ENVIRONMENTAL STUDIES AND LIFE SCIENCES

Seema Tharannum
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BIOMIMETICS

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BIOMIMETICS

- Biomimetics is the application of biological methods and systems found in nature to the study and design of engineering systems and modern technology.
- Also known as Bionics, biognosis, biomimicry or bionical creativity engineering.

BIOMIMETICS-Strategies and principles

- Nature fits form to function, utilizes a variety of non orthogonal forms and design methods in its constructions to ensure maximization in terms of structural efficiency.
- It minimizes the required input of material.
- Nature recycles everything, Uses waste as a resource.
- Nature uses an ordered hierarchy of structures.
- Nature banks on diversity, constantly mutating and adapting in a flexible and dynamic flow of change.
- Nature self assembles and generates structural organization on all scales.
- Nature is resilient to changes and self healing.
- Nature optimizes rather than maximize, using the least materials for optimal structure and function.

BIOMIMETICS

In Europe, Japan, and the USA, biomimetics is being recognized as the technology of the future and there is increasing interest and funding.

In particular, global companies such as Ford, General Electric, Herman Miller, HP, IBM, and Nike are collaborating with scientists and designing laboratories to explore novel technologies.

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BIOMIMETICS- APPLICATION

CONSTRUCTION: Termite Den = Self Cooling Office Building

ENERGY: Whale Edged Fins = Energy Efficient Turbine Blades

MEDICAL: Shark Skin Structure = Anti-bacterial Surface

PACKAGING: Burrs of Burdock = Velcro (hook and loop fastener)

MOBILITY: Kingfisher beak = Low resistance/noise Train Design

SELF-CLEANING: Lotus Leaves = Hydrophobic Paints/Surfaces

https://www.futurebridge.com/

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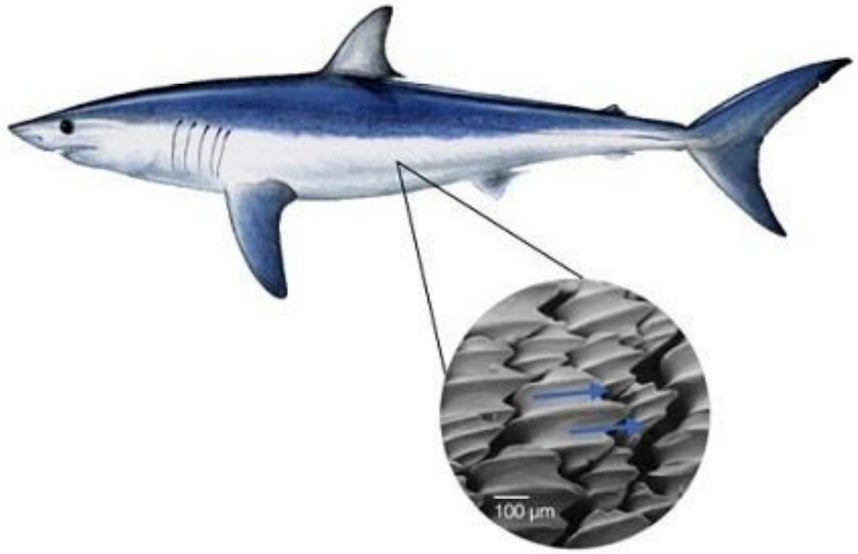
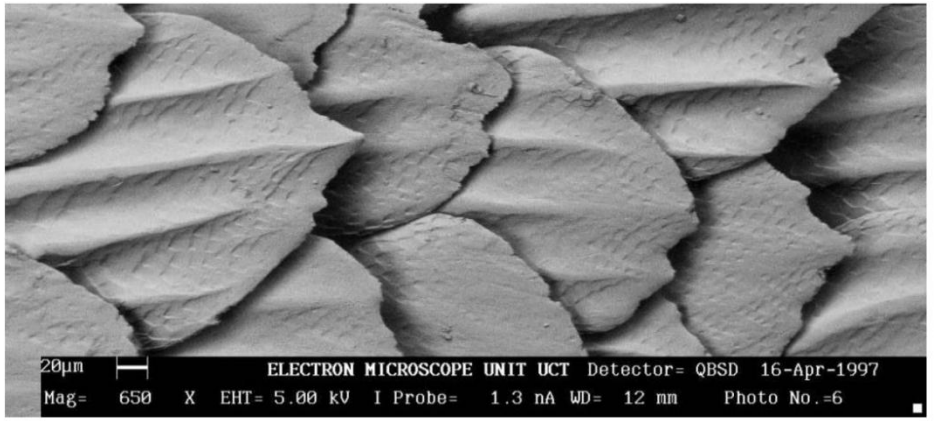
BIOMIMETICS- APPLICATION

- Shark skin is constructed of overlapping scales.
- Nature through evolution, has ensured that water flows over the scales extremely efficiently, helping the shark to reach high speeds.





https://illumin.usc.edu/

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BIOMIMETICS- APPLICATION

- Special alignment and grooved structure of denticles embedded in shark skin decrease drag and thus greatly increase swimming proficiency.
- Airbus fuel consumption down 1.5% when “shark skin” coating applied to aircraft.
- It is possible to increase the efficiency of Air planes up to 4% by adjusting riblets.
- Brings increase of speed up to 1.56%.
- The results of the use of riblets are a – reduction of the total drag, – a higher glide ratio and – a better handling of the aircraft.

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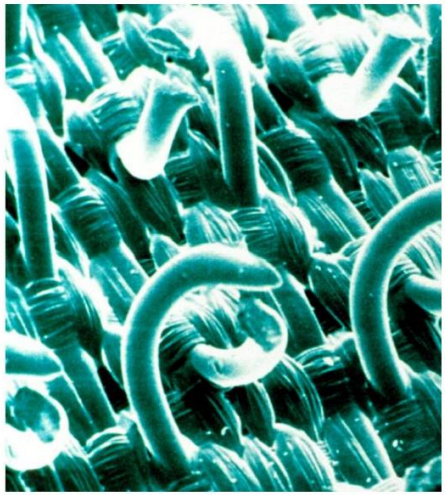
BIOMIMETICS- APPLICATION

- Small hooks enable seed-bearing burr to cling to tiny loops in fabric.
- Velcro fastening was invented in 1941 by Swiss engineer George de Mestral, who took the idea from the burrs that stuck to his dog's hair.
- Under the microscope he noted the tiny hooks on the end of the burr's spines that caught anything with a loop - such as clothing, hair or animal fur.
- The 2-part Velcro fastener system uses strips or patches of a hooked material opposite strips or patches of a loose- looped weave of nylon that holds the hooks

https://www.bloomberg.com/



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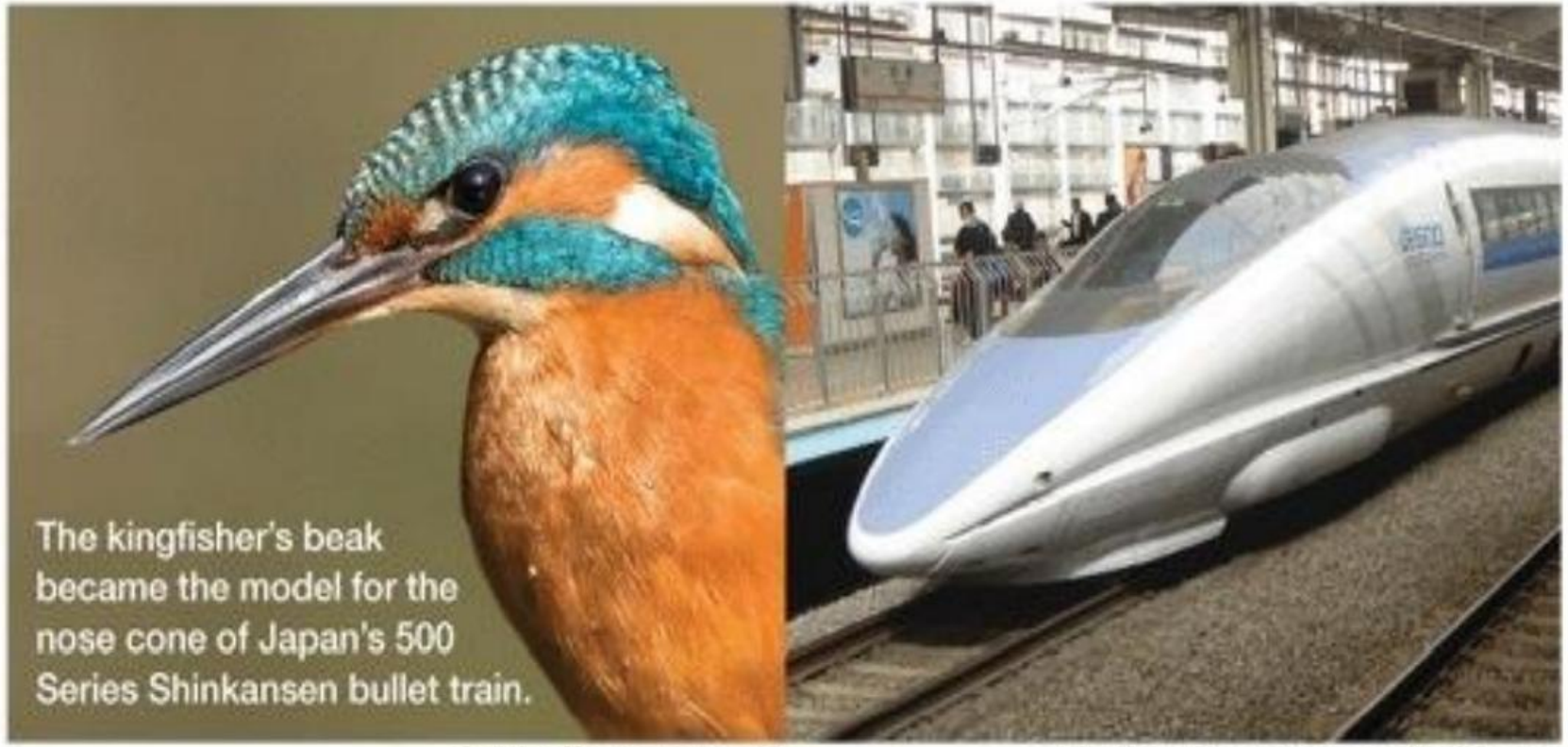
BIOMIMETICS- APPLICATION



BIOMIMETICS- APPLICATION

- The fastest train in the world at speeds of up to 200 miles per hour, Japan's Shinkansen Bullet Train was a marvel of modern technology.
- But there was one major problem after its initial debut: noise. Each time the train emerged from the tunnel, it caused a change in air pressure that caused thunder-like sounds that were a nuisance from a quarter of a mile away.
- The train's chief engineer, a bird-watcher, had an idea: taking inspiration from the shape of a bird's beak to make it more aerodynamic.
- The resulting design was based on the narrow profile of a kingfisher's beak, resulting in a quieter train that also consumes 15% less electricity and goes 10% faster than before.

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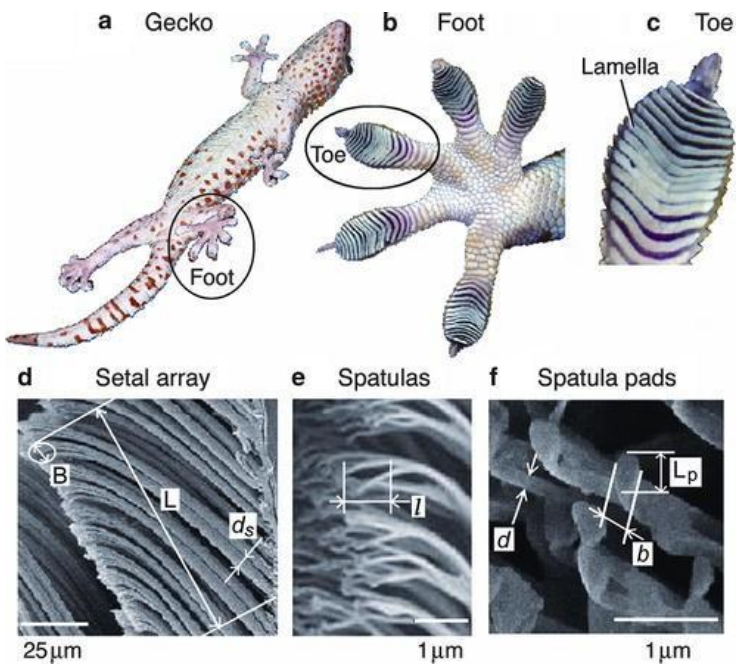
BIOMIMETICS- APPLICATION

- Gecko is a nocturnal lizard which has adhesive pads on the feet to assist in climbing on smooth surfaces.
- Geckos hang single-toed from walls and walk along ceilings using fine hairs on feet.
- Gecko's feet comprise of lamellae. Lamellae are equipped with setae; each seta ends in a spatula-like structure. Nanoscale spatulae interact with wall atoms; generate Van der Waal's forces. The adhesive system demonstrates high friction.
- Gecko Tape is a material covered with nanoscopic hairs that mimic those found on the feet of gecko lizards.
- These millions of tiny, flexible hairs exert van der Waals forces that provide a powerful adhesive effect. One square centimeter of gecko tape could support a weight of one kilogram.
- University of California - Berkeley created an array of synthetic micro-fibres using very high friction to support loads on smooth surfaces.
- Gecko-footed robots could climb to the roof and emplace permanent anchors for suspension of utilities, transportation, or even entire lunar bases.



https://link.springer.com/

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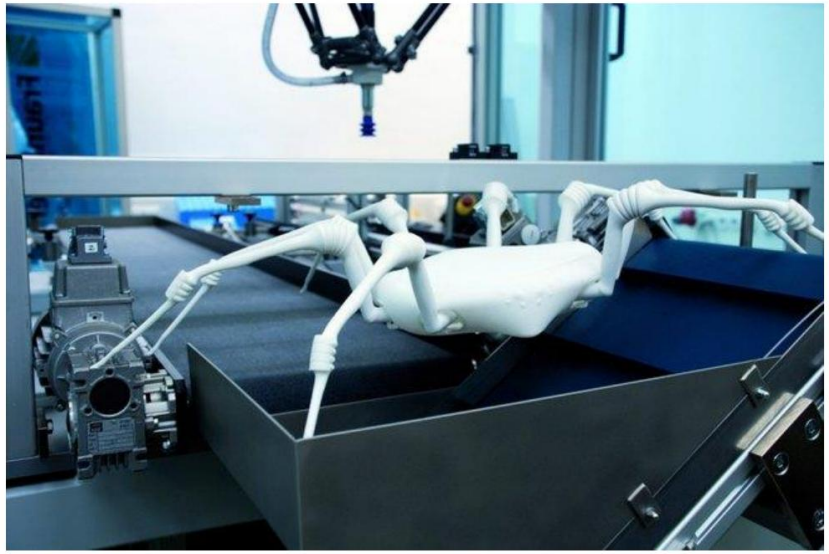
BIOMIMETICS- APPLICATION

- A butterfly's wings are one of nature's most remarkable materials.
- These tiny but complex structures reflect light in such a way that specific wavelengths interfere with each other to create intensely vivid colors one could only find in nature.
- By carefully studying this process, engineers at Qualcomm have been able to mimic this effect, allowing them to develop a system that produces colored electronic screens that are extremely efficient and can be viewed under any light conditions.

https://inhabitat.com/

BIOMIMETICS- APPLICATION

- The ability to squeeze through tight spaces and turn on a dime makes the spider an ideal model for lifesaving robots that could make their way through rubble after a disaster to locate survivors.
- Researchers at Germany's Frauenhofer Institute say this robot can be cheaply reproduced using 3D printers.
- After natural catastrophes and industrial or reactor accidents, or in fire department sorties, it can help responders, for instance by broadcasting live images or tracking down hazards or leaking gas.



https://www.theverge.com/

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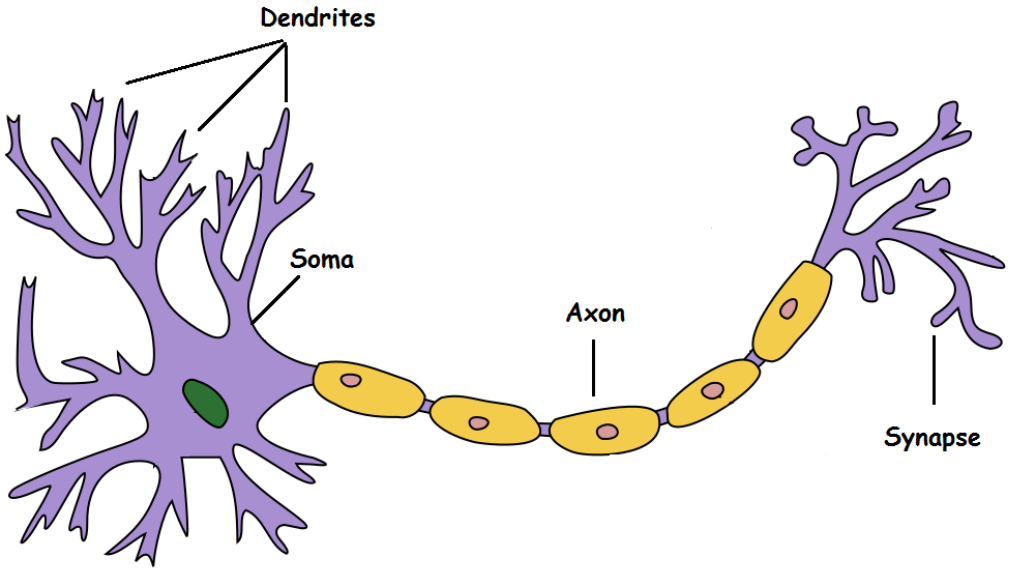
BIOINSPIRED ANN

BIOINSPIRED ANN

- A biological neuron has three types of main components; dendrites, soma (or cell body) and axon.
- Dendrites receives signals from other neurons.
- The soma, sums the incoming signals. When sufficient input is received, the cell fires; that is it transmit a signal over its axon to other cells.

Human Biological Neuron



towardsdatascience.com

BIOINSPIRED ANN

- In the human brain, a typical neuron collects signals from others through a host of fine structures called *dendrites*.
- The neuron sends out spikes of electrical activity through a long, thin stand known as an *axon*, which splits into thousands of branches.
- At the end of each branch, a structure called a *synapse* converts the activity from the axon into electrical effects that inhibit or excite activity in the connected neurons.

BIOINSPIRED ANN

Artificial Neural Network-ANN is an information processing system that has certain performance characteristics in common with biological nets.

Several key features of the processing elements of ANN are suggested by the properties of biological neurons:

- The processing element receives many signals.
- Signals may be modified by a weight at the receiving synapse.
- The processing element sums the weighted inputs.
- Under appropriate circumstances (sufficient input), the neuron transmits a single output.
- The output from a particular neuron may go to many other neurons.

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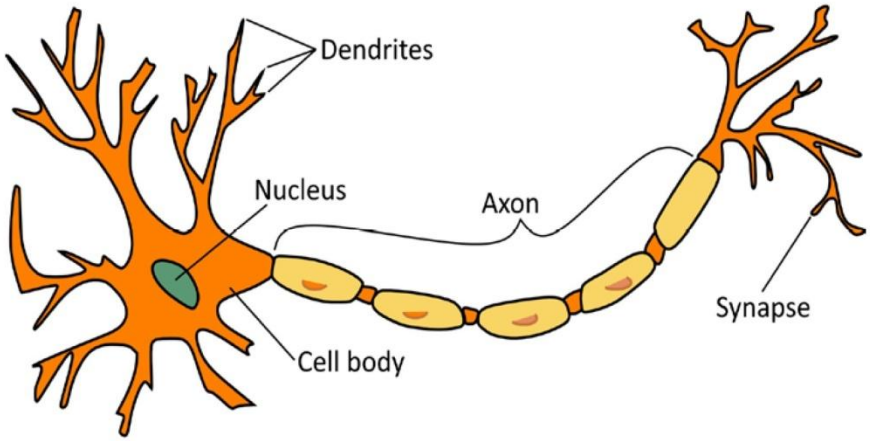
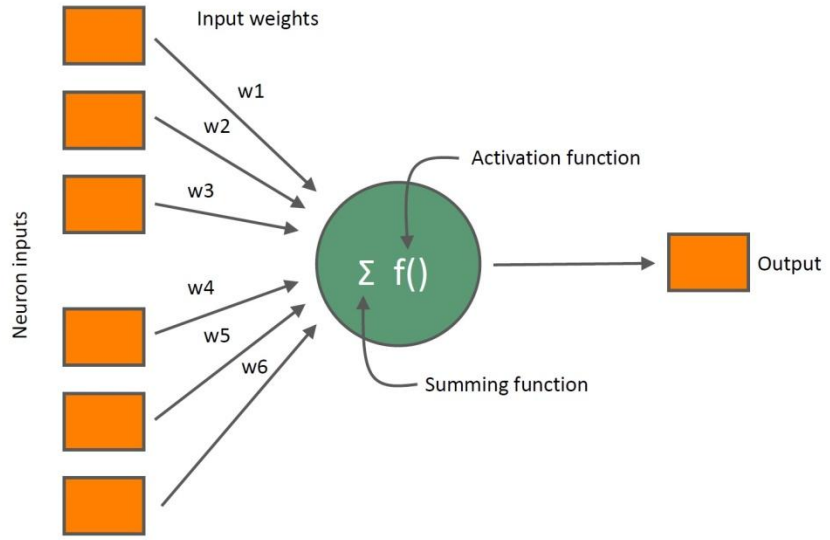
- From experience: examples / training data
- Strength of connection between the neurons is stored as a weight-value for the specific connection.
- Learning the solution to a problem = changing the connection weights





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BIOINSPIRED ANN

ANNs have been developed as generalizations of mathematical models of neural biology, based on the assumptions that:

- Information processing occurs at many simple elements called neurons.
- Signals are passed between neurons over connection links.
- Each connection link has an associated weight, which, in typical neural net, multiplies the signal transmitted.
- Each neuron applies an activation function to its net input to determine its output signal.

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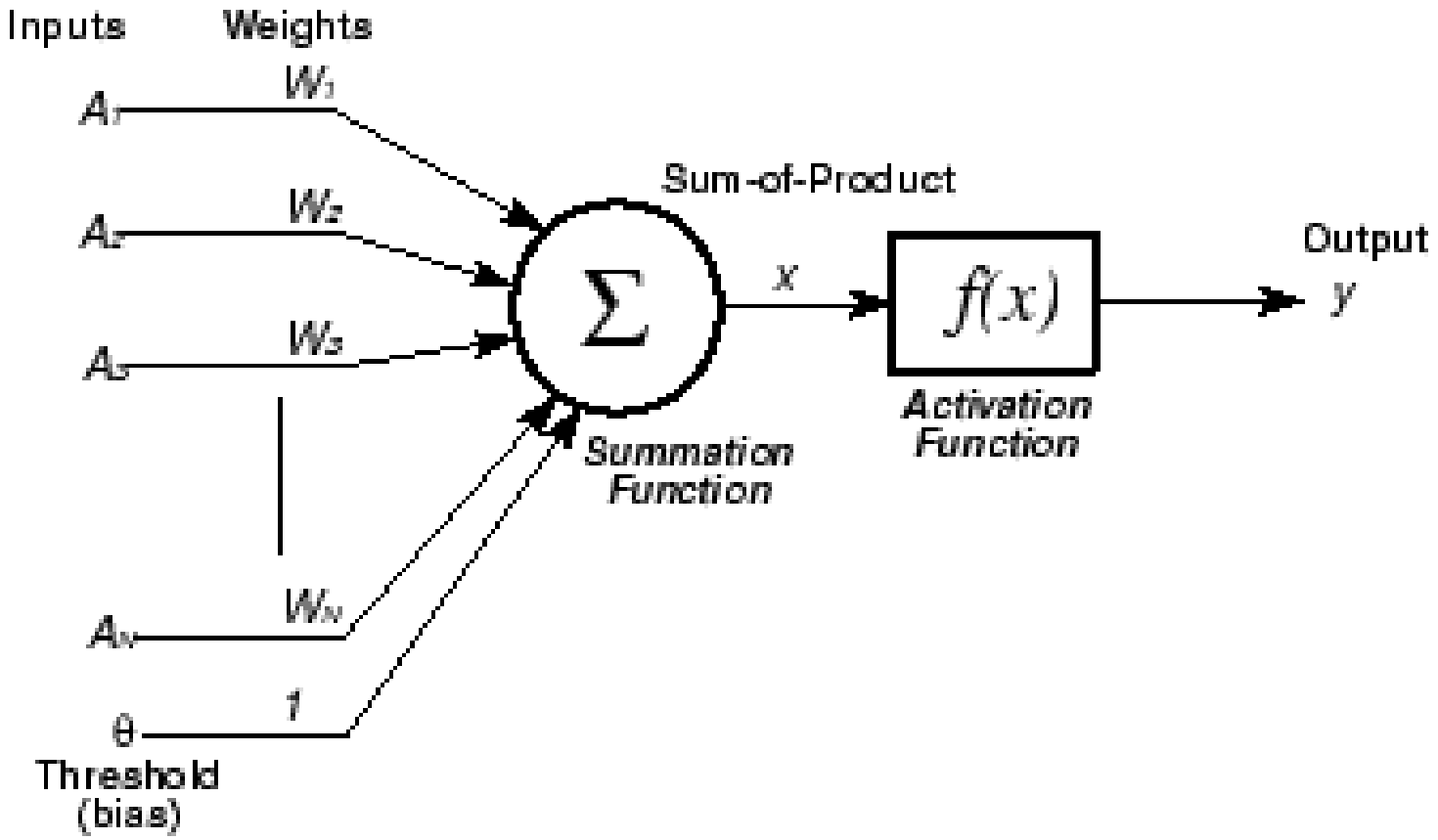

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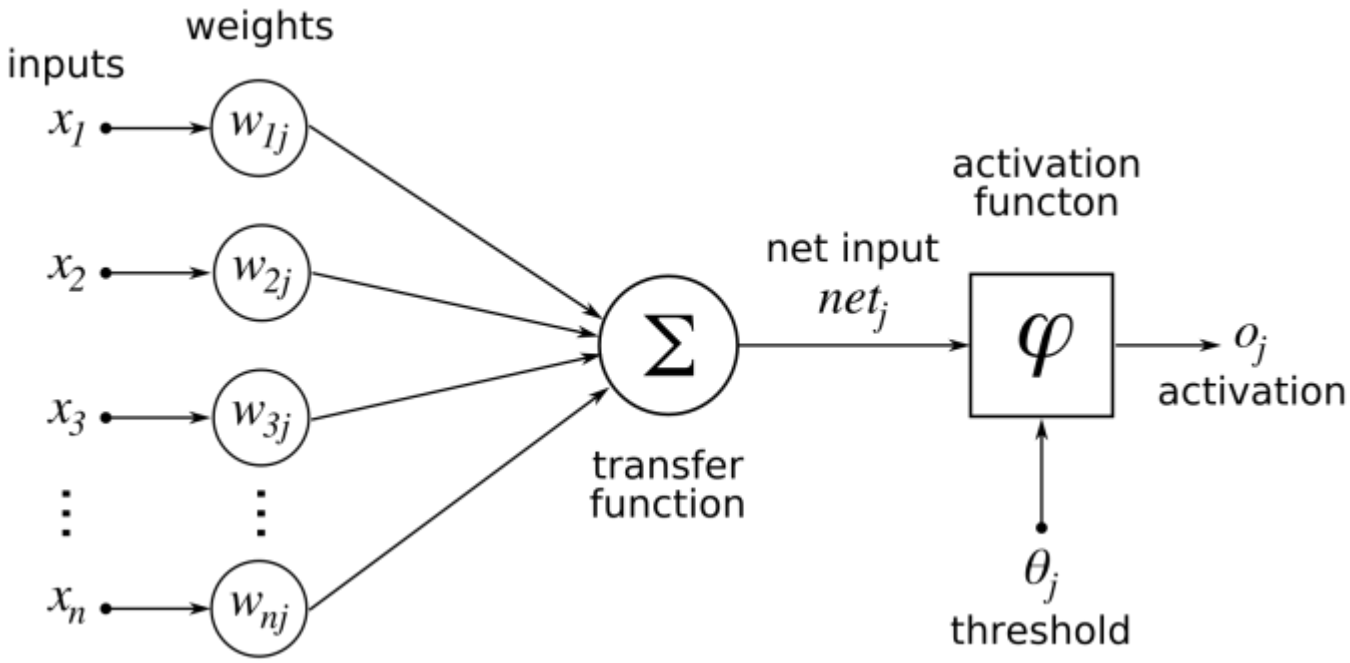
Artificial Neural Network



-A neuron receives input, determines the strength or the weight of the input, calculates the total weighted input, and compares the total weighted with a value (threshold)
-The value is in the range of 0 and 1
- If the total weighted input greater than or equal the threshold value, the neuron will produce the output, and if the total weighted input less than the threshold value, no output will be produced

https://bdtechtalks.com/

Characterization

- Architecture
  - a pattern of connections between neurons
    - Single Layer Feedforward
    - Multilayer Feedforward
    - Recurrent
- Strategy / Learning Algorithm
  - a method of determining the connection weights
    - Supervised
    - Unsupervised
    - Reinforcement
- Activation Function
  - Function to compute output signal from input signal

Some Properties of Artificial Neural Networks

- Assembly of simple processors
- Information stored in connections
- Massively Parallel
- Massive connectivity
- Fault Tolerant
- Learning and Generalization Ability
- Robust
- Individual dynamics different from group dynamics
- All these properties may **not** be present in a particular network

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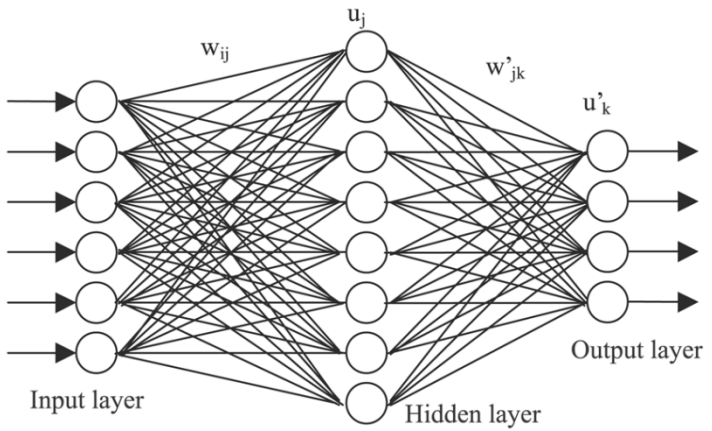
- Input Layer - The activity of the input units represents the raw information that is fed into the network.
- Hidden Layer - The activity of each hidden unit is determined by the activities of the input units and the weights on the connections between the input and the hidden units.
- Output Layer - The behavior of the output units depends on the activity of the hidden units and the weights between the hidden and output units.
- This simple type of network is interesting because the hidden units are free to construct their own representations of the input.
- The weights between the input and hidden units determine when each hidden unit is active, and so by modifying these weights, a hidden unit can choose what it represents.



https://www.extremetech.com/

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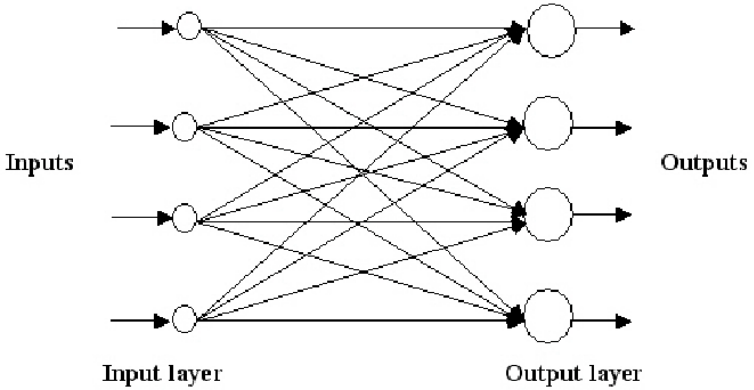
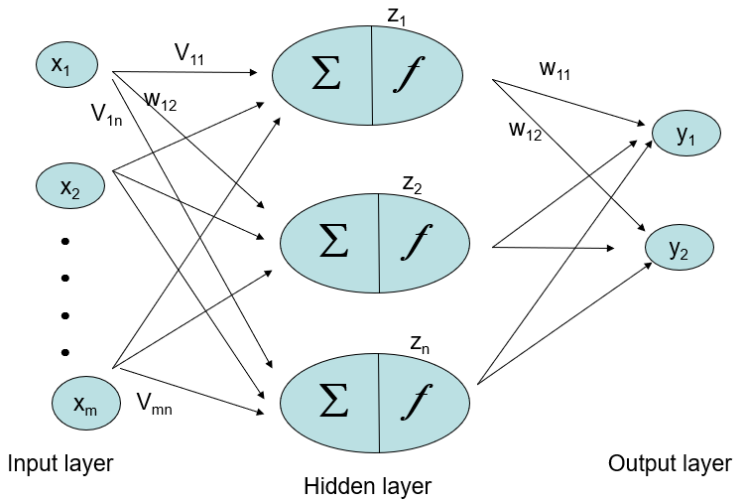
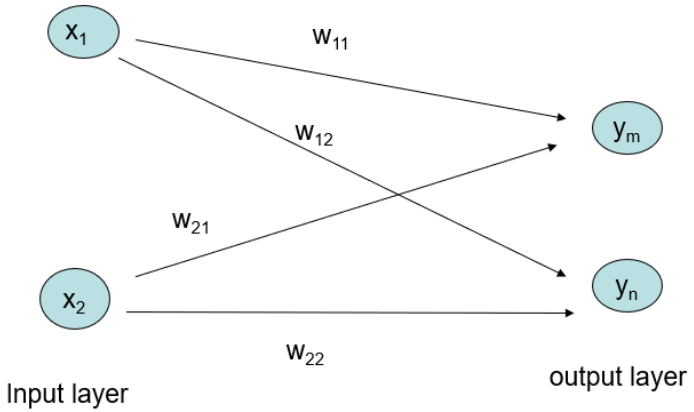


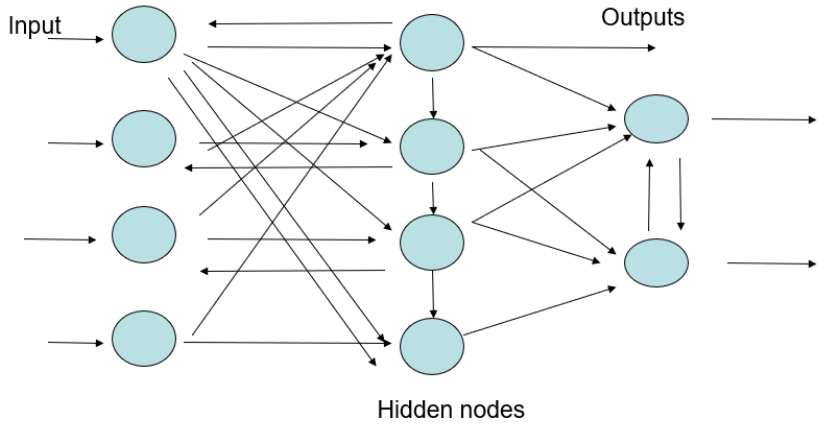
Multilayer Neural Network



Single Layer Feedforward NN



Recurrent NN



https://www.researchgate.net/

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- Artificial Neural Networks (ANN) are currently a 'hot' research area in medicine and it is believed that they will receive extensive application to biomedical systems in the next few years.
- At the moment, the research is mostly on modeling parts of the human body and recognizing diseases from various scans (e.g. cardiograms, CAT scans, ultrasonic scans, etc.).
- Neural Networks are used experimentally to model the human cardiovascular system.
- Diagnosis can be achieved by building a model of the cardiovascular system of an individual and comparing it with the real time physiological measurements taken from the patient.

BIOINSPIRED ANN

- A model of an individual's cardiovascular system must mimic the relationship among physiological variables (i.e., heart rate, systolic and diastolic blood pressures, and breathing rate) at different physical activity levels.
- If a model is adapted to an individual, then it becomes a model of the physical condition of that individual.
- If this routine is carried out regularly, potential harmful medical conditions can be detected at an early stage and thus make the process of combating the disease much easier.

THANK YOU

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