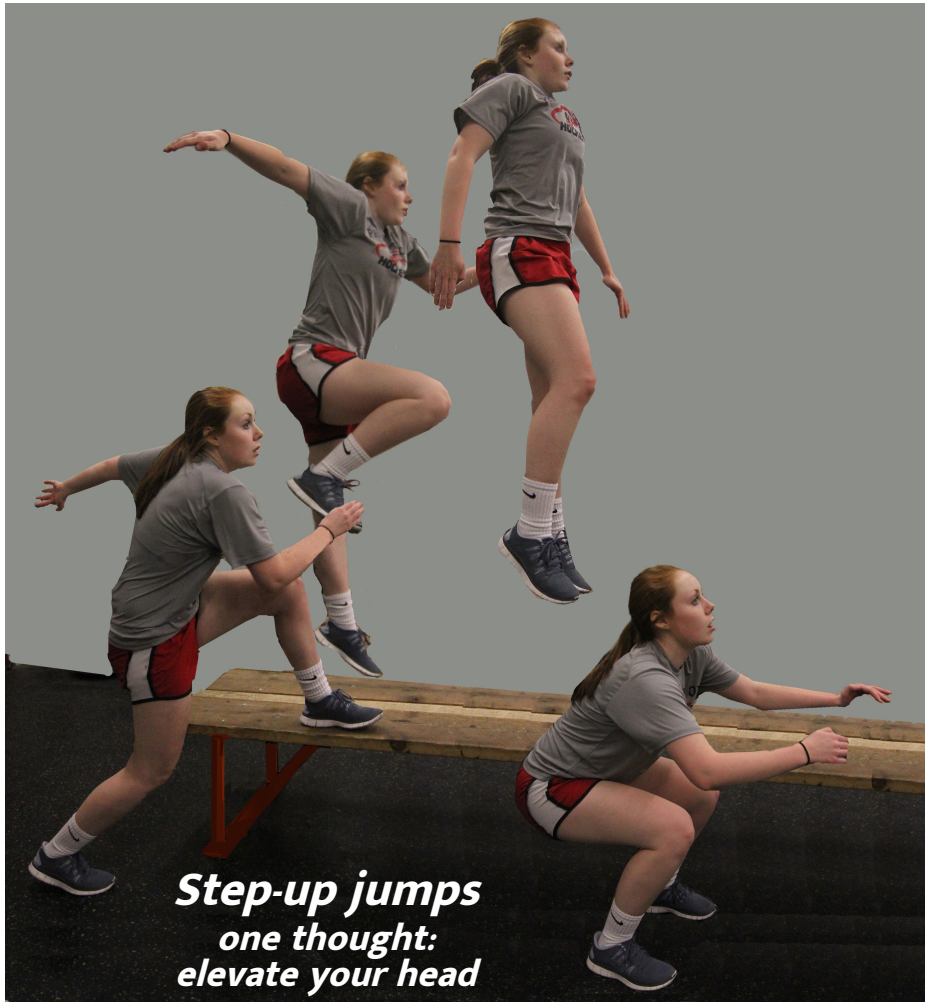
(1) the changes in *function* due to practice: increased speed, strength, agility, efficiency, coordination, reactivity, proprioception;

(2) associated *anatomical, chemical changes* in the brain and spinal cord we can actually *'see'* with computerized technologies.

After 18 weeks of explosive training, this 17 y/o girl now jumps higher from one leg than she had previously jumped from two.

Keep in mind that all forces in hockey come from one leg at a time, so one-legged explosiveness must be added to traditional strength training.

***Movement*, not coaching, taught these kinesthetic feelings.**



***S**traight **L**ine **X**tension & upper body multiplication of lower body force*
are kinesthetic feelings, learned at a young age from explosive repetitions
not from slow, restrictive weight training. Add supersets.

During adolescent years, neuroplasticity is the highest priority when planning athletic development.



A word to the wise:

Move your body as quickly and efficiently as possible or forget about building athleticism. If a young person chooses to lie around all day or get up and sprint; skate fast or slowly; play video games or play highly active sports — whatever is done often determines the future.

Technology has advanced to the point where computer images show which neurons and connections (synapses) are active when we move - or when we intend to move - or when we watch someone else do it.

Observable microscopic changes are proof of the principle specificity, that has been known for years, even without technology that looks inside the brain and spinal cord.



Specificity: the more your training looks and feels like the desired outcome, the more likely it will accomplish that goal - and change the nervous system for that purpose.

You BECOME what you REPEAT most often. So, both range and speed of motion should approximate the desired outcome.

The Central Nervous System, CNS …

… includes the brain and spinal cord, which extends down into the pelvis. Two important glial cells are also shown (astrocytes and oligodendrocytes).

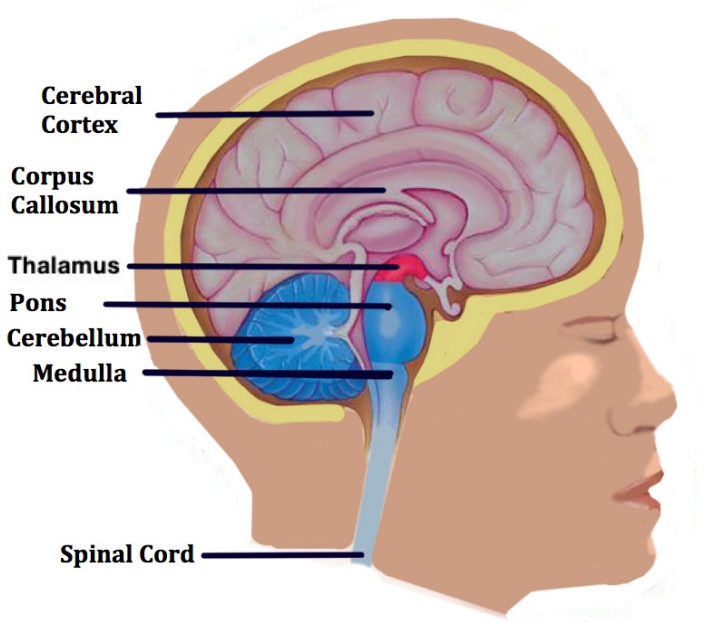
There are as many as 100 billion neurons (electrically excitable nerve cells) in the CNS, and about 9 times as many glial cells (Fields, 2004). Each neuron has somewhere between a few connections and hundreds, with other neurons. The connections are called 'synapses,' and their plasticity is the story of this chapter.

It is because of the plasticity of glial cells, neurons, and synapses (and other mechanisms, yet to be discovered!) that we have the ability to learn new athletic movements and think new thoughts *(Keith, 2006)*.

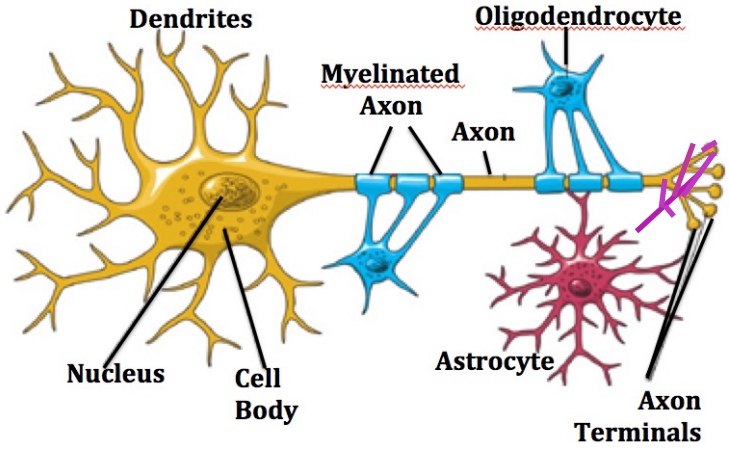
To understand *plasticity* it is <u>not</u> necessary to know how neurons and glia change … just that they do when we repeat movements. Details are extra credit.

At right is a diagram of a **<u>neuron</u>** with a short Axon, the 'wire' that carries voltage signals toward the axon terminals. Axons can be longer than a meter.

(Modified from Fields, 2004)



Above and below: colors are just for the diagrams. In real life, glial cells appear as white matter; the neurons are more gray.



So, how does this system work?

A Neuron functions when the cell body becomes excited by incoming messages from other neurons.

Continued

... and now for some biophysics (without apology).

The resting voltage potential difference across the membrane of the cell is elevated by incoming signals. Some signals are negative, some positive in this respect. If the membrane potential reaches a given **threshold** it triggers a huge spike in voltage, called an **action potential**. The mechanism of these membrane changes will not be discussed here (see Google).

The action potential is transmitted along the axon toward its terminals. These are the areas where the electrical signal is transduced to chemical packets that cross a small gap from the axon terminals to the dendrites of the next neuron. There the signal is transduced back to an electrical signal. The site of communication (axon terminal + gap junction + dendrite) is called a 'synapse.'

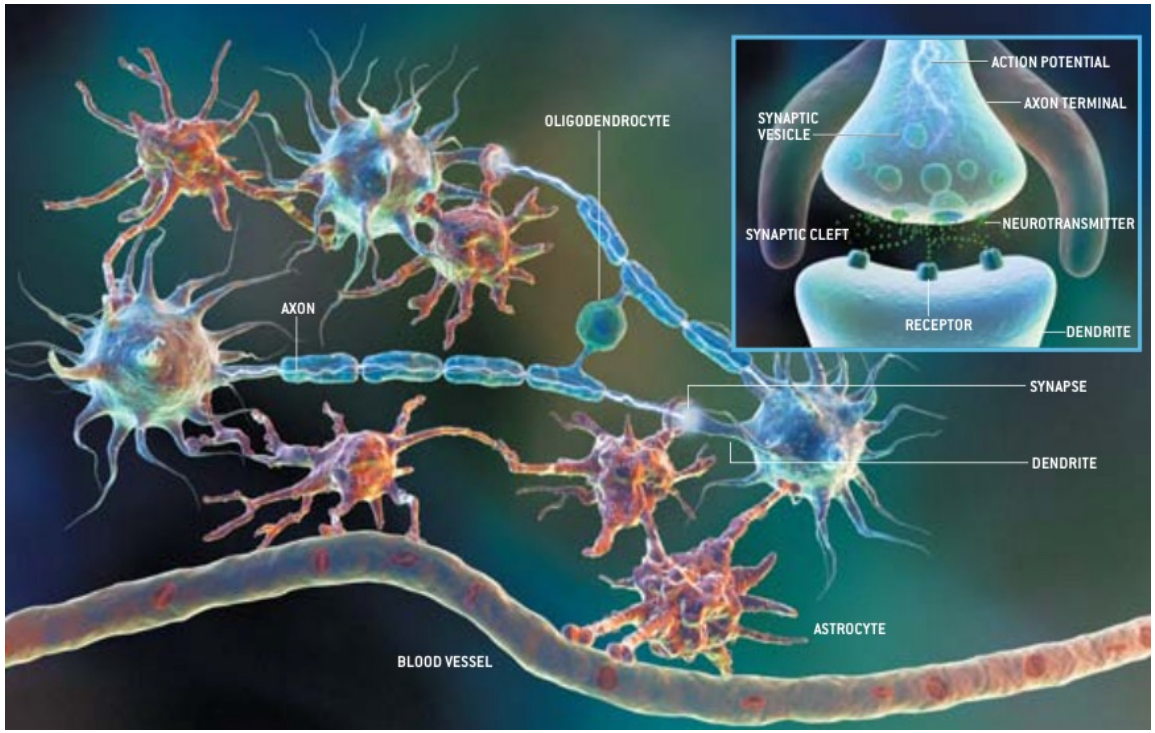
Modification of synapses represents a major part of the plasticity of the CNS.

Astrocytes are an important player in neuroplasticity.

They are one of the glial cells monitoring activity of synaptic communications, and they enhance the synapse or increase their number when they sense that more is needed.

Mechanisms will not be discussed here. See Fields, 2004, for a thorough discussion.

Note: in the diagrams from Fields (Scientific American, 2004) the colors are for clarity only. Glial cells appear whitish in real life; neurons are the gray matter.



Oligodendrocytes, another player in neuroplasticity, wraps Myelin, a white insulating sheath around the axon. This insulation speeds up the electrical signal that travels at speeds up to 50m/second. The more myelin, the faster the signal travels, and the 'sausage-appearance' with gaps (called nodes of Ranvier) ensures that action potential magnitude is conducted without decrement by jumping from one gap to the next (this is biophysics that won't be detailed here). It is known that elite athletes and musicians have a lot of white matter. Those who practice by the hour have more myelin than those who practice less, and this learning takes place well into adulthood. **Oligodendrocytes 'listen in' on neuron and glial activity, adjusting the myelin amount to improve timing of input to nerves**.
(Maggie, 2014. Karolinska Institutet, 2014. Also, R.Douglas Fields, PhD, Principal investigator at the US National Institute of Health, reviews details of these two glial cells in excellent articles that are cited in the bibliography (Fields 2004, 2005).

Training reps make semi-permanent habits. If we repeat slow feet or poor skill – even if we do it in the name of 'conditioning' – the habits are implanted into the nervous system. It has nothing to do with what we call it.

A third aspect of neuroplasticity is the proliferation of more neurons and synapses, This leaves the busiest pathways intact, and represents a process of '***streamlining***' of the oft-repeated signals. It was previously thought this cycle was not likely to occur after puberty, but Dr. Giedd and others have shown this extends into the 20s.

Dr. Jay Giedd discusses this research on teen-age plasticity in a Frontline interview, cited in the bibliography.

The cerebellum is a major contributor to plasticity.

The Cerebellum is located at the base of the brain in the back, near the spinal cord, and has more neurons than any other comparable-sized area of the brain. For several decades neuroscientists have known that the Cerebellum is important for the coordination of motor activities. Athletic movement, once initiated by the Cerebral Cortex, is controlled to a large extent in the spinal cord & Cerebellum.

Conscious control of movement often has a negative impact – 'Paralysis by Analysis.'

(Once the conscious brain initiates a golf swing or skating stride, control is best left to the cerebellum and natural reflexes).

More on the cerebellum:

I am told (not firsthand) that some dinosaurs had two cerebelli but a small cerebral cortex, presumably because motor coordination of distant muscles was a greater priority than solving calculus problems.

Park and coworkers (2009) used MRI imaging to show that basketball players had more highly-developed areas of the cerebellum (presumed to be active in motor learning) when compared to controls.

Technology also reveals that the cerebellum is active during cognitive thoughts *(Giedd, 2005,2014)* **probably fine-tuning higher brain decisions to be more appropriate in context, just as it fine-tunes motor activity.**

Dr.Giedd found that the Cerebellum is plastic later than was previously thought – into the 20s. His interviews on PBS are a good starting point for research on adolescent neurological development.

Training-related changes in nerves, synapses, and glial cells are especially plastic shortly after puberty and well into the 20's.

Changes WITHIN nerve cells, not just between them:

In future years neurophysiologists will uncover many mechanisms of plasticity not mentioned today. It's the nature of science, but especially neuroscience. Recent evidence suggests that Calcium storage-release in the spines* of dendrites is altered by electrical signals propagated backwards toward the dendrites. *(Johenning, 2015. Note* the spine of the dendrite is a small area known to facilitate communication of 'incoming signals')*.

The net affect is that dendrites become better ***'listeners'*** to the incoming signals from another neuron (via the impact of Ca^{++} ions). This local mechanism is dependent upon the activity of incoming synaptic signals. In other words the biochemistry **inside** the cell is part of the mechanism of 'learning.' So synapse modifications are not simply due to the extracellular monitoring and modification by glial cells.

Can sleep increase your ability to learn new moves?

A very recent review of literature by Pan et al. *(2015)* concludes, "Quantitative meta-analyses involving 34 articles, 88 experimental groups and 1,296 subjects confirmed the empirical pattern of a large performance gain following sleep and a significantly smaller gain following wakefulness." However, they point to issues with the experimental protocols, concluding, **"There was no evidence that sleep enhances learning."**

However, (as an example of the seemingly contrary evidence in research) in a previous study, a complex new task on a piano keyboard was introduced to 15 subjects *(Tamaki, 2013)*. They slept for 3 hours, while brain waves were monitored, were awake for an additional hour, then performed the piano test again. Compared to six controls who did not sleep, the 'sleepers' **performed the task quicker and better**.

Sleeping brain-wave patterns were analyzed, and compared to baseline patterns from three previous nights. In the Supplementary Motor Cortex region of the brain the patterns were different during delta (deep) sleep after the first piano task, compared to their patterns of three nights. The authors concluded, **"The brain may benefit from sleep … perhaps because distractions and new inputs are fewer."**

Be scientists. Keep experimenting.

Quality Reps
to build
Powerful corners



Remember:
Speed x Acceleration of your mass is Power





Don't believe all you read about the closing of 'Windows of Opportunity.'

For 50 years, we've tested and found significant speed improvements in males and females over 20 years old, after the fictitious Window of Opportunity was supposed to have closed.

Maximum improvement from training occurs when athletes are most motivated.

Olympian, Gigi Marvin, sprinting uphill here, made huge gains in off-ice explosiveness that transferred to skating … after college. And she's still getting faster into her 30's*

As players age into their late 30s, it is very common to stop training for speed, and just do slow aerobic cardio and slow strength training – a deleterious plan. !



*****Highly accurate electronic timing of On-ice and off-ice acceleration tests for the USA Women's Team, showthather results and those of team-mates continue to get better.*

Mirror Neurons!!!

Learning movement by observation rather than by analysis

There's nothing new in the knowledge that children learn much of their movement, behavior, and language by copying others. In fact, the 'addition' of mirror neuron activity during evolution is likely the point at which intelligence increased rapidly. Researchers have gained some understanding of what takes place in the brain to make this possible.

Neuroscientists have known for several decades that when a person skates, or throws a ball or moves fingers, or eyes, or tongue, that neurons in a well-identified area of the motor cortex are active. Very specific regions are associated with each different movement, so it is easy to "map" which areas are associated with the fingers, or legs, eyes, tongue, etc.

The message for coaches is that regions of the cortex which are active when an athlete skates (for example) are also active if the athlete sits quietly and watches someone else skate!

Mirror Neurons, are responsible for brain mimicking, and scientists believe this is an important part of the process by which all children learn movement. So, don't over-analyze; allow kids to mimic role-models.

Mirror neurons might also be important in developing the ability to **anticipate** what others on the ice are about to do, perhaps the most important skill in hockey. When a baseball player observes another starting to throw – even in the initial stages, the familiarity of the throwing motion is actually **felt** by the observer, not just **seen**, and the brain knows the rest of the throwing program. In this way, an athlete actually ***feels*** what an opponent is about to do.

This research leaped forward by accident when a monkey was sitting quietly in a lab while Italian physiologists monitored brain activity associated with arm movements, in an experiment that had nothing to do with mirror neurons. Then, when a grad student came into the room and picked up something, and brought it to his mouth to eat, the brain of the monkey was active in the same region as if he were the one moving the arm to eat, even though the monkey made no movement at all. Since that time it has been learned that humans have a much more active "mirror system" than other primates. This is one reason humans have a greater ability to learn from each other – thus the more rapid growth of language, knowledge, and culture *(See TED talks: Ramachandran neurons that shaped civilization)*.

This field is growing rapidly, and coaches should race along with it to find effective ways to use Mirror Neurons to help athletes learn skills.



Put your Mirror Neurons to work before sleeping.

Study a great skater – just study – and you've already improved your skating.

Is he Jumping? Slide-boarding? Skating?



He's loading up on the right before jumping to the left; arms will lead.

Close your eyes. Visualize putting maximum strength into a jump to the left, or into a slide to the left, a skating stride to the left, ... then back again from left to right.

You have already improved as if you really skated, thanks to mirror neurons.