GMSS 2017 "Tutorial (meaning: creatively learned)"

"**Longevity and Creativity**"

"A mind is such a terrible thing to be wasted".

Why sleep deficiency breeds dementia! Because much smaller (1/10th) Astrocytes glial of billion cells need brain blood passages, Glymphatic system, to clean up those large waste products generated by billions neurons, e.g. β–Amyloid, etc. (since our brain consumes about 20% energy of our whole body, sleep tight about 8 hours is recommended to clean up those by-products), "Brain Drain" M. Nedergaad & S. Goldman," Sci. Am., pp. 45-48, March 2016.

Harold Szu

Research Ordinary Prof. BME, Catholic Univ. Am. Wash DC;

Fellows of IEEE **(#1075,1997**), AIMBE, OSA(**1995**), INNS, SPIE(**1994**);

A Founder of INNS 1988(inception secretary & treasurer. 1988; Leesburg ***Int'l Xerox Edu. Ctr***. Published. "**Opt. & Hybrid Computing**" ed. Harold Szu,**1988**),

Foreign Academician of Russian Academy of NL Sciences**:(#135, Jan 15, 1999 St. Petersburg)**;

Senior Scientist, Army Night Vision ESD, Ft. Belvoir, VA

szuharoldh@gmail.com

Scientists at Google, CALICO (CA Life Co), NIH/NIA believe that human is possible to be **rocketed** to the "**immortality promising land**" with a sufficient **escape velocity**. e.g. ***2012 Nobel Laureate Shinya Yamanake*** of Kyoto (4 specific genes of ***induced Pluripotent Stem (iPS)*** can rewind back the "clock (of Hayflick)" to embryonic state. This fact has been done to mice already, some human also been successfully.

Longevity may be (1) due to Nonstop Production of Telomerase Enzyme; or (2) P. Mattson's (NIA Dir.) "Dietary (Calorie) Restriction Normalizes Glucose Metabolism and Brain-Derived Neurotrophic Factor Levels, Slows Disease Progression and Increases Survival in Huntington Mutant Mice" PNAS Feb. 10 2003; (3) Nobel 2012 Shinya Yamanaka 4 induced Pluripotent Stem (iPS) Genes of mice & human.

We anticipate Scotland Dolly the Sheep cloned at mother 6 years old somatic cells nuclear tfr, should be winding the clock back to embryonic state using iPS (TBD). Cf. W. Duan, et. al.;

Dolly the Sheep

A Brief History on Dolly

- In 1996, Dolly the Sheep was the first cloned animal
- She was cloned by the process called: somatic cell nuclear transfer (SCNT)
- Though having been only 6.5 years old before being euthanized, her legacy allowed many other large animals to be cloned.
- The idea of human cloning began with the success of Dolly the Sheep.
- She was euthanized due to a progressive lung disease called Sheep Pulmonary Adenomatosis (SPA)
- It is speculated that she could have been born (cloned) as a 6 year old

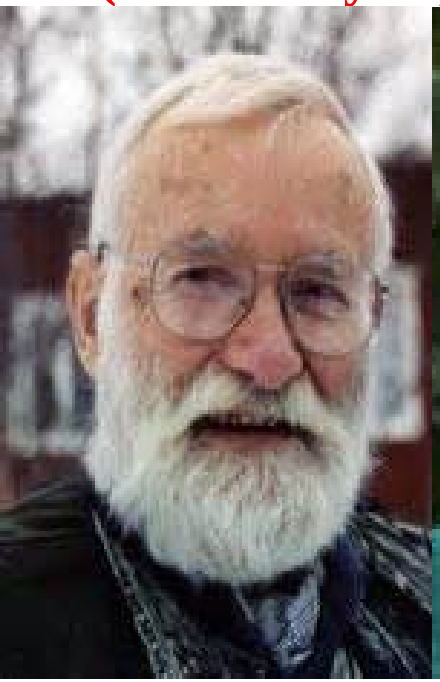
2012 Nobel Prize in Physiolo

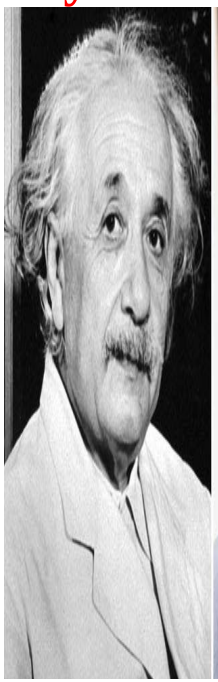
Shinya Yamanaka
University of Kyoto, Japan
Photo Credit:
Center for iPS cell Research and Application, Kyoto University

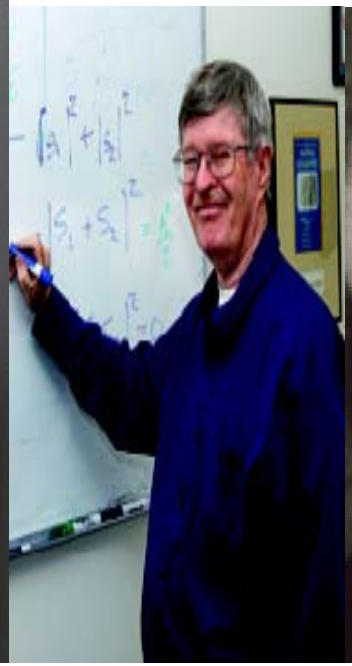
Lobsters (telomerase) 150 yrs. Galápagos tortoise 190 yrs; Arctic Clam of 400 yars

Imagine those great scientists & teachers who were alive, they can contribute so much more to the Humanity & the Science.

(That's why I speak about Longevity and Creativity:*"je pense, donc je suis"*)






- **Walter Jackson Freeman III 89 years** young for chaos olfactory smell (https://en.wikipedia.org/wiki/Walter_Jackson_Freeman_III)
- **Adolf W. Lohmann, 87 years** young for Optical Info Proc, Hologram
- **Albert Einstein 76 years young**, 1879–1955
- **H. John Caulfield 76 years young** for self reference opt. sig. proc. holograms (http://www.osa.org/en-us/about_osa/newsroom/obituaries/h_john_caulfield/)
- **David P. Casasent 73 years young** for 2-D optical signal computing, SPIE President 1993 (http://www.legacy.com/obituaries/triblive-pittsburgh-tribune-review/obituary.aspx?pid=176551675)
- **And those scientists who if you are respect to them, you may call out (as if we were in Church during Easter resurrection)**

I shall reminiscent about their wisdoms in Science, Teaching, & Publication.

1. Walter Freeman: the chaos can happen in any iterative nonlinear dynamic, e.g. for a rapid response of smelling for the survival we have pairs of olfactory balls near each attractor basin, one basin per each smell, the switch from one to the other must be fast.

2. Adolf Lohmann: "Scientific discussion is always cordial, straightforward and challenging, since Lohmann was constantly looking to push the limits." OSA Web

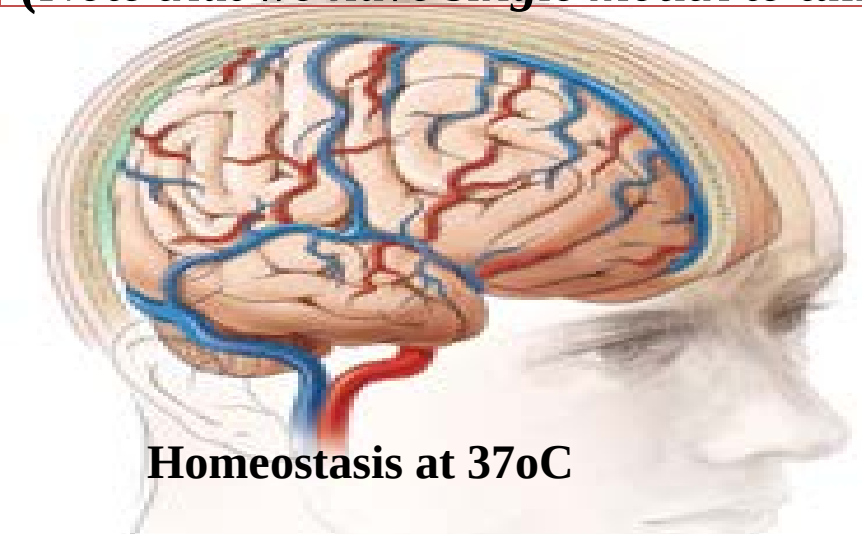
3. Albert Einstein: "Science has a little or nothing to do with the Truth; but the Consistency;" so that "make it simple not any more simpler." $E=mC^2$ after time & space integrations dropping all the lower limits of Vacuum Fluctuations (Higg's Bosons). I was a "Visiting Member" of Princeton Inst. Of Adv. Studies for few years, after my Rockefeller Univ. degree & job at NRL

4. John Caulfield: Elbow Room: Once he said to me "Harold you must give me the elbow rooms to work." About Writing & Presentation: Tell the audience what you are going to say; said it; and told them what you have said. About Publication: This is my way of paying back to the community that I learned from.

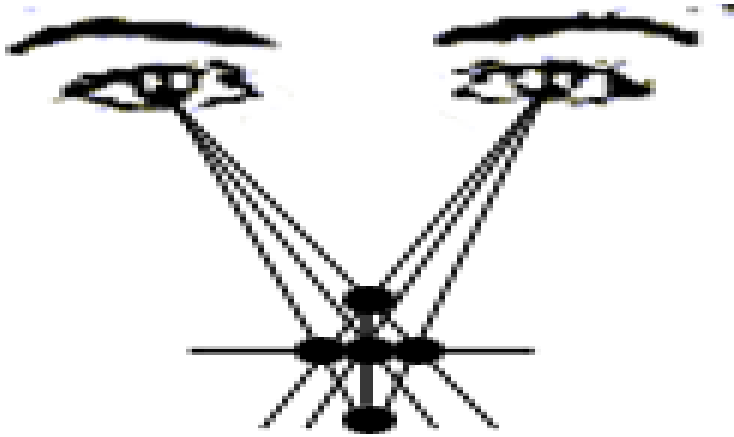
5. David Casasent: About Smiling: He wears a disarming charming smile all the time. He said to me once: " How come everywhere I went, you were there too--- Israel, Graz, Poland, Kyoto, Beijing. His disarming smiling made me so relaxing (without need to defend my behavior), I "replied a question by asking another question" (I learned from my Jewish colleagues at RU) how come I found you were always there jogging on quickly a yellow note pad? (I'm jealousy about his ability to catch me and go beyond) Is this for your next paper? He smiled and nodded (FYI Dave has published 650 papers, one of the most proliferated scientists I know. One of his students Dr. Brian Telfer worked with me as Post Doc).

"A mind of NI is a terrible thing to waste" Why in the buzzing & hustling world our Unsupervised Deep Learning(UDL) generates Natural Intelligence? The Necessary and Sufficient Conditions of NI are (1) Homeostasis Constant Temperature Brain 37°C (elasticity of hemoglobium) supporting UDL by relaxing the input generated thermal excitations; (2) Power of Pairs 5 Sensory (2 eyes, 2 ears, 2 nostrills (olfactory balls pairs chaos via Water Freeman & Bob Kozma), 2 hands, 2 taste buds)

(Note that we have single mouth to talk and eat; why receptors prefer pairs)



Homeostasis at 37oC



Power of Pair of Eyes

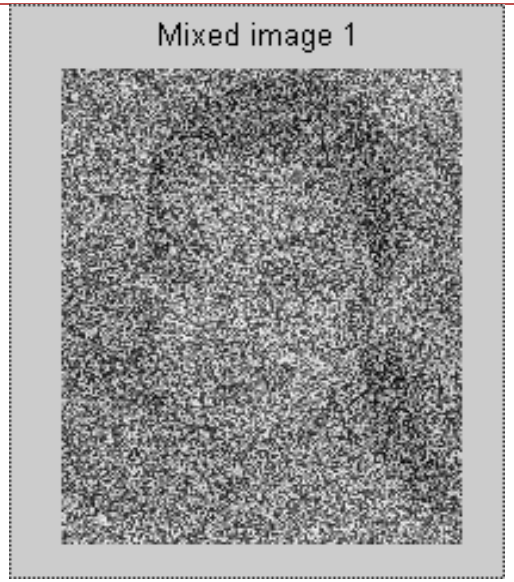
(1)Hardware fault tolerance (correct);

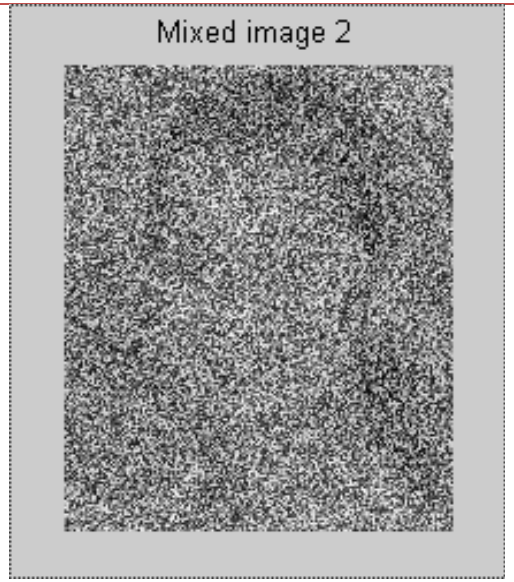
(2)Stereovision range info: cf. David Marr Binocular Parallax (need moving head left & right for 4 eyes) (maybe)

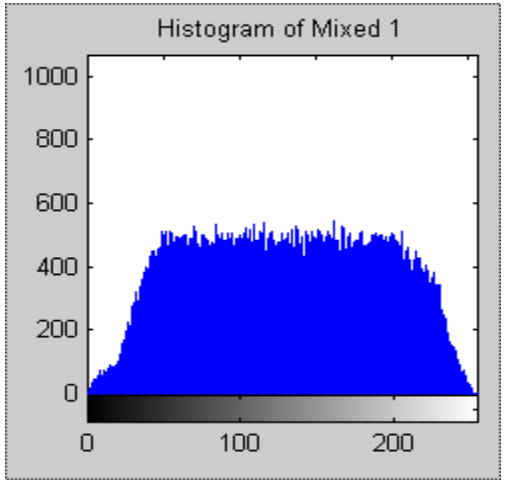
(3) Coincidence Account, quick for survival "Agree, the Signal; Disagree, the Noise" (YES)

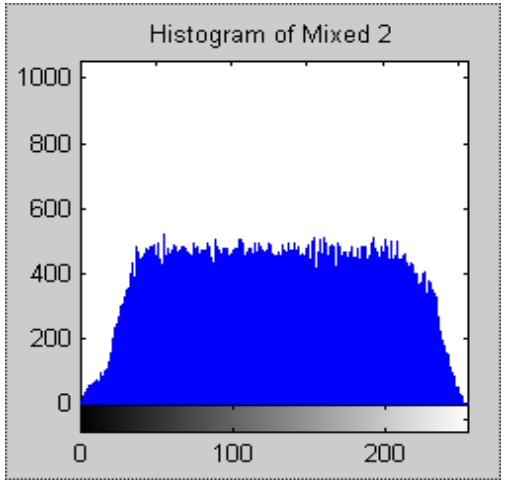
Two eyes could see through the fog---

a perfect restoration among two eyes as opposed to one eye image processing is merely re-shoveling foggy weather or snow!

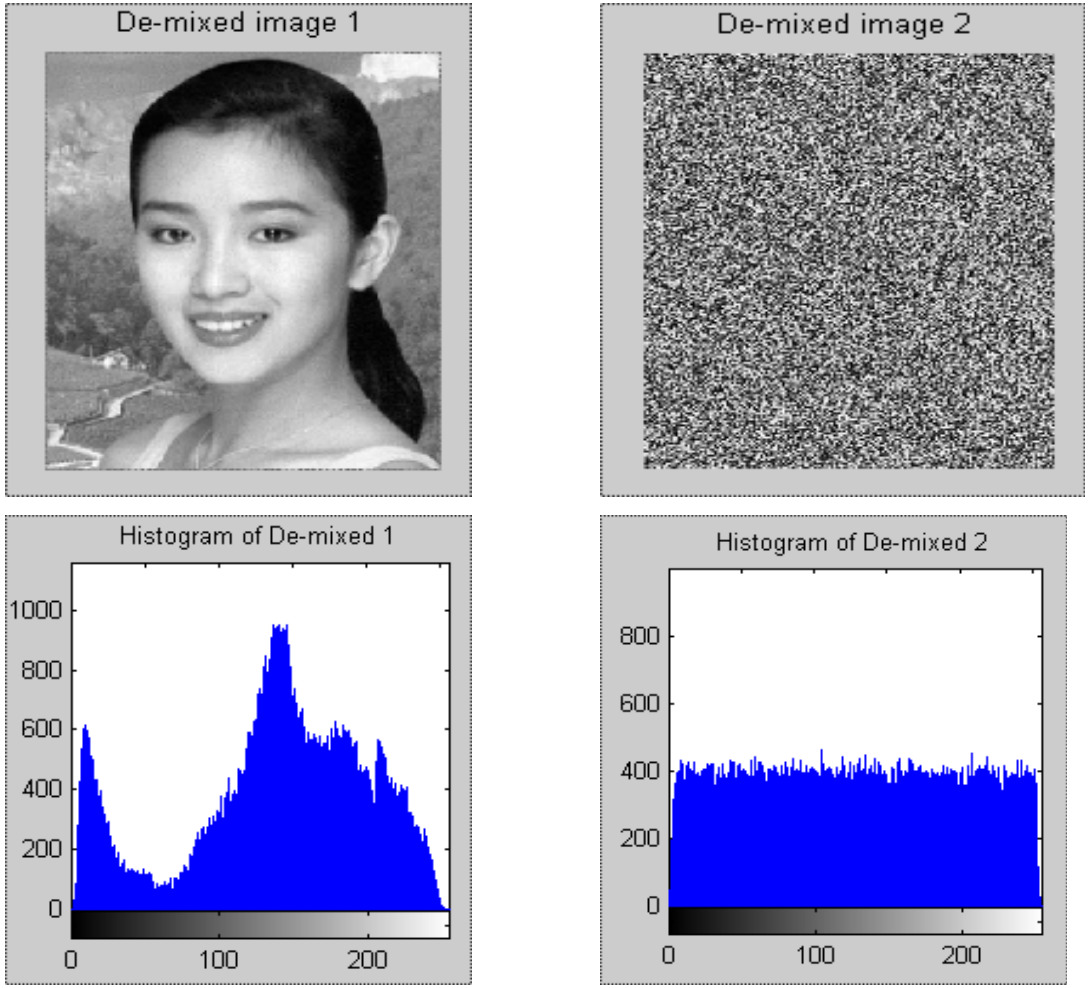








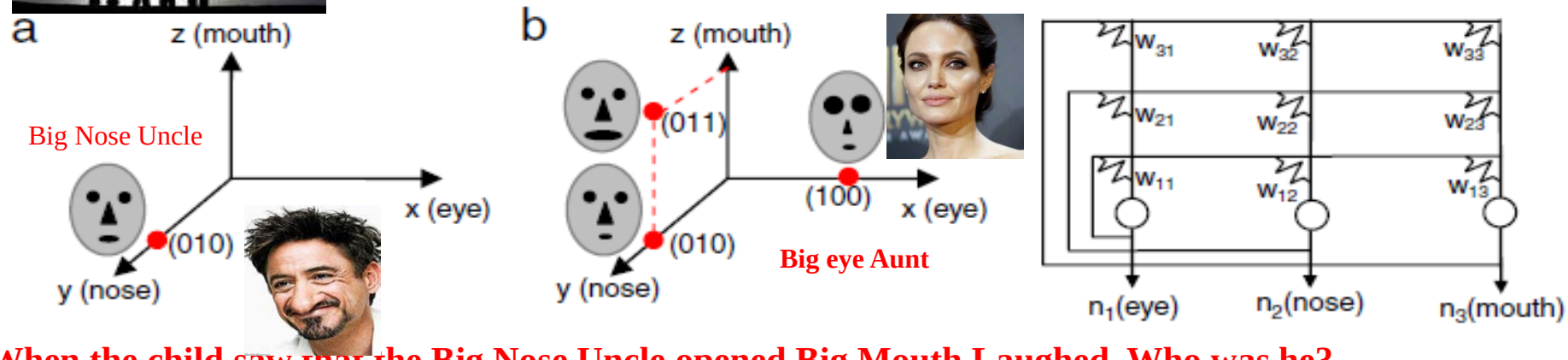
A simple & fast image pre-processing: “While agree, the signal; disagree, the noises.” This is universal 2nd look in parallel in real time principle for survival that innate born with and need no teacher! Unsupervised Deep Learning V1~V5 at our back of the head (Cortex 17 for Feature Extraction & store into Hippocampus as matrix Associative Memory Storage (Amygdala where Grand Mother cells stored as the e-IQ)



Feature Domain Classifier requires Ortho-normal (ON) set; so that FE Classifier can enjoy Fault Tolerance And Generalization as two sides of the same coin NI defined as (1) **Power of Sensor Pairs Unsupervised Deep Learning (UDL) Feature Extraction (FE)**; (2) **Homeostasis Brain by relaxing toward constant global temperature**

"Write by outer products" and "Read by inner product." enjoy **Fault Tolerance Abstraction Generalization (FT,A,G).**

H. Szu et al. / Neural Networks 29–30 (2012) 1–7



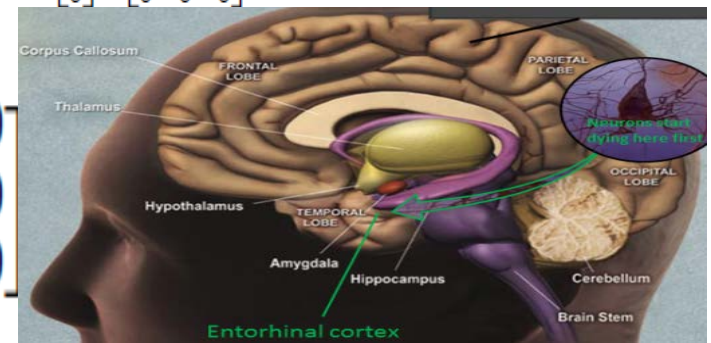
When the child saw that the Big Nose Uncle opened Big Mouth Laughed, Who was he?

MPD WRITE: Hippocampus AM

$$[AM]_{big\ eye\ aunt} = \overrightarrow{output} \otimes \overrightarrow{input} = \begin{bmatrix}1\\0\\0\end{bmatrix} \begin{bmatrix}1 & 0 & 0\\1 & 0 & 0\\0 & 0 & 0\\0 & 0 & 0\end{bmatrix}$$

$$[AM]_{big\ nose\ unde} = \overrightarrow{output} \otimes \overrightarrow{input} = \begin{bmatrix}0\\1\\0\end{bmatrix} \begin{bmatrix}0 & 1 & 0\\0 & 0 & 0\\0 & 1 & 0\\0 & 0 & 0\end{bmatrix}$$

$$[AM]_{big\ nose\ unde} + [AM]_{big\ eye\ aunt} = \begin{bmatrix}1 & 0 & 0\\0 & 1 & 0\\0 & 0 & 0\end{bmatrix}$$



MPD READ:

$$Recall\ Vector = [AM][error\ transmitted]$$

$$\cong \sigma\left(\begin{bmatrix}1 & 0 & 0\\0 & 1 & 0\\0 & 0 & 0\end{bmatrix}\begin{bmatrix}0\\1\\1\end{bmatrix}\right) = \begin{bmatrix}0\\1\\0\end{bmatrix}_{uncle\ smiles}.$$

Introduction to Deep Learning ANN

What is Single Layer Neural Network MPD Recursive Update?

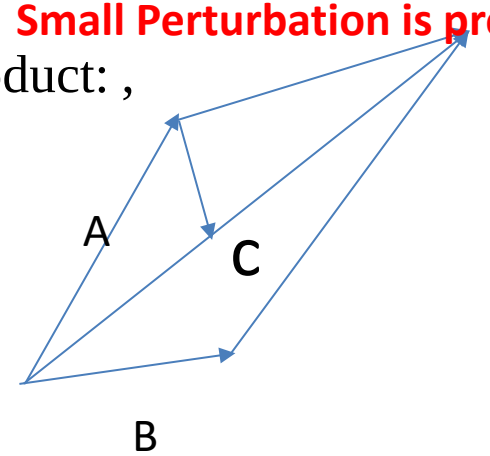
To achieve sequentially Wiener Filter is Kalman Filter

- *Given N uniform (or LMS weighted) average*
- Wiener Filter $< X >_N = \frac{1}{N}\sum_{n=1}^{N} X_n$
- $< X >_{N+1} = \frac{N+1-1}{(N+1)}\frac{1}{N}\left(\sum_{n=1}^{N} X_n\right) + \frac{1}{N+1}X_{n+1} = < X >_N + \frac{1}{N+1}\left(X_{n+1} - < X >_N\right)$
- Kalman Filter $< X >_{N+1} = < X >_N + K_{n+1}\left(X_{n+1} - < X >_N\right)$
- Centroid Update
- $\vec{C} = (\vec{A} + \vec{B})/2 = \vec{A} + (\vec{B} - \vec{A})/2$

Opt. Expert System Szu & Caulfield Applied Optics Vol. 26,Issue 10,pp. 1943-1947(1987)https://doi.org/10.1364/AO.26.001943 **Small Perturbation is prefer for stability**

Neural Networks I/O: **Write** by Outer product: ,

$$\begin{bmatrix} \\ \\ \end{bmatrix}\begin{bmatrix} \\ \\ \end{bmatrix} = \begin{bmatrix} \\ \\ \end{bmatrix} = [HAM]$$

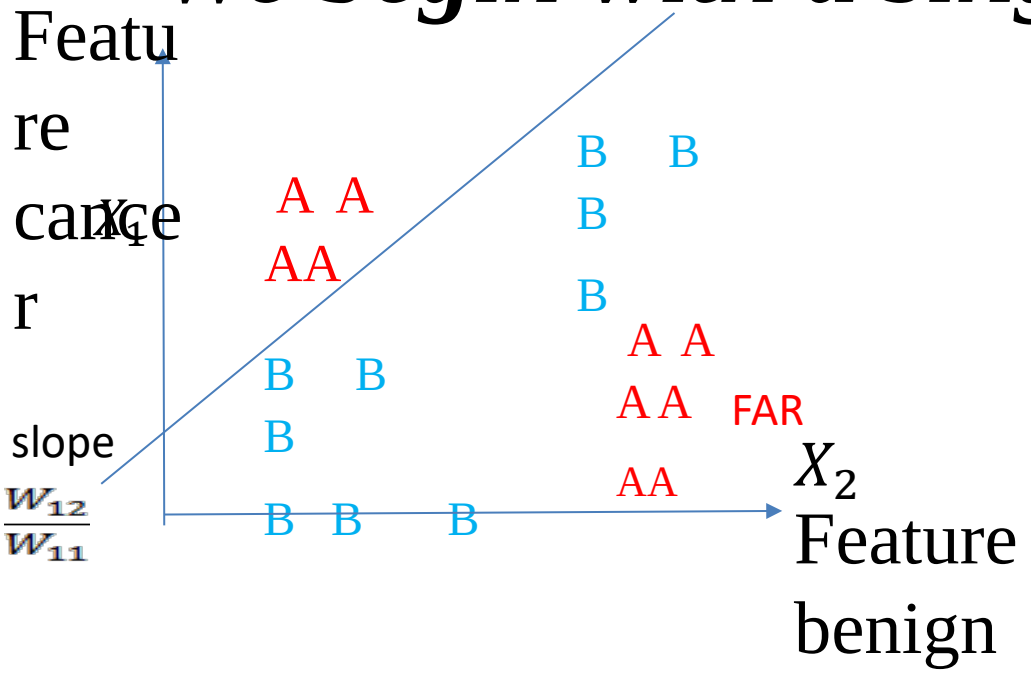


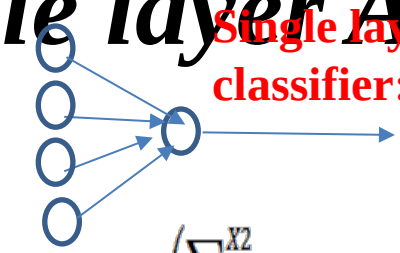
Read by inner product:

$$[HAM]\begin{bmatrix} \\ \\ \end{bmatrix} = \begin{bmatrix} \\ \\ \end{bmatrix}\begin{bmatrix} \\ \\ \end{bmatrix} = \begin{bmatrix} \\ \\ \end{bmatrix}$$

Mathematically speaking, *why Multiple Layers Deep Learning (DL)?*

We begin with a single layer ANN:





Single layer is Linear classifier:

$$S_i = \sigma\left(\sum_{j=X1}^{X2} W_{ij} X_j - \theta_i\right) \geq 0$$

$$X_1 W_{11} + X_2 W_{12} \geq \theta_1$$

$$X_1 W_{21} + X_2 W_{22} \geq \theta_2$$

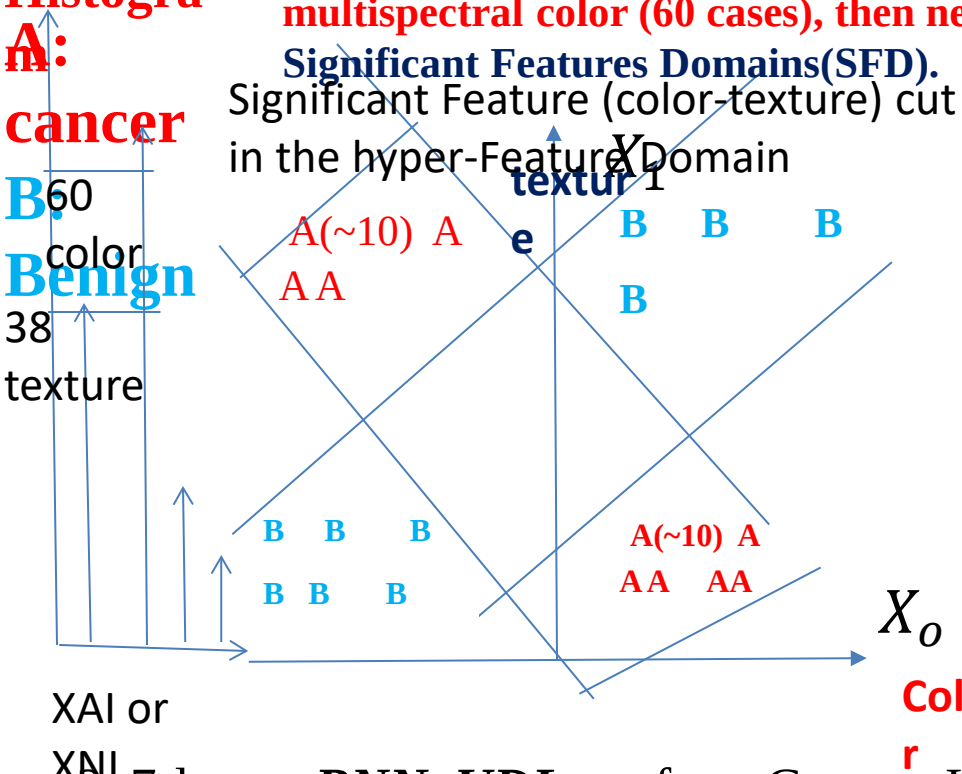
$$X_1 + \frac{W_{12}}{W_{11}} X_2 = \Delta\theta$$

1-layer Artificial Neural Network (ANN)
is a **Linear Classifier** for target **A (e.g.** malignant cancer) & non-target **B (e.g.** benign tumor), with high **False Alarm (Cancer A) Rate (FAR) causing delay**

Multiple Layers namely deep (layer-wise convex hull) learning will be better (next).

We need Multiple Spectral Layers (MSL) separates the Cortex 17 back of the head Feature Extraction (SFE) from Hippocampus Associative Memory (HAM) under two hemisphere of brain (Logical LHS & Emotional RHS) where Multiple Layers (ML) Machine (Convex Hulls) Classifier (MC) to explainable NI with Histogram.

FE histogram yields XAI or XNI that Melanomas are significantly determined by the multispectral color (60 cases), then next by the texture (38 cases) out of 100, as % of Significant Features Domains(SFD).



- 3x7-layers ***BNN UDL*** are for a Convex Hull **Machine Classifier (MC)**
- Enhance **Receiver Operation Characteristics (ROC),**
- Learning to Increase the **Probability of Detection (PD)** reduce the **False Alarm Rate (FAR)**,
- This goal ***can be directly mapped*** into **Unsupervised Deep Learning**. (cf. **NI & BNN**; Ph. D. Thesis in Data Mining, Intelligent Robots, Autopilots, XAI, ECI, NI, etc.)

BDA Drug Discovery by Explainable AI

Is the Herbal Mushroom G Lucidum, Lingzhi (that 2000 Nobel Laureate Literature Mr. Gao Xingjian recovered in cancer) similar to Merck immunotherapy Keytruda (Pembrolizumab) drug (that President Jimmy Carter Liver and Brain Metastasis cancer: Aug. 2015 ~Feb. 2016)?

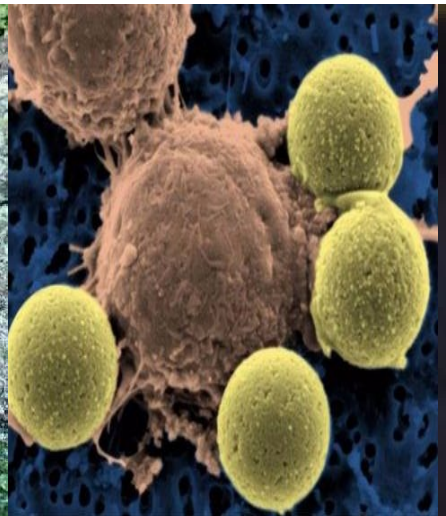
While Merck drug (Yellow balls) are targeted at the Programmed cell Death 1 (PD-1) receptor and allows the body's own immune system go after the cancer cells. While they are all worked on human immune systems, the key difference between Oriental Herbal Medicine and Western Molecular personalized precision targeted drug is mainly in that the holistic herbal medicine is slow in nature for years versus Western drug fast in half a year.

2000 Literature Nobel Laureate China Mr. Gao Xingjian recovered from cancer

NIH/CAM: Herbal Medicine
G Lucidum, Lingzhi

Merck Keytruda (Pembrolizumab)

Jimmy Carter Liver and **brain Metastasis advanced Melanoma**
Aug. 2015 ~Feb. 2016

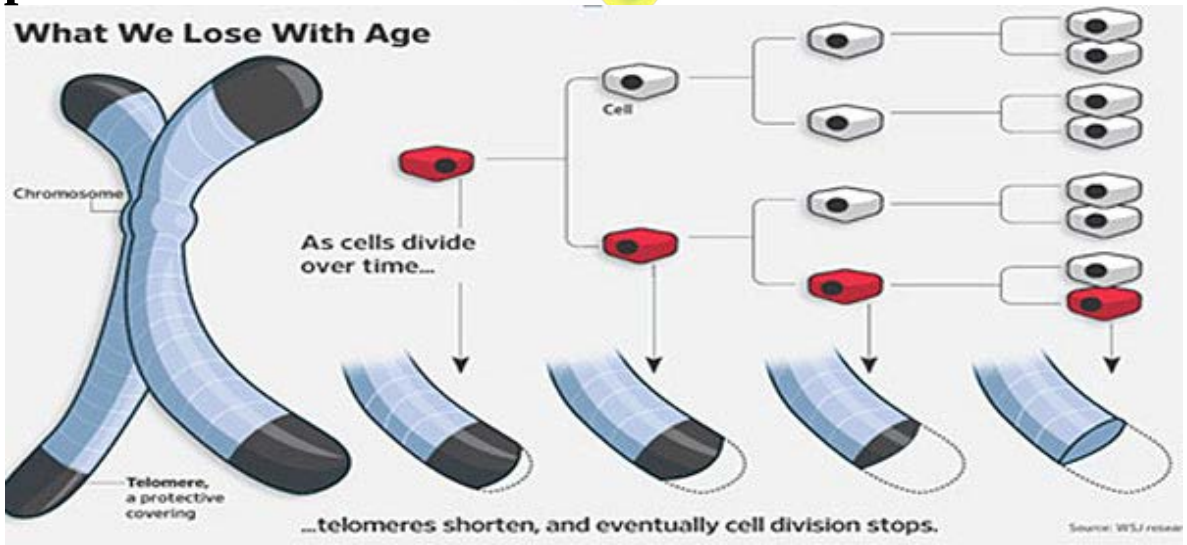


Longevity: "Nothing beats good genes (genome), except phoneme or epigenetic (outside the gene)" "Reverse Aging" Calico (California Life Co.) said maybe. To prevent the irreversible heat death , we need all scale longevity requires **Yamanaka Induced Pluripotent Stem cells** 4 genes, **Blackburn Telomere Length &** Hayflick turns, epigenetic Methylation Histone marker, NIA Dir. Mattson Restrictive Calorie.

3 billion pairs of A-T C-G codons of DNA packed in 23 pairs in a total of 46 chromosomes un-winded linearly in 3m long

Kenyon of UCSF discovered worm DAF-2 aging gene; DAF-16 for Longevity gene ; but we're complex

We lose telomere size i.e. 50 times in 9 months known as Hayflick limit



2 mm to 20 mm X-X female, X-Y male

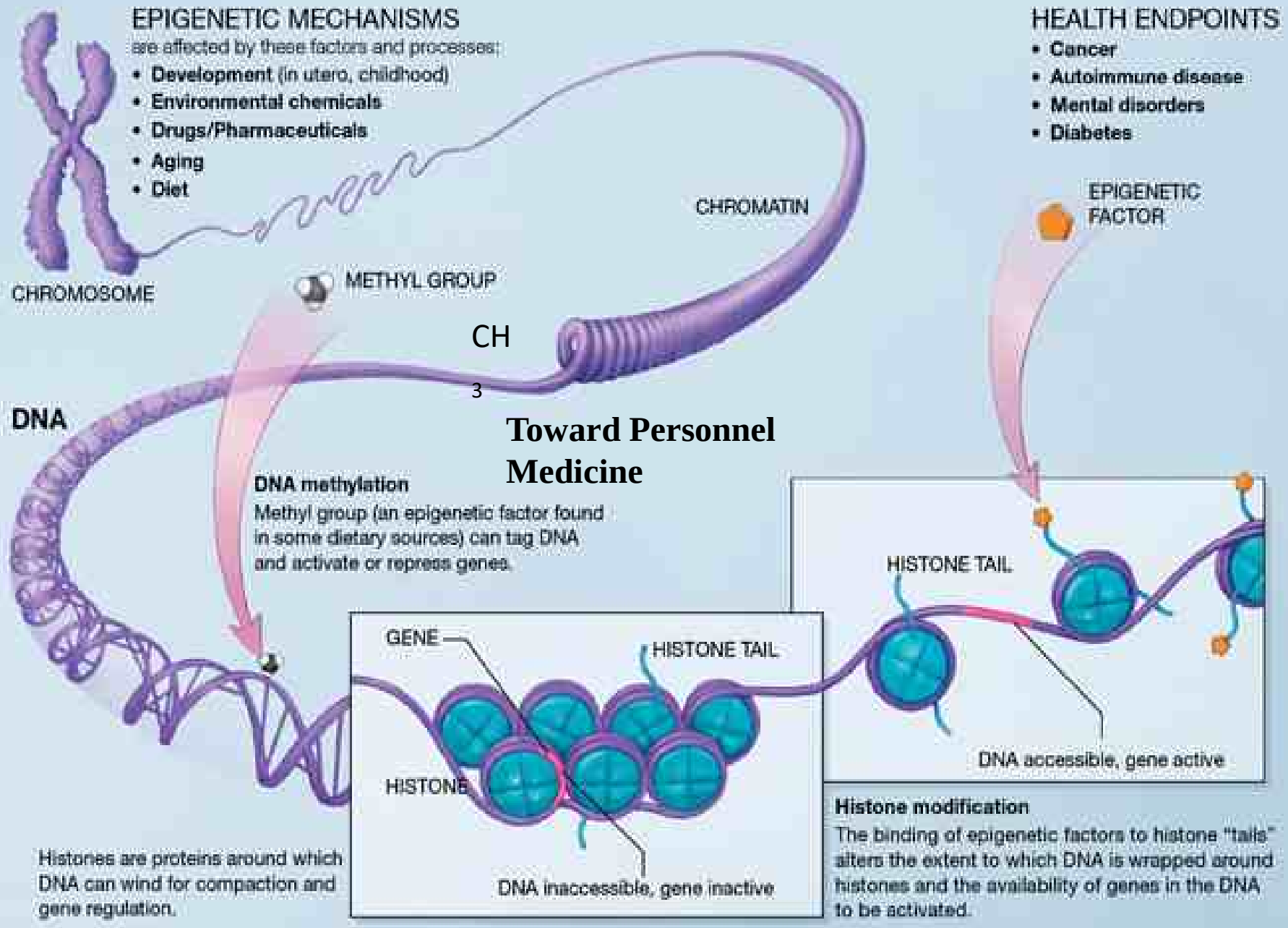
Eukaryote ("Eu=well" has a nuclei & Mitochondria foreign energy production cells inside our cell) billions years ago; Prokaryote ("Pro=pre") primitive cell

UN/WHO/NIH/NAAS

Le télomère protège le chromosome contre les dégradations

Elizabeth H. Blackburn Carol W. Greider Jack W. Szostak

Prix Nobel de physiologie ou médecine, 2009

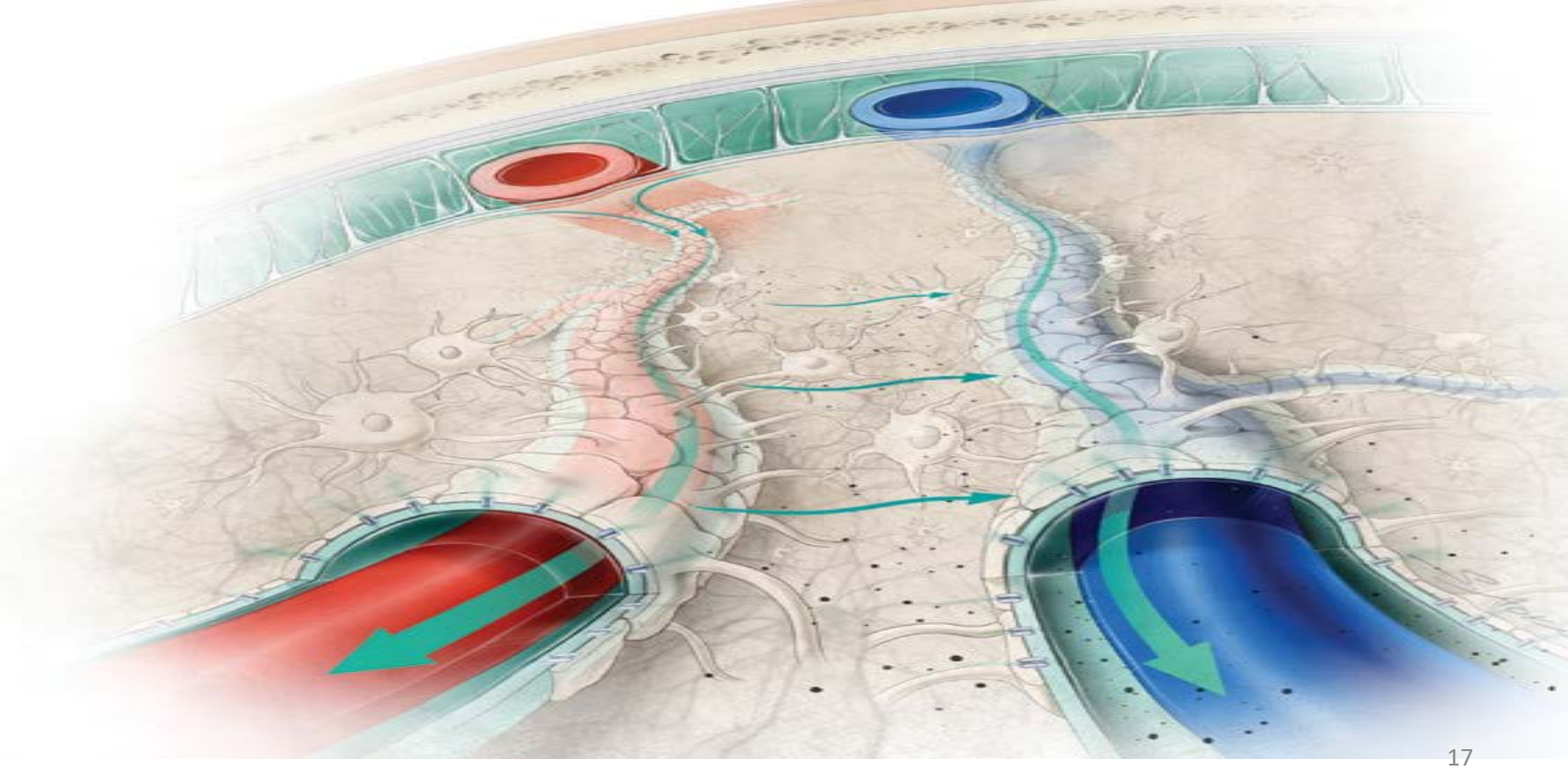


Toward Personnel Medicine

“Brian Drain,” M. Nedergaad & S. Goldman

Sci. Am. Mar 2016 : Brain Blood Barrier Glymphatic System

only when sleep Astrocytes Neuroglia cells can have the chance clean up 20% of full body energy by-products beta-Amyloids etc. without further block by more junks through those restrictive brain cells narrow passages. That’s why sleep tight with 8 hours is critical mental health.



Cogito ergo sum."***I Think therefore I am*** (***living***)." René Descartes.
"***je pense, donc je suis***" "*Discourse on the Method*," (1637).

"*Lesson in Creativity, editorial,*") Szu & Driggers, Appl. Opt. 54, 2015/08)
(*"how to think and how to work out ones thought"* Renaissance Trade Secret)
4C individual creativity principles, **10 G**roup Rules how **1+1=11;1+1<2**

1. **Courage:** not just ask the question; but answer the question yours
2. **Comprehensiveness: Eugene Clark Maxwell** did not invent 2 static sources laws **C**
Bio-Savart magnetic dipole, and 2 moving sources generate cross-over the other field
induction law; but he discovered the self-consistency of 4 equations if added the displa
within the Capacitor, that complete the **Maxwell** field 4 equations. Thus, the **Hertz** rad
fluctuation energy and the ground state Higg's bosons, for the condensation of the univ
3. **Complimentary: Paul Ehrenfest** QM Operator Commutator $[P, Q] = i\hbar\{P, Q\}$ equ
4. **Conscientiousness:** 90% Perspiration & 10% Inspiration Thomas **Edison**

A. **Emotional e-Brain**: Praise in public ands criticize in private; 2. Be patient with immature ideas; 3.Be the most positive member of the team, 4. Be a mentor to junior team members;
B. **Logical L-Brain**: 1. develop multiple resolution talks about the project/proposal/etc. one-minute(elevator) three minute (office) and ten minute (seminar); 2 Practice cooperation during a t least one interaction daily; 3. Remember and recognize individual contribution; 4. Keep two notebook: one to document research and another as a to-do list.
C. **Claustrum C-Brain**: 1. Sharpen public speaking and writing skills as well as social skills; 2. Talk the initiative to celebrate a team member's important days and events.

Renaissance Trade Secret passed down along Ph. D. Thesis Disciples: from **Ludwig Boltzmann, to Paul Ehrenfest, to George Uhlenbeck, and to Harold Szu, among others**, to all of their Ph.D. Students (cf. https://www.genealogy.math.ndsu.nodak.edu/Harold_Szu2/)

Multiple Resolution Q/A

How to Express Yourself to Go Ahead

Always Prepare *10 second* (Elevator) "*Small Talk*" "Wearing a smile!" WTP (*Weather*, *Travel*, *Hobby*), No PRS (*Politics*, *Religion*, *Sex*)

Prepare *1 minute Office Talk Deep Learning shall be explainable AI*

Prepare *10 minute Seminar Talk: Go beyond AI ANN via BI BNN to NI to NNN*

How to express yourself in writing

Journalist Writing versus Scientific Writing

Journalist Writing: Who When Where What How & (never speculate Why)

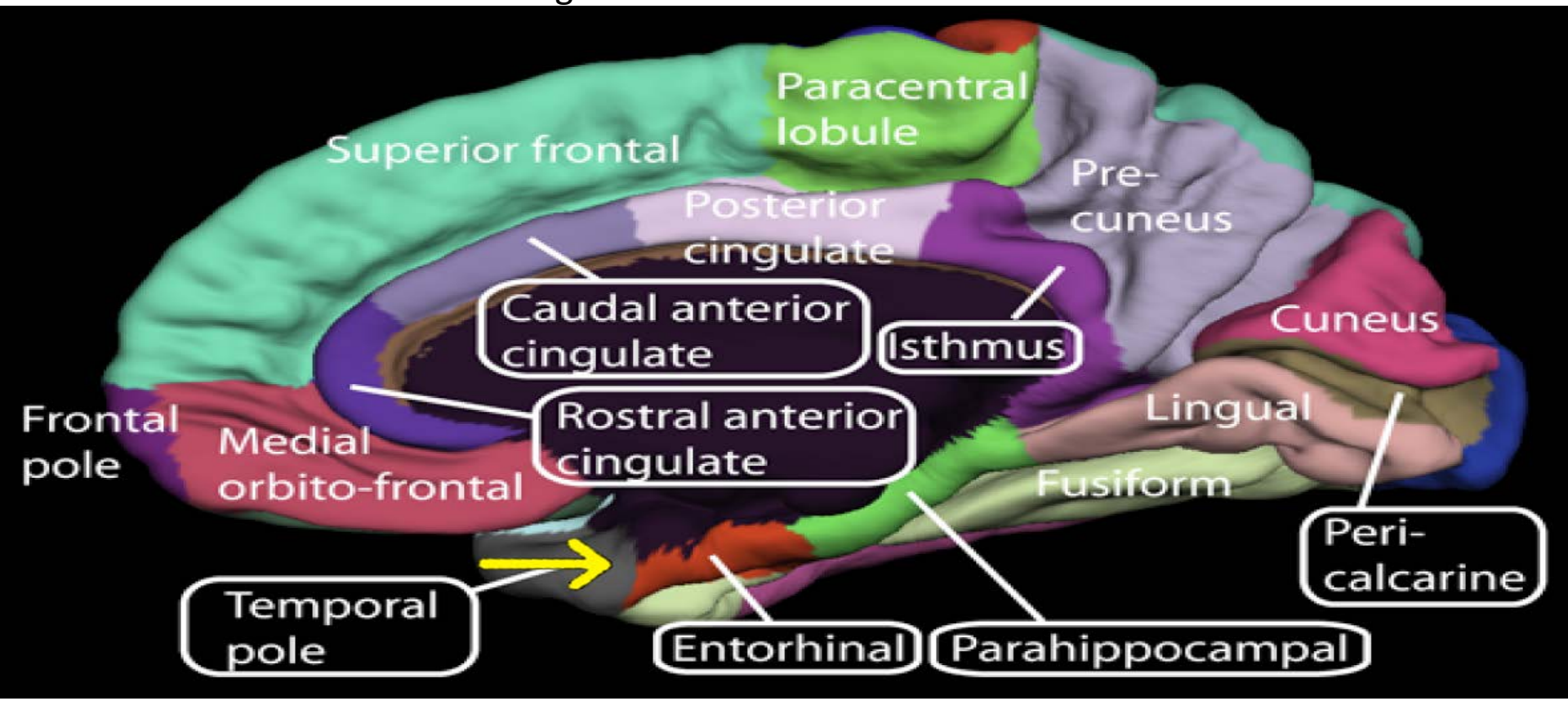
"Anything is publishable– A small idea publish a small paper, a big idea a big paper, but never mixed them u, a small idea write a big paper, a big idea a small paper." Albert Einstein.

For English of Second Language the Best Weekly Reading is Time, or Newsweek Magazine or New York Times Week end Columnist

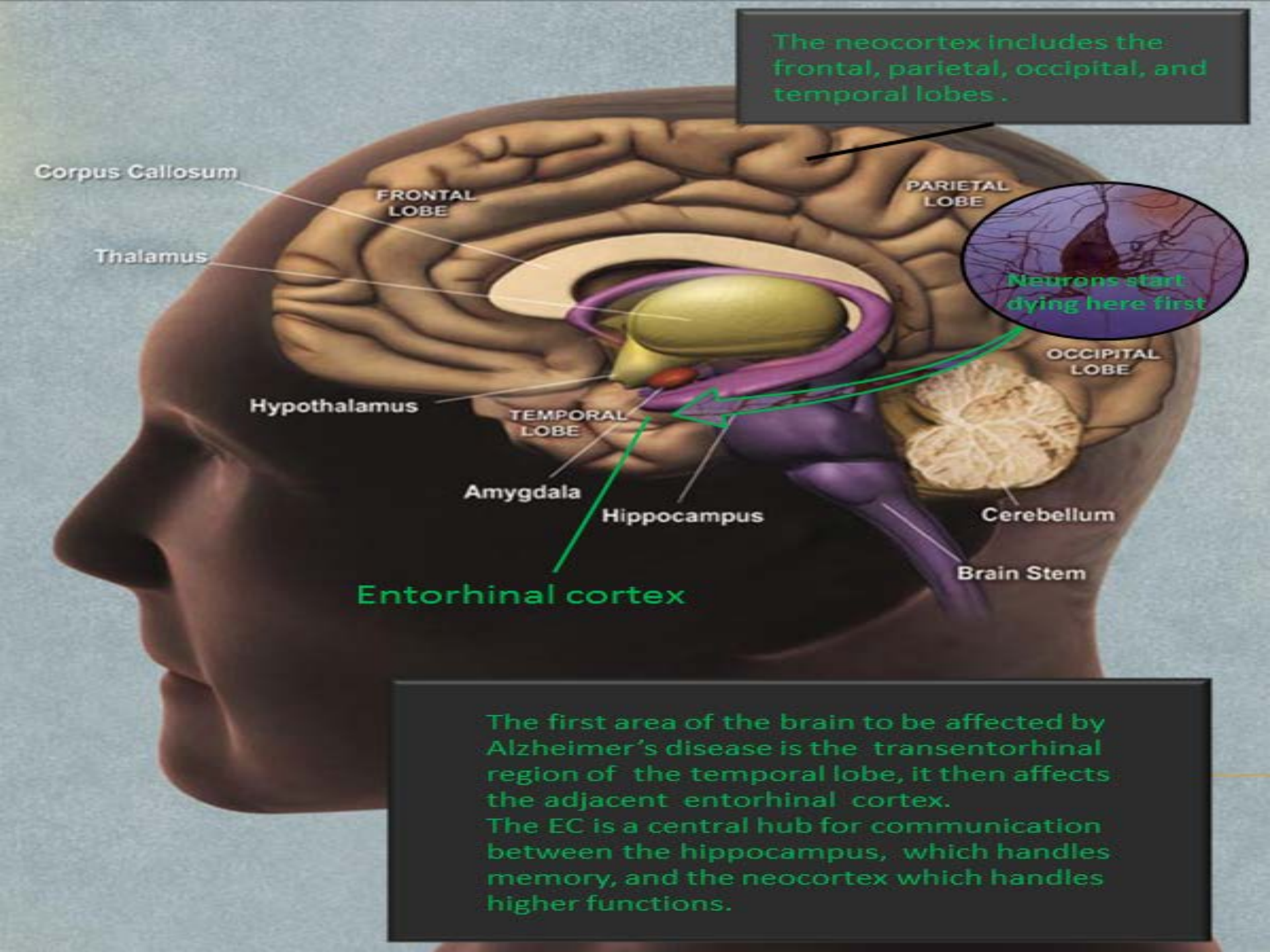
Joint RIKEN-MIT Lab at Japan Prof. Susumu Tonegawa
Science April 6 2017

• 1950 H. Molaison Epilepsy Surgery damaged Hippocampus lost the memory by Cortex (17 V1—V6) remains to have memory

•A new MIT study of the neural circuits that underlie this process reveals, for the first time, that memories are actually formed simultaneously in the hippocampus and the long-term storage location in the brain's cortex. However, the long-term memories remain "silent" for about two weeks before reaching a mature state.



Entorhinal Cortex ("Interior Nose", ear-eye association) LTM & Hippocampus STM


The neocortex includes the frontal, parietal, occipital, and temporal lobes .
Corpus Callosum
FRONTAL LOBE
PARIETAL LOBE
Thalamus
Neurons start dying here first
OCCIPITAL LOBE
Hypothalamus
TEMPORAL LOBE
Amygdala
Hippocampus
Cerebellum
Brain Stem
Entorhinal cortex
The first area of the brain to be affected by Alzheimer's disease is the transentorhinal region of the temporal lobe, it then affects the adjacent entorhinal cortex.
The EC is a central hub for communication between the hippocampus, which handles memory, and the neocortex which handles higher functions.

RIKEN Brain Science Institute; & MIT Picower Institute for Learning and Memory

•**Learning and memory** are vital for living—finding our way home to playing tennis to giving a cohesive speech. Some of us have devastating consequences in **Alzheimer's patients**, or difficulty in suppressing a recall of a memory as seen in **PTSD** patients.

•When we visit a friend, our brain stores a **short-term memory** called the **hippocampus**.

•A new **MIT study** of the neural circuits that underlie this process reveals, for the first time, that memories are actually formed simultaneously in the **hippocampus and the long-term storage location in the brain's cortex**. long-term memories remain "silent" for about **two weeks before reaching a matu**re state.

•When you remember a particular experience, that memory has three critical elements — **what, when, and where**. MIT neuroscientists have now identified a brain circuit that processes the "**when" and "where**" components of memory.

•This circuit, which connects the **hippocampus** and a region of the **cortex known as entorhinal cor**tex, separates location and timing into two streams of information. The researchers also identified two populations of neurons in the **entorhinal cortex** that convey this information, dubbed "ocean cells" and "island cells."

•Previous models of memory had suggested that the **hippocampus**, separates **timing and context information**. However, the new study shows that this **information is split even before it reaches the hippocampus…**

No general math solutions of BDA (heterogeneous) or LDA (homogeneous): Goal is to extract salient Features so that the final classifier is fast and explainable

Given a set of admissible k images in c categories

$\{\vec{X}_k^c(x,t)|k=1, K; c=1,2,\ldots C\}$,

we wish analyze a set of orthonormal features vectors per class c, and into group

$G\{f_l^c(x)|l=1,..N^c\}$.

We need BNN to iterative recursiv

Deep Learning with feedback.

$$\{\vec{X}_k^c(x,t)\} \supset \{f_l^c(\mathbf{x})\} \supset \{G(\vec{X}_k^c|f_l^c)$$

Longevity till the death we apart; from the death we learn the life, from disorder we learn the order, as the truth is complement to the false:

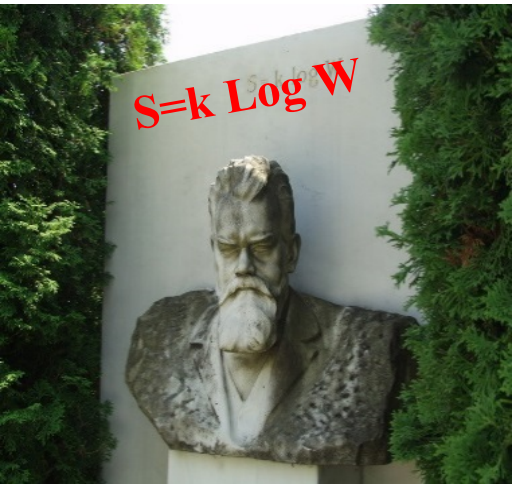
(i) Biological Neural Net (BNN) is based on constant global temperature Brain Thermodynamics at Minimum Free Energy (MFE);

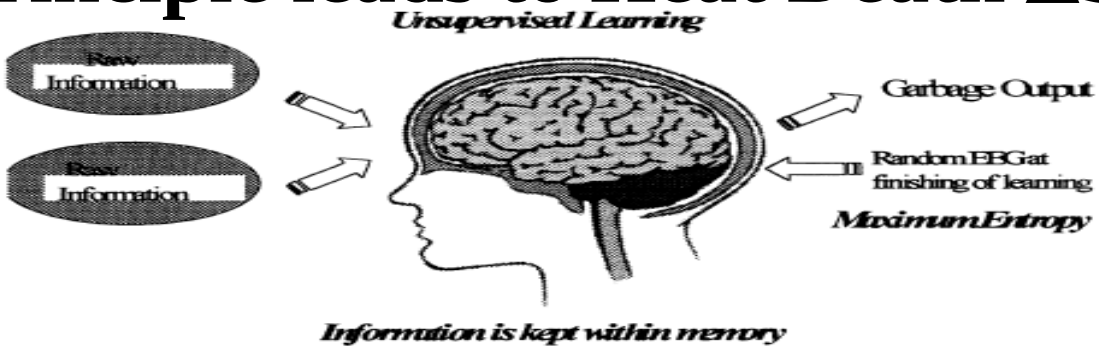
(ii) Smartness inheritance? ***Genome by DNA & Phenome by Epigenetic;***

(iii) Heathy Longevity by ***Telomerase Enzyme***.

(iv) Brain Tumor is known as **Glioma**. A **glioma** is a type of **tumor** that starts in the **brain** or spine. It is called a **glioma** because it arises from glial cells. The most common site of **gliomas** is the **brain**. **Gliomas** make up about 30% of all **brain** and central nervous system **tumors** and 80% of all malignant **brain tumors**. (https://en.wikipedia.org/wiki/**Glioma)**

Theorem NI learning at Min. Free Energy(MFE) Homeostasis Principle leads to Heat Death ΔS>o





Boltzmann said the Entropy is a measure of the degree of uniformity, e.g. neuron firing rates. Which has a larger entropy? Sands or Rocks?

Boltzmann Equilibrium Thermodynamics

$$S_{tot} \equiv k_B \, Log \, W_{tot}; W_{tot} \equiv \exp\left(\frac{S_{tot}}{k_B}\right) = \exp\left(\frac{(S_{brain} + S_{env.})T_o}{k_B T_o}\right) = \exp\left(\frac{S_{brain}T_o - E_{brain}}{k_B T_o}\right)$$

$$= \exp\left(-\frac{H_{brain}}{k_B T_o}\right) \equiv W_{MB}$$

Maxwell Boltzmann Canonical Probability is the statistical equilibrium is known as Homeostasis

$$H_{brain} \equiv E_{brain} - T_o S_{brain}$$

$$\Delta H_{brain} \equiv \Delta E_{brain} - T_o \Delta S_{brain}$$

Boltzmann heat death $\Delta S_{brain} > 0$ due to incessant collisional mixing towards more uniformity (Inequilibrium Thermodynamics)

$$\Delta H_{brain} \equiv \Delta E_{brain} - T_o \Delta S_{brain} \leq 0$$

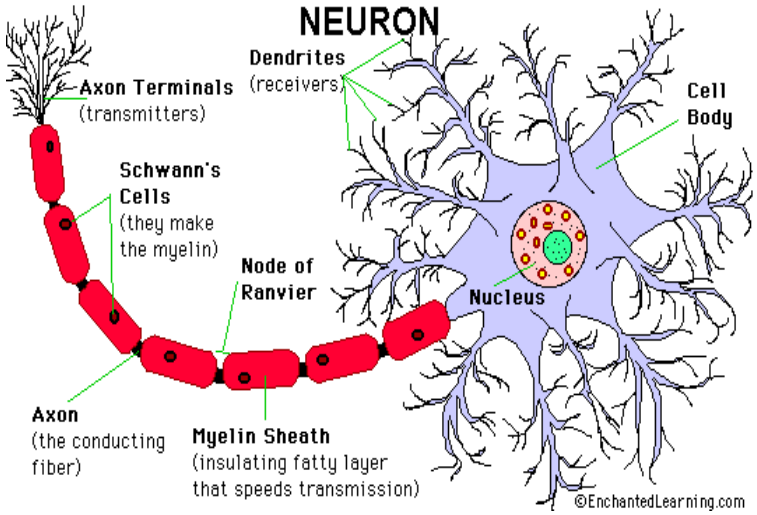
Stable Brain Dynamics is necessary for robust

MFE: $\Delta H_{brain} \equiv \Delta E_{brain} - T_o \Delta S_{brain} \leq$

Aleksandr Lyapunov

June 6, 1857, November 3, 1918, [St. Petersburg State University]

https://en.wikipedia.org/wiki/File:Alexander_Ljapunow_jung.jpg



$$\frac{\Delta H_{brain}}{\Delta t} = \left(\frac{\Delta H_{brain}}{\Delta[W_{i,j}]}\right)\frac{\Delta[W_{i,j}]}{\Delta t} = -\frac{\Delta[W_{i,j}]}{\Delta t}\frac{\Delta[W_{i,j}]}{\Delta t} = -$$

we have derived the MFE Gradient Force in consistent with the Neurody

$$\frac{\Delta[W_{i,j}]}{\Delta t} = -\frac{\Delta H_{brain}}{\Delta[W_{i,j}]}$$

A half century ago, Canadian Biologist Donald. O. Hebb (1904-1985) observed the synaptic weigh

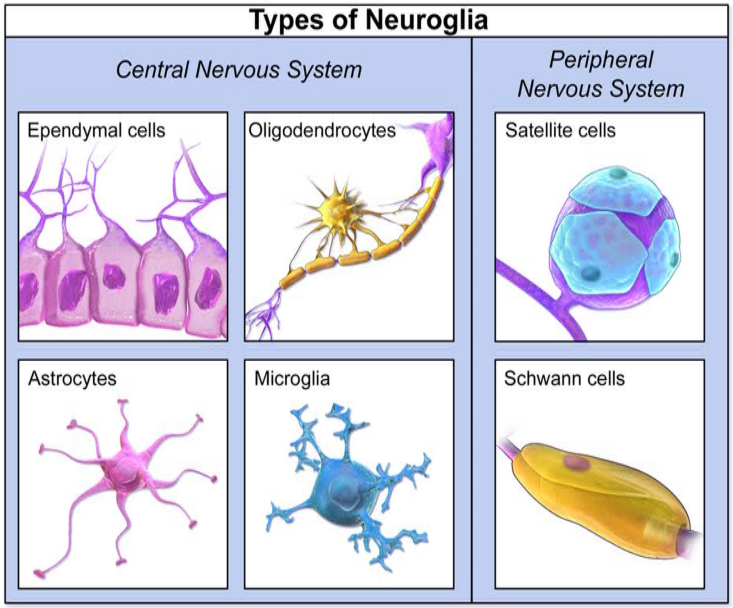
Dendrite net defines input vector glial

morphologically dependent on cell typir

$$\overrightarrow{Dendrite_j} \equiv \sum_i [W_{i,}$$

$$\frac{\Delta[W_{i,j}]}{\Delta t} \equiv \left(-\frac{\Delta \mathrm{H}_{brain}}{\Delta[W_{i,j}]}\right) = \left(-\frac{\Delta \mathrm{H}_{brain}}{\Delta \overrightarrow{Dendrite_j}}\right.$$

$$\vec{\mathrm{g}}_j \equiv -\frac{\Delta \mathrm{H}_{brain}}{\Delta \overrightarrow{Dendrite_j}}$$ (**Szu 201**



We have derived for the first time the **mathematical definition of glia** (discovered by pathologist **Rudolf Virchow *1856).*** This math definiti explains the unified theory of all different neuron typing about 15 in m predicts different Dendrite vectors defining different kinds of Glial Ce kinds of Glial cells (4 in CNS: Ependymal, Oligodendrocytes, Astrocy in PNS: Satellite, Schwann cells). $\Delta[W_{i,j}] = [W_{i,j}(t+1)] - [W_{i,j}(t)]$

Joel Fuhrman, M.D. “Eat to Live,” National Bestseller 2003,2011

- **Joel Fuhrman**, M.D: "Eat to Live", National Bestseller, Little, Brown and Co. pp. 380, NY, NY, 2003, 2011.
- **Michael Greger** M. D. with Gene Stone "Not To Die,", Flatiron Book NY,pp.562 2015); cf. www.NutritionFacts.org. For example: p.122 how not die from high blood pressure,p.124 sodium is the culprit.
- **Yanomamo Indians** have the lowest sodium intake kept BP: 100/60 at all age; "Poultry industry injects **chicken carcasses with salt water to artificially** inflate their weight, and yet label 100 percent natural." p.127 Consumer Report. "Salt is our culprit."
- Using **Laser Doppler velocity meter**, one can measure the capillary flow speed. A subject taken a few mini gram of salt can reveal a slowdown of blood flow. Human tend to retain salt. When too much salt retain water in the blood, the heart beats and blood pressure can be increasing to cause the onset of sudden death of patients having a narrowed artery

NIH Inst. Of Complimentary Alternative Medical (CAM) Yoga

This goal is possible unless we emulate BNN NI to separate Feature Extraction from Machine Classification for BDA in drug discovery, in law enforcement, in order to accountable of salient features for Machine Classifier

- We keep i-Robot without e-IQ loving feeling toward master & jeopardies spouse. Then, no Terminator III danger of AI control the world. In general, ***MIQ*** $\subseteq$ **50%** should be in a supervised learning category using large data basis training by the lookup table setup. Since no e-IQ in MIQ.
- Machine intelligence about 20% to 30% should understand simple language & recognize human emotion and some extrapolation and interpolation capability.
- Other than those robots working on the factory floor, the futurist intelligent robots happen in **Deep Ocean, Outer space, Melt down Reactor** with an **unforeseeable NL dynamics interwoven with non-stationary complexity**.
- They may need ***MIQ*** $\supseteq$ **50%** When **MIQ** $\supseteq$ **50%** a machine shall behave human-like with some intrinsic *e-IQ* for better machine-human interface, machine sensory are equipped with learning without the supervision. For example, the team **MIQ** of *UXV (X=air, ground, marine)* shall be equipped with the *Swarming Intelligence* for unsupervised self-organization team formation.

“Science has nothing to do with the truth, but the consistency,” Albert Einstein circa 1910

we can unified Sources of Attractive Field Theory: electron radius, gravitational diameter, and glial cell size.

$$\frac{ee}{r_o} = E = m_e C_o^2; \quad r_o = \frac{e^2}{m_e C_o^2} = 2.8\ 10^{-13}\text{c}$$

$$F = -m_o g = -G\frac{m_o M}{|d_o|^2}; \quad E = m_o C_o^2; \qquad d_o =$$

$$\frac{2F}{\pi G M <\rho_o>} \qquad \vec{\mathrm{g}}_j \equiv -\frac{\partial \mathrm{H}}{\partial \overrightarrow{Dentritic_j}} = O\left(\frac{neuron}{10\ glials}\right)$$

$$\left|\overrightarrow{Dendritic_j}\right| \equiv \left|\sum_{i=1}^{N}\left[W_{i,j}\right]\vec{S}_i'^{(t)}\right| = size\ of\ glial = 0.1 \text{ size c}$$

H is the diameter of neurons in sub-millimeters. Inversely, we observation of 0.1 neuron size, the Glue force is 0.1 chemical layers

Whether the smartness of NI is endowed or cultured? Epigenetic Methylation (Phenome) versus Genetic (**A-T C-G codons** Genome)?

- Older & Wiser (Longevity gain more experience & more judgment.)
- Is NI coded in Genome DNA A-C, G-T pairs or Phenome Methylation (**3 billion pairs of A-T C-G codons of DNA packed in 23 pairs in 46 Chromosomes un-winded linearly in 3m long)**
- European (EU) **Human Epigenetic Programs (HEP)** have investigated many identical twins that their lifestyles may have influenced the epigenetics that pass down to influence the next gen.
- The United Sates (US) **Human Genome Program (HGP)** has decoded the full human genome.
- If Genetic DNA like a **hardware**; then Epigenetic is like a **software**. We need both the US/HGP & the EU/HEP.

Morphological Learning

(1) Beer Belly architecture for a large internal representation degree of freedom (d. o. f.) for easy Generalization of numerous representations capability in compression to the output class.

(2) Hourly glass architecture with less d. o. f. for Abstraction

(3) Input data-driven determines connectivity morphology by glial cells two ad hoc principles

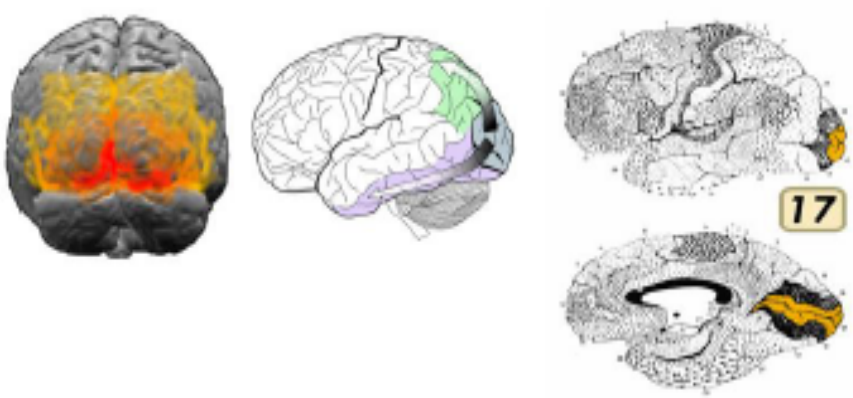
(i) Use it or Lose it, Pruning Node or Growth Connect Node may be decided by difference in MFE's with it or without

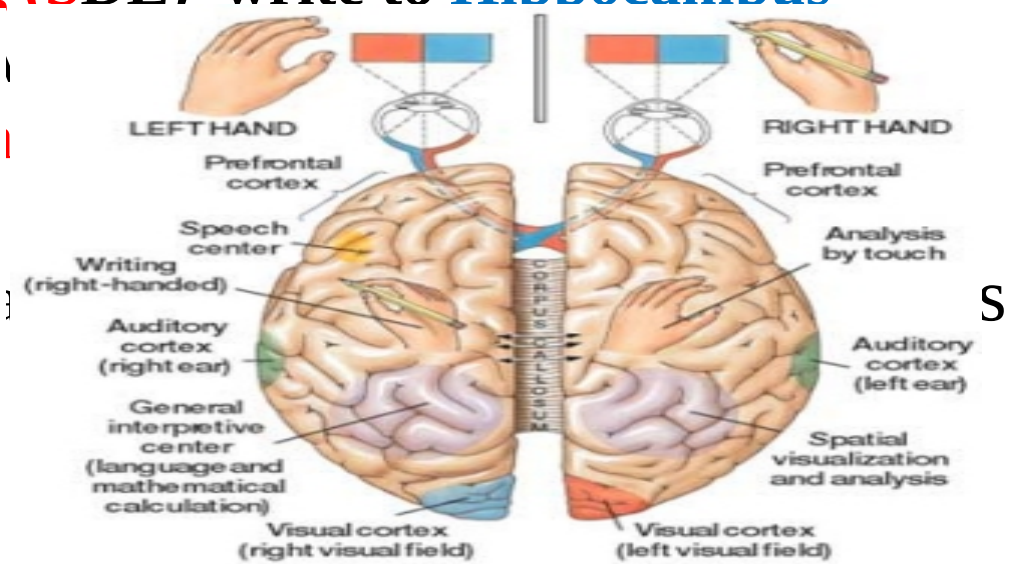
(ii) Hot spot traffic jam recruit more neurons

Explainable NI is based on Feature Domain Classifier driven y evolutional survival need thus redundant development into LHS rational & RHS emotional brain, modeled by the connectionists Biological Neural Networks (BNN). Due to “the fittest for the survival,” BNN functional block connectivity's are different but complimentary in the critical utility of food intake & mating (color & smell help prevent poison enhance the taste; cannot replace the taste buds sensing “proof of pudding is at eating” (energy required for life).

- BNN takes two regions mapping to categories by means of massive parallel distributed associative memory **defined by Write by Outer Product; Read by Inner Product.**
- (1) **Unsupervised Deep Learning (UDL)** for **HVS** (V1~V7) from analog pixel to Feature Extraction (FE);
- (2) **Supervised Deep Learning (SDL) write to Hippocampus**

BA17 Occipital lobe has Dorsal stream V1,V2, V5: where & how eyes &arms; & Ventral stream V1 V2





Back to the other people success story and go beyond

Graphic Processor Unit (GPU), Mini-super MPD Computers, adopted by Internet Giants Google, Face Book, YouTube for AI ANN Big Data Analysis(BDA)

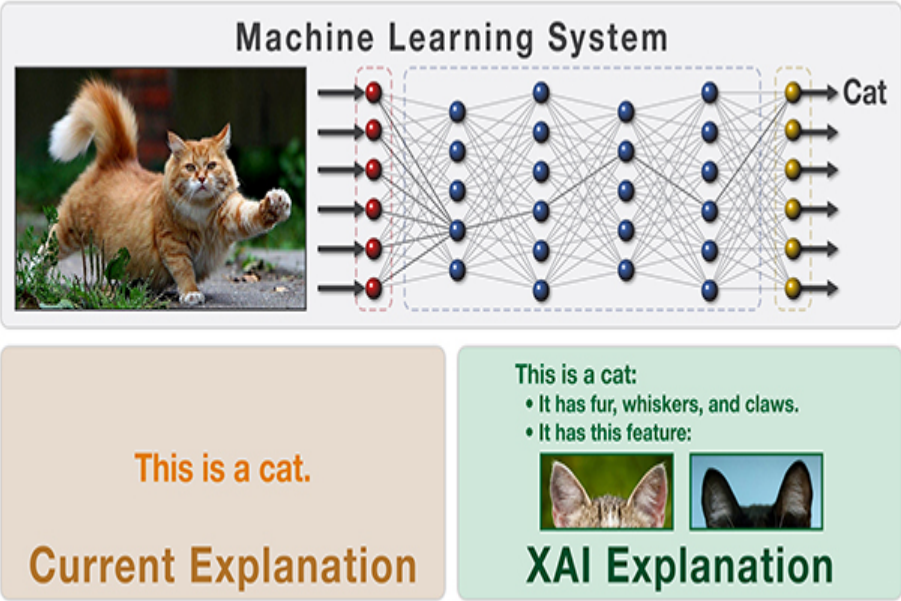
- ***What is AI? Alan Turing*** *introduced* ***AI*** *as that "one cannot tell the difference whether the other end of computer terminal is human or machine,"* *circa WWII.*

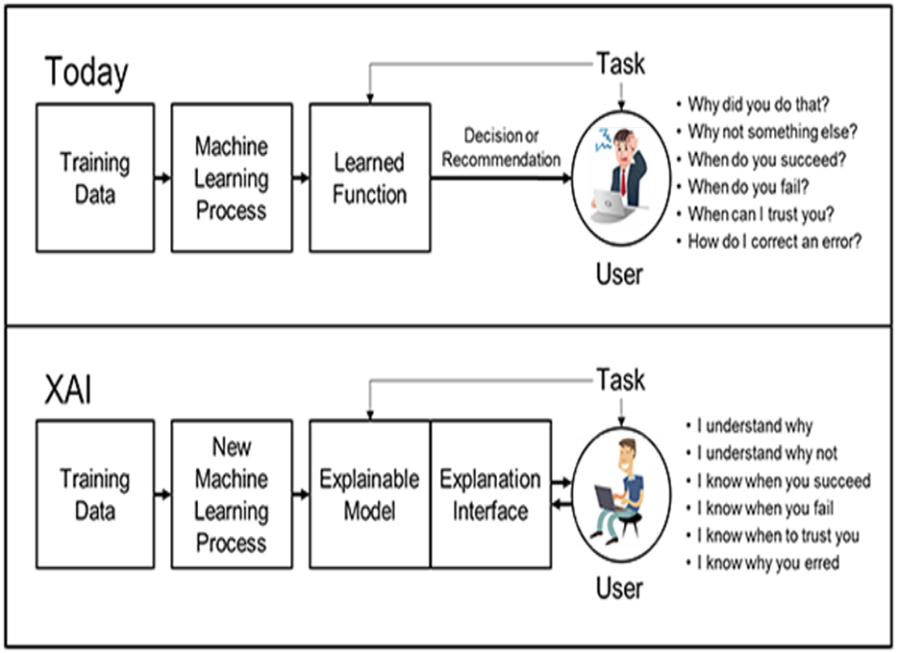
- ***Now the other end of computer can beat human in a chess game, face recognition , video perception.***
- **Google** co-founder ***Sergey Brin*** sponsored ***AI Alpha Go*** (围棋**)** was surprised by the intuition, the beauty & the communication skills displayed by Alpha Go **which** had beat Korean Go Grand Master ***Lee Sedol (***李世石**)** ***in*** 4 to 1 score on March 9-15, 2016, as millions watched on Internet**).**
- **YouTube** has applied AI **Deep Learning** to annotate videos automatically & discovered the favorite video on YouTube turns out to be about favorite pet Cats. (why? led to DARPA XAI)
- **Facebook** applied AI **Deep Learning wishes to achieve** aging & e-IQ independent facial expressions.

DARPA-BAA-16-53(~$10M Program: XAI Explainable AI)

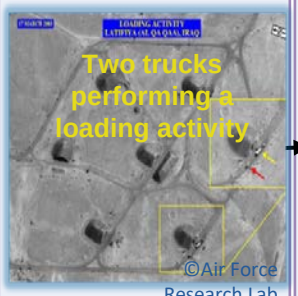
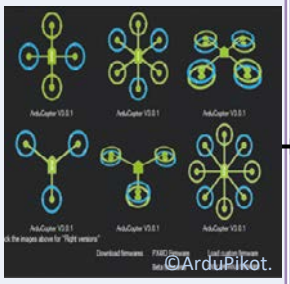
www.darpa.mil/attachments/DARPA-BAA-16-53.pdf

- DARPA Info Innov. Office(I2O) Dir. David Gunning observed "***effectiveness of AI will be limited by the machine's inability to explain its decisions and actions to users***"; Explainable AI (XAI) RFP: Aug. 2016; May 2017+4 Yrs.
- ***Shortfall: More than Pixel Domain Classifier*** vs. ***Feature Domain Classifier***.

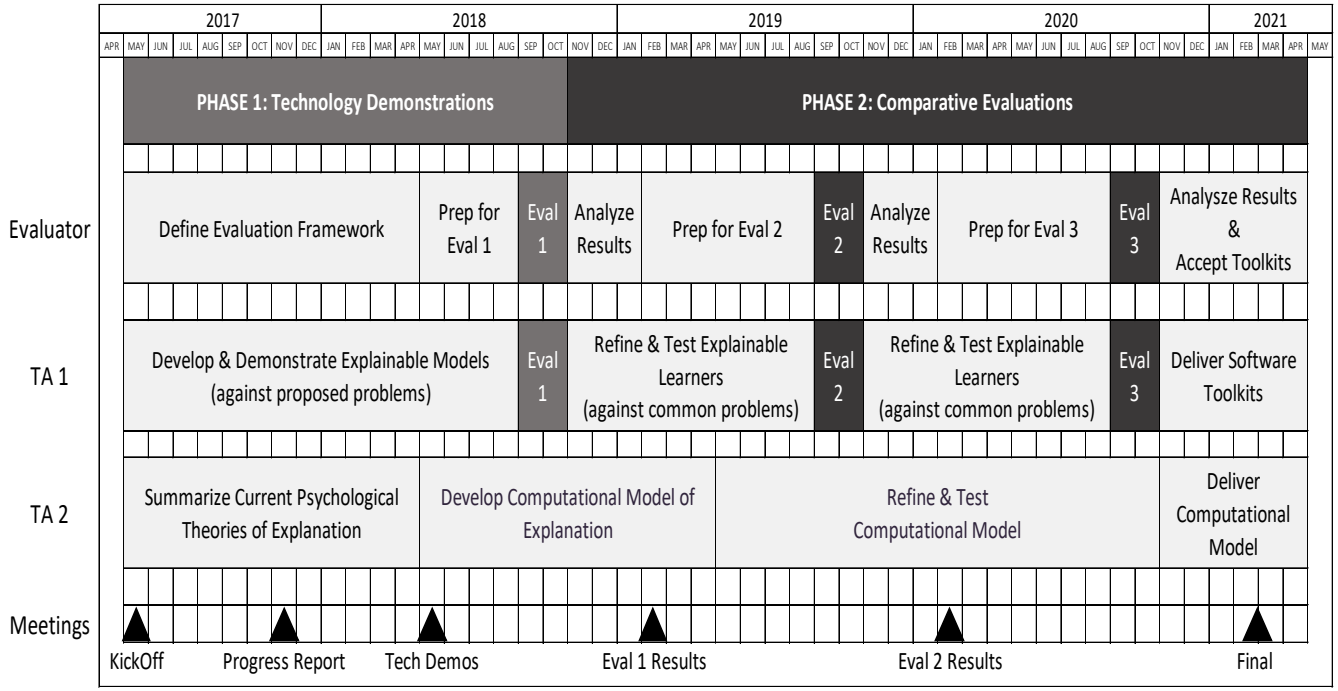




Explainable AI – Challenge Problem Areas

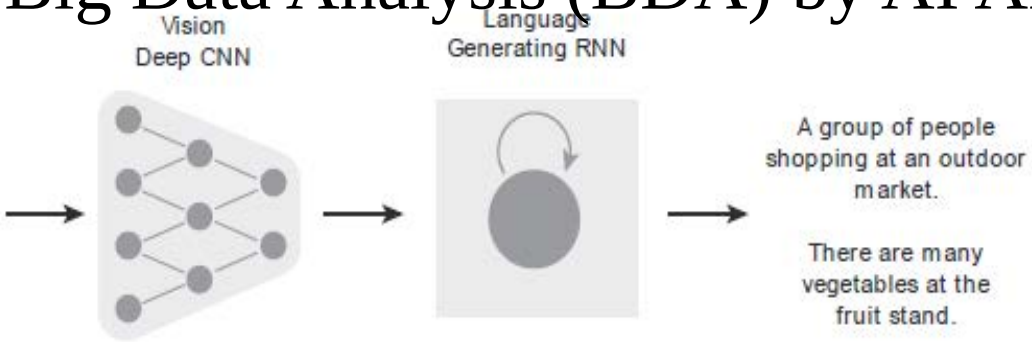
	Learn a model to perform the task	Explain decisions, actions to the user	Use the explanation to perform a task	
Data Analytics Classification Learning Task	 Multimedia Data Classifies items of interest in large data set	Explainable Model → Explanation Interface Explains why/why not for recommended items	Recommend → ← Explanation  Analyst decides which items to report, pursue	An analyst is looking for items of interest in massive multimedia data sets
Autonomy Reinforcement Learning Task	 ArduPilot & SITL Simulation Learns decision policies for simulated missions	Explainable Model → Explanation Interface Explains behavior in an after-action review	Actions → ← Explanation  Operator decides which future tasks to delegate	An operator is directing autonomous systems to accomplish a series of missions

E. Schedule and Milestones



- Technical Area 1 Milestones:
  - Demonstrate the explainable learners against problems proposed by the developers (Phase 1)
  - Demonstrate the explainable learners against common problems (Phase 2)
  - Deliver software libraries and toolkits (at the end of Phase 2)
- Technical Area 2 Milestones:
  - Deliver an interim report on psychological theories (after 6 months during Phase 1)
  - Deliver a final report on psychological theories (after 12 months, during Phase 1)
  - Deliver a computational model of explanation (after 24 months, during Phase 2)
  - Deliver the computational model software (at the end of Phase 2)

Big Data Analysis (BDA) by AI ANN on GPU



Yann LeCun (Facebook AI, NYU), Yoshua Bengio (Montreal) , Geoffrey Hinton (Google, Toronto) . “Deep Learning”, Nature 521, pp. 436-444,May 28, 2015

A woman is throwing a frisbee in a park.

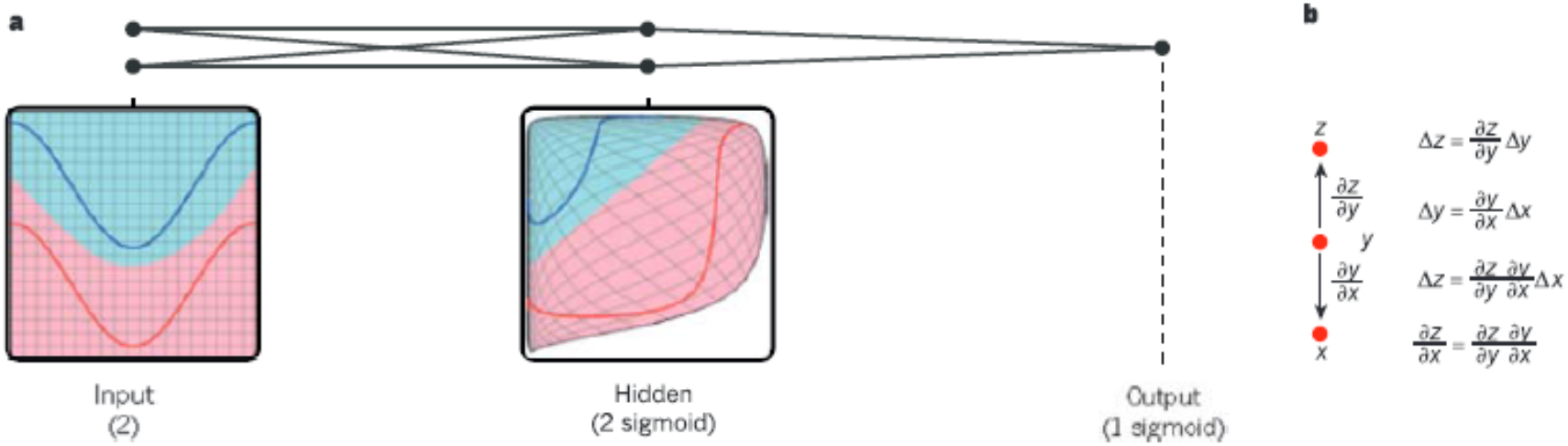
A dog is standing on a hardwood □oor.

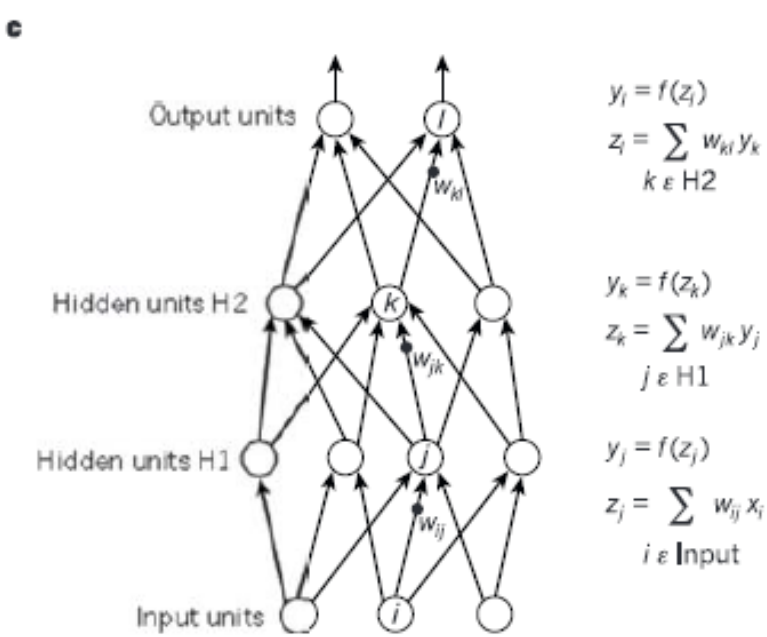
A stop sign is on a road with a mountain in the background

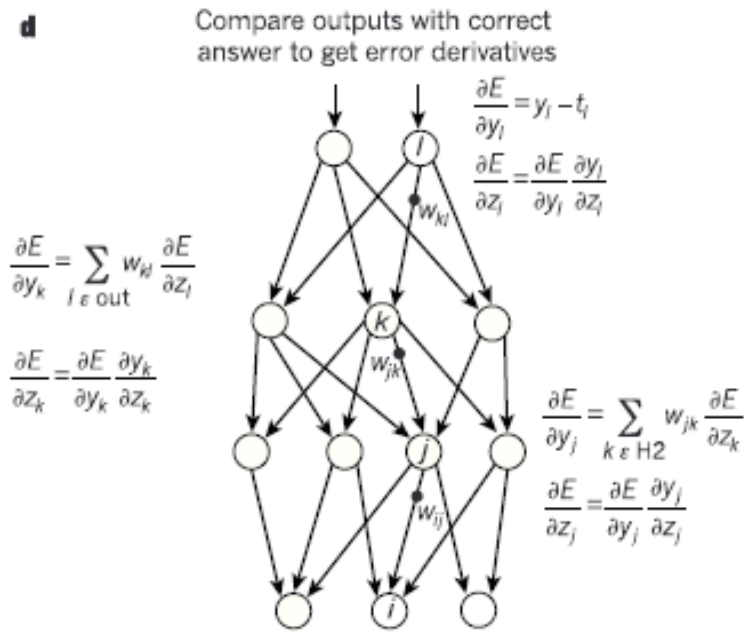
A little girl sitting on a bed with a teddy bear.

A group of people sitting on a boat in the water.

A gira□e standing in a forest with trees in the background.

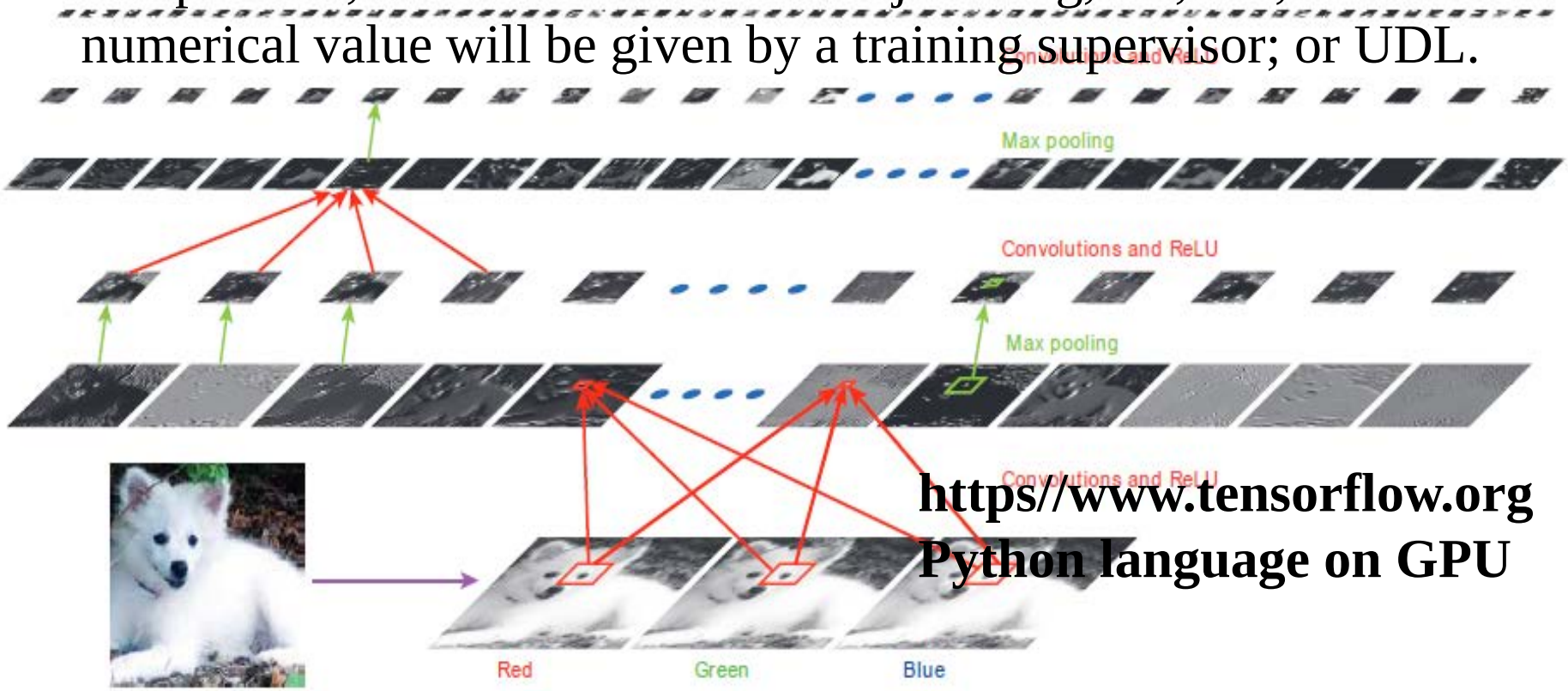

a
Input
(2)
Hidden
(2 sigmoid)
Output
(1 sigmoid)
b
z
y
x
$\frac{\partial z}{\partial y}$
$\frac{\partial y}{\partial x}$
$\Delta z = \frac{\partial z}{\partial y}\Delta y$
$\Delta y = \frac{\partial y}{\partial x}\Delta x$
$\Delta z = \frac{\partial z}{\partial y}\frac{\partial y}{\partial x}\Delta x$
$\frac{\partial z}{\partial x} = \frac{\partial z}{\partial y}\frac{\partial y}{\partial x}$


c
Output units
Hidden units H2
Hidden units H1
Input units
w_{kl}
w_{jk}
w_{ij}
$y_l = f(z_l)$
$z_l = \sum_{k \varepsilon H2} w_{kl} y_k$
$y_k = f(z_k)$
$z_k = \sum_{j \varepsilon H1} w_{jk} y_j$
$y_j = f(z_j)$
$z_j = \sum_{i \varepsilon Input} w_{ij} x_i$


d
Compare outputs with correct answer to get error derivatives
$\frac{\partial E}{\partial y_l} = y_l - t_l$
$\frac{\partial E}{\partial z_l} = \frac{\partial E}{\partial y_l}\frac{\partial y_l}{\partial z_l}$
$\frac{\partial E}{\partial y_k} = \sum_{l \varepsilon out} w_{kl}\frac{\partial E}{\partial z_l}$
$\frac{\partial E}{\partial z_k} = \frac{\partial E}{\partial y_k}\frac{\partial y_k}{\partial z_k}$
$\frac{\partial E}{\partial y_j} = \sum_{k \varepsilon H2} w_{jk}\frac{\partial E}{\partial z_k}$
$\frac{\partial E}{\partial z_j} = \frac{\partial E}{\partial y_j}\frac{\partial y_j}{\partial z_j}$
w_{kl}
w_{jk}
w_{ij}

SDL & UDL Training Procedure:

- **Input** has mltiple layers edge at layer, curvature layer, texture layer, RGB color pixels per neurons, hidden layers Internal knowledge representation.
- **Hidden layers** has 10 to 100 layers.
- **Output** Classification (SDL) is a supervised category vector has components, one for each class of object: dog, cat, fox, etc. whose numerical value will be given by a training supervisor; or UDL.



https//www.tensorflow.org
Python language on GPU

Data Big Data Analysis:

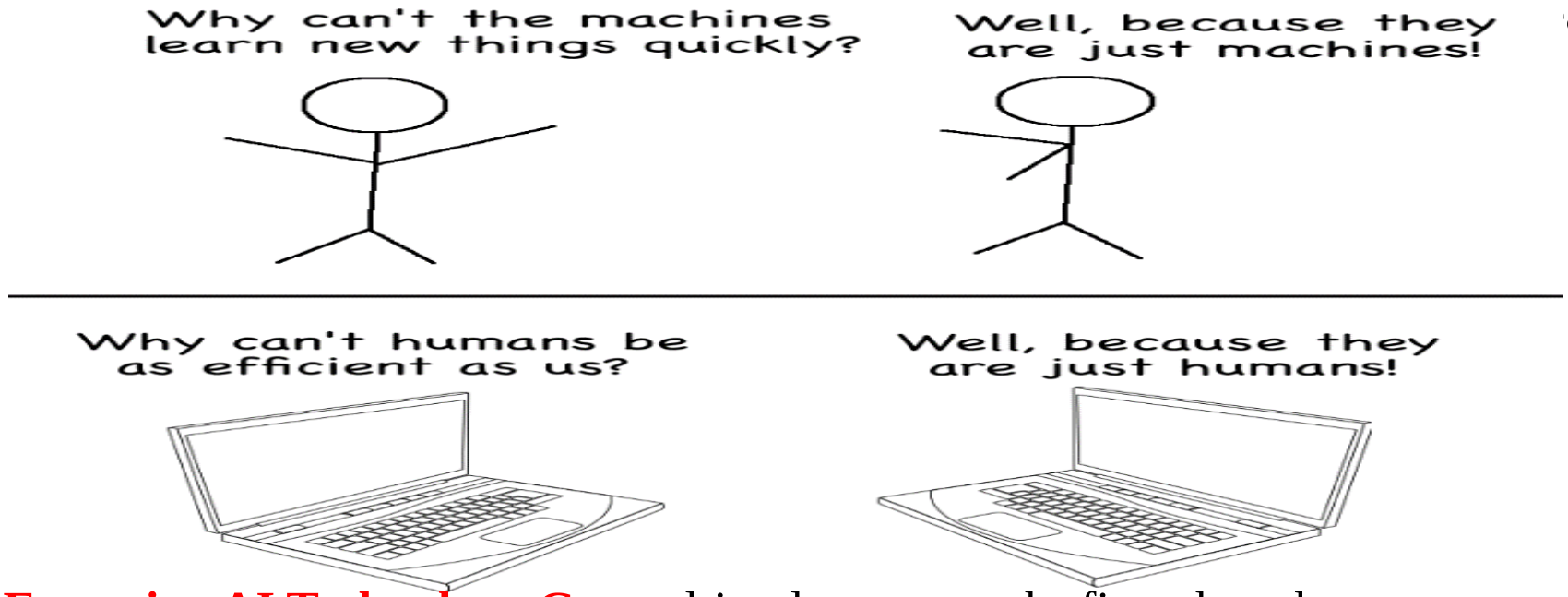
DoC/DoT/DHS: Intelligent Robots/Cops require Explainable & Quantifiable Computational Intelligence (EQCI) and **Consumer Index Machines IQ: MIQ = AI/NI**

1. **MIQ=10%** is loyal to its human master and its own survivability to differentiate electric power plug having a two-porn's of 110 Volts or three porn's of 220 Volts.2.
2. **MIQ=20%** is able to understanding human conversation in a fixed semantic network for a closed domain dialogue.
3.**MIQ=30%** is able to read facial expression and voice tone for e-IQ to understanding the emotion need of human being.
4. **MIQ=40%** is able to command and control a small team of other robots.
5. **MIQ=50%** is able to "explore the tolerance of imprecision," e.g. using fuzzy logic to negotiate a single precision path finding in an open save terrain.

When we live longer, a machine gets smarter.
How we & machine can co-exit peacefully become important

1. How GPU Mini-Super MPD Computers add wings to Artificial Intelligence (AI) .

$M Nvidia made of 64 racks and each rack has 8 GPU in a small room size for air cooling. Current machine can support 100 layers & each layer with thousands by thousands millions nodes computed Artificial Neural Nets (ANN) in a pseudo-real time. Man-Machine interface requires an **Explainable Artificial/Computational Intelligence** a



2. Emerging AI Technology Gaps: driverless car works fine; though consumer report said that driverless machine have been terrorized by some human drivers on the road. All the other applications may require Explainable Computational Intelligence (ECI), esp. for DoD Aided Target Recognition (AiTR).

Hopfield Error Correction Dynamic Code: Nothing but living style can beat a good gene for health longevity: Error Correction in walking meditation can keep the Telomerase enzyme in dynamic balance of telomeres to prevent a premature aging &/or carcinoma.

- In contrary to popular belief, the hydrogen bonds do n
  DNA, and stabilization is mainly due to 3-D stacking
  phenome helps the ***DNA genome***). The ***back-chainin***
  can reduce error rate below Maxwell-Boltzmann Prob
  error in 10,000 ten thousands

$$MBP_{CG} = \exp - \left(\frac{\Delta H_{CG}}{k_B T}\right) \leq MBP_{AT} = \exp$$

ΔH_{CG} is slightly higher than ΔH_{AT}, thus MBP_{AT} is more
MBP_{CG}

- BSS $\vec{X} = [A]\vec{S}$; $\vec{S} = [W]\vec{X}$. $e.g.$ Given Beethoven first 3 notes: " 5, 5
  1+4; <u>2+3; 3+2</u>; 4+1; 5+0) in MBP unit at K_BT=1/40eV for T=300°; Find
  2=3 and 3+2 occurring twice that have the highest MBP 2 exp(-2/K_BT)

Tools forDeep Learning Machine Learning Tensor flow Python Language or Math Lab by Math Works:
Dr. Joanna Pingel, “Object Recognition Deep Machine Learning for Computer Vision”

https://www.tensorflow.org/ Python Language for GPU

another video from MATHWORKS - szuharoldh@gmail.com - Gmail.html

Appendix F: Dr. Hesham M. Eraqi; hesham.eraqi@gmail.com Matlab Code (8 pages with comments)

http://heraqi.blogspot.com.eg/2015/11/mlp-neural-network-with-backpropagation.html

Appendix : Multilayer Perceptron Feed Forward Fully Connected Neural Network with a Sigmoid activation function[1]

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%
% Multilayer Perceptron (MLP) Neural Network Function using MATLAB:      %
%  An implementation for Multilayer Perceptron Feed Forward Fully        %
%  Connected Neural Network with a sigmoid activation function. The      %
%  training is done using the Backpropagation algorithm with options for  %
%  Resilient Gradient Descent, Momentum Backpropagation, and Learning
%
%  Rate Decrease. The training stops when the Mean Square Error (MSE)     %
%  reaches zero or a predefined maximum number of epochs is reached.      %
%                                                   %
%  Four example data for training and testing are included with the      %
%  project. They are generated by SharkTime Sharky Neural Network        %
%   (http://sharktime.com/us_SharkyNeuralNetwork.html)                 %
%                                                   %
% Copyright (C) 9-2015 Hesham M. Eraqi. All rights reserved.            %
%                 hesham.eraqi@gmail.com                           %
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%

%% Clear Variables, Close Current Figures, and Create Results Directory
clc;
clear all;
close all;
mkdir('Results//'); %Directory for Storing Results
%% Configurations/Parameters
dataFileName = 'sharky.spirals.points'; %sharky.linear.points -
sharky.circle.points - sharky.wave.points - sharky.spirals.points
% nbrOfNeuronsInEachHiddenLayer = [10 10]; %linear:[4] - circle:[10] -
wave,spirals:[10 10]
nbrOfNeuronsInEachHiddenLayer = [4 4]; %linear:[4] - circle:[10] -
wave,spirals:[10 10]
nbrOfOutUnits = 2;
unipolarBipolarSelector = 0; %0 for Unipolar, -1 for Bipolar

learningRate = 0.15;
nbrOfEpochs_max = 500000;
```

```
enable_resilient_gradient_descent = 1; %1 for enable, 0 for disable
learningRate_plus = 1.2;
learningRate_negative = 0.5;
deltas_start = 0.9;
deltas_min = 10^-6;
deltas_max = 50;

enable_decrease_learningRate = 0; %1 for enable decreasing, 0 for disable
learningRate_decreaseValue = 0.0001;
min_learningRate = 0.05;

enable_learningRate_momentum = 0; %1 for enable, 0 for disable
momentum_alpha = 0.05;

draw_each_nbrOfEpochs = 100;

%% Read Data
importedData = importdata(dataFileName, '\t', 6);
Samples = importedData.data(:, 1:length(importedData.data(1,:))-1);
TargetClasses = importedData.data(:, length(importedData.data(1,:)));
TargetClasses = TargetClasses - min(TargetClasses);
ActualClasses = -1*ones(size(TargetClasses));

%% Calculate Number of Input and Output NodesActivations
nbrOfInputNodes = length(Samples(1,:)); %=Dimention of Any Input Samples
% nbrOfOutUnits = ceil(log2(length(unique(TargetClasses)))) + !; %Ceil(Log2(
Number of Classes ))

nbrOfLayers = 2 + length(nbrOfNeuronsInEachHiddenLayer);
nbrOfNodesPerLayer = [nbrOfInputNodes nbrOfNeuronsInEachHiddenLayer
nbrOfOutUnits];

%% Adding the Bias as Nodes with a fixed Activation of 1
nbrOfNodesPerLayer(1:end-1) = nbrOfNodesPerLayer(1:end-1) + 1;
Samples = [ones(length(Samples(:,1)),1) Samples];
```

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Multilayer Perceptron Feed Forward Fully Connected Neural Network with a Sigmoid activation function$_2$

```
%% Calculate TargetOutputs %TODO needs to be general for any
nbrOfOutUnits
TargetOutputs = zeros(length(TargetClasses), nbrOfOutUnits);
for i=1:length(TargetClasses)
   if (TargetClasses(i) == 1)
      TargetOutputs(i,:) = [1 unipolarBipolarSelector];
   else
      TargetOutputs(i,:) = [unipolarBipolarSelector 1];
   end
end

%% Initialize Random Wieghts Matrices
Weights = cell(1, nbrOfLayers); %Weights connecting bias nodes with
previous layer are useless, but to make code simpler and faster
Delta_Weights = cell(1, nbrOfLayers);
ResilientDeltas = Delta_Weights; % Needed in case that Resilient Gradient
Descent is used
for i = 1:length(Weights)-1
   Weights{i} = 2*rand(nbrOfNodesPerLayer(i), nbrOfNodesPerLayer(i+1))-1;
%RowIndex: From Node Number, ColumnIndex: To Node Number
   Weights{i}(:,1) = 0; %Bias nodes weights with previous layer (Redundant
step)
   Delta_Weights{i} = zeros(nbrOfNodesPerLayer(i),
nbrOfNodesPerLayer(i+1));
   ResilientDeltas{i} = deltas_start*ones(nbrOfNodesPerLayer(i),
nbrOfNodesPerLayer(i+1));
end
Weights{end} = ones(nbrOfNodesPerLayer(end), 1); %Virtual Weights for
Output Nodes
Old_Delta_Weights_for_Momentum = Delta_Weights;
Old_Delta_Weights_for_Resilient = Delta_Weights;

NodesActivations = cell(1, nbrOfLayers);
for i = 1:length(NodesActivations)
   NodesActivations{i} = zeros(1, nbrOfNodesPerLayer(i));
end
NodesBackPropagatedErrors = NodesActivations; %Needed for
Backpropagation Training Backward Pass
```

```
%% Iterating all the Data
MSE = -1 * ones(1,nbrOfEpochs_max);
for Epoch = 1:nbrOfEpochs_max

   for Sample = 1:length(Samples(:,1))
      %% Backpropagation Training
      %Forward Pass
      NodesActivations{1} = Samples(Sample,:);
      for Layer = 2:nbrOfLayers
         NodesActivations{Layer} = NodesActivations{Layer-
1}*Weights{Layer-1};
         NodesActivations{Layer} =
Activation_func(NodesActivations{Layer}, unipolarBipolarSelector);
         if (Layer ~= nbrOfLayers) %Because bias nodes don't have
weights connected to previous layer
            NodesActivations{Layer}(1) = 1;
         end
      end
      % Backward Pass Errors Storage
      % (As gradient of the bias nodes are zeros, they won't contribute
to previous layer errors nor delta_weights)
      NodesBackPropagatedErrors{nbrOfLayers} =
TargetOutputs(Sample,:)-NodesActivations{nbrOfLayers};
      for Layer = nbrOfLayers-1:-1:1
         gradient = Activation_func_drev(NodesActivations{Layer+1},
unipolarBipolarSelector);
         for node=1:length(NodesBackPropagatedErrors{Layer}) % For
all the Nodes in current Layer
            NodesBackPropagatedErrors{Layer}(node) =  sum(
NodesBackPropagatedErrors{Layer+1} .* gradient .*
Weights{Layer}(node,:) );
         end
      end
```

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Multilayer Perceptron Feed Forward Fully Connected Neural Network with a Sigmoid activation function3

```
% Backward Pass Delta Weights Calculation (Before multiplying by
learningRate)
    for Layer = nbrOfLayers:-1:2
      derivative = Activation_func_drev(NodesActivations{Layer},
unipolarBipolarSelector);
      Delta_Weights{Layer-1} = Delta_Weights{Layer-1} +
NodesActivations{Layer-1}' * (NodesBackPropagatedErrors{Layer} .*
derivative);
    end
  end

  %% Apply resilient gradient descent or/and momentum to the
delta_weights
  if (enable_resilient_gradient_descent) % Handle Resilient Gradient Descent
    if (mod(Epoch,200)==0) %Reset Deltas
      for Layer = 1:nbrOfLayers
        ResilientDeltas{Layer} = learningRate*Delta_Weights{Layer};
      end
    end
    for Layer = 1:nbrOfLayers-1
      mult = Old_Delta_Weights_for_Resilient{Layer} .*
Delta_Weights{Layer};
      ResilientDeltas{Layer}(mult > 0) = ResilientDeltas{Layer}(mult > 0) *
learningRate_plus; % Sign didn't change
      ResilientDeltas{Layer}(mult < 0) = ResilientDeltas{Layer}(mult < 0) *
learningRate_negative; % Sign changed
      ResilientDeltas{Layer} = max(deltas_min, ResilientDeltas{Layer});
      ResilientDeltas{Layer} = min(deltas_max, ResilientDeltas{Layer});
      Old_Delta_Weights_for_Resilient{Layer} = Delta_Weights{Layer}
      Delta_Weights{Layer} = sign(Delta_Weights{Layer}) .*
ResilientDeltas{Layer};
    end
  end
  if (enable_learningRate_momentum) %Apply Momentum
    for Layer = 1:nbrOfLayers
      Delta_Weights{Layer} = learningRate*Delta_Weights{Layer} +
momentum_alpha*Old_Delta_Weights_for_Momentum{Layer};
    end
    Old_Delta_Weights_for_Momentum = Delta_Weights;
```

```
  if (~enable_learningRate_momentum &&
~enable_resilient_gradient_descent)
    for Layer = 1:nbrOfLayers,      Delta_Weights{Layer} = learningRate *
Delta_Weights{Layer};
    end
  end

  %% Backward Pass Weights Update
  for Layer = 1:nbrOfLayers-1
    Weights{Layer} = Weights{Layer} + Delta_Weights{Layer};
  end

  % Resetting Delta_Weights to Zeros
  for Layer = 1:length(Delta_Weights),      Delta_Weights{Layer} = 0 *
Delta_Weights{Layer};
  end
   %% Decrease Learning Rate
  if (enable_decrease_learningRate)
    new_learningRate = learningRate - learningRate_decreaseValue;
    learningRate = max(min_learningRate, new_learningRate);
  end
 %% Evaluation
  for Sample = 1:length(Samples(:,1))
    outputs = EvaluateNetwork(Samples(Sample,:), NodesActivations,
Weights, unipolarBipolarSelector);
    bound = (1+unipolarBipolarSelector)/2;
    if (outputs(1) >= bound && outputs(2) < bound) %TODO: Not generic role
for any number of output nodes
      ActualClasses(Sample) = 1;
    elseif (outputs(1) < bound && outputs(2) >= bound)
      ActualClasses(Sample) = 0;
    else
      if (outputs(1) >= outputs(2)),            ActualClasses(Sample) = 1;
      else
        ActualClasses(Sample) = 0;
      end
    end
  end
```

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Multilayer Perceptron Feed Forward Fully Connected Neural Network with a Sigmoid activation function$_4$

```
MSE(Epoch) = sum((ActualClasses-TargetClasses).^2)/(length(Samples(:,1)));
  if (MSE(Epoch) == 0)
    zeroRMSReached = 1;
  end

  %% Visualization
  if (zeroRMSReached || mod(Epoch,draw_each_nbrOfEpochs)==0)
    % Draw Decision Boundary
    unique_TargetClasses = unique(TargetClasses);
    training_colors = {'y.', 'b.'};
    separation_colors = {'g.', 'r.'};
    subplot(2,1,1);
    cla;
    hold on;
    title(['Decision Boundary at Epoch Number ' int2str(Epoch) '. The max
number of Epochs is ' int2str(nbrOfEpochs_max) '.']);

    margin = 0.05; step = 0.05;
    xlim([min(Samples(:,2))-margin max(Samples(:,2))+margin]);
    ylim([min(Samples(:,3))-margin max(Samples(:,3))+margin]);
    for x = min(Samples(:,2))-margin : step : max(Samples(:,2))+margin
      for y = min(Samples(:,3))-margin : step : max(Samples(:,3))+margin
        outputs = EvaluateNetwork([1 x y], NodesActivations, Weights,
unipolarBipolarSelector);
        bound = (1+unipolarBipolarSelector)/2;
        if (outputs(1) >= bound && outputs(2) < bound) %TODO: Not generic
role for any number of output nodes
          plot(x, y, separation_colors{1}, 'markersize', 18);
        elseif (outputs(1) < bound && outputs(2) >= bound)
          plot(x, y, separation_colors{2}, 'markersize', 18);
        else
          if (outputs(1) >= outputs(2))
            plot(x, y, separation_colors{1}, 'markersize', 18);
          else
            plot(x, y, separation_colors{2}, 'markersize', 18);
          end
        end
```

```
      end
    end
    for i = 1:length(unique_TargetClasses)
      points = Samples(TargetClasses==unique_TargetClasses(i),
2:end);
      plot(points(:,1), points(:,2), training_colors{i}, 'markersize', 10);
    end
    axis equal;

    % Draw Mean Square Error
    subplot(2,1,2);
    MSE(MSE==-1) = [];
    plot([MSE(1:Epoch)]);
    ylim([-0.1 0.6]);
    title('Mean Square Error');
    xlabel('Epochs');
    ylabel('MSE');
    grid on;

    saveas(gcf, sprintf('Results//fig%i.png', Epoch),'jpg');
    pause(0.05);
  end
  display([int2str(Epoch) ' Epochs done out of '
int2str(nbrOfEpochs_max) ' Epochs. MSE = ' num2str(MSE(Epoch)) '
Learning Rate = ' ...
    num2str(learningRate) '.']);
  nbrOfEpochs_done = Epoch;
  if (zeroRMSReached)
    saveas(gcf, sprintf('Results//Final Result for %s.png',
dataFileName),'jpg');
    break;
  end
end
display(['Mean Square Error = ' num2str(MSE(nbrOfEpochs_done))
'.']);
```

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