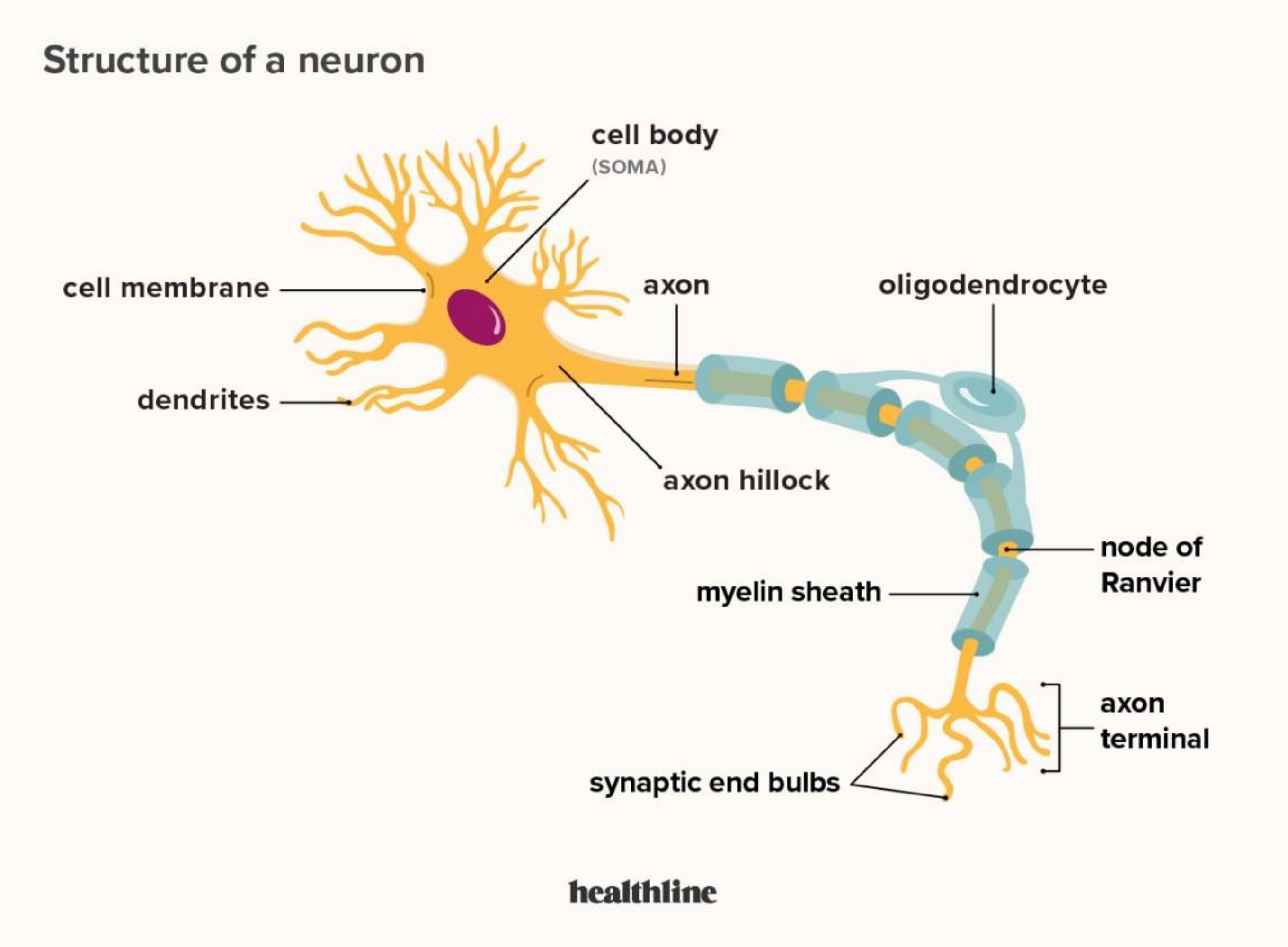
Unit 4 - Session 1

SLO 1: Basics of Neurons

Basics of neurons:

Neurons, also known as nerve cells, send and receive signals from your brain. While neurons have a lot in common with other types of cells, they're structurally and functionally unique. Neurons, also known as nerve cells, send and receive signals from your brain. While neurons have a lot in common with other types of cells, they're structurally and functionally unique. Specialized projections called axons allow neurons to transmit electrical and chemical signals to other cells. Neurons can also receive these signals via root like extensions known as dendrites.



Parts of a neuron

Neurons vary in size, shape, and structure depending on their role and location. However, nearly all neurons have three essential parts: a cell body, an axon, and dendrites.

Cell body

Also known as a soma, the cell body is the core section of the neuron. The cell body contains genetic information, maintains the neuron's structure, and provides energy to drive activities.

Like other cell bodies, a neuron's soma contains a nucleus and specialized organelles. It's enclosed by a membrane that both protects it and allows it to interact with its immediate surroundings.

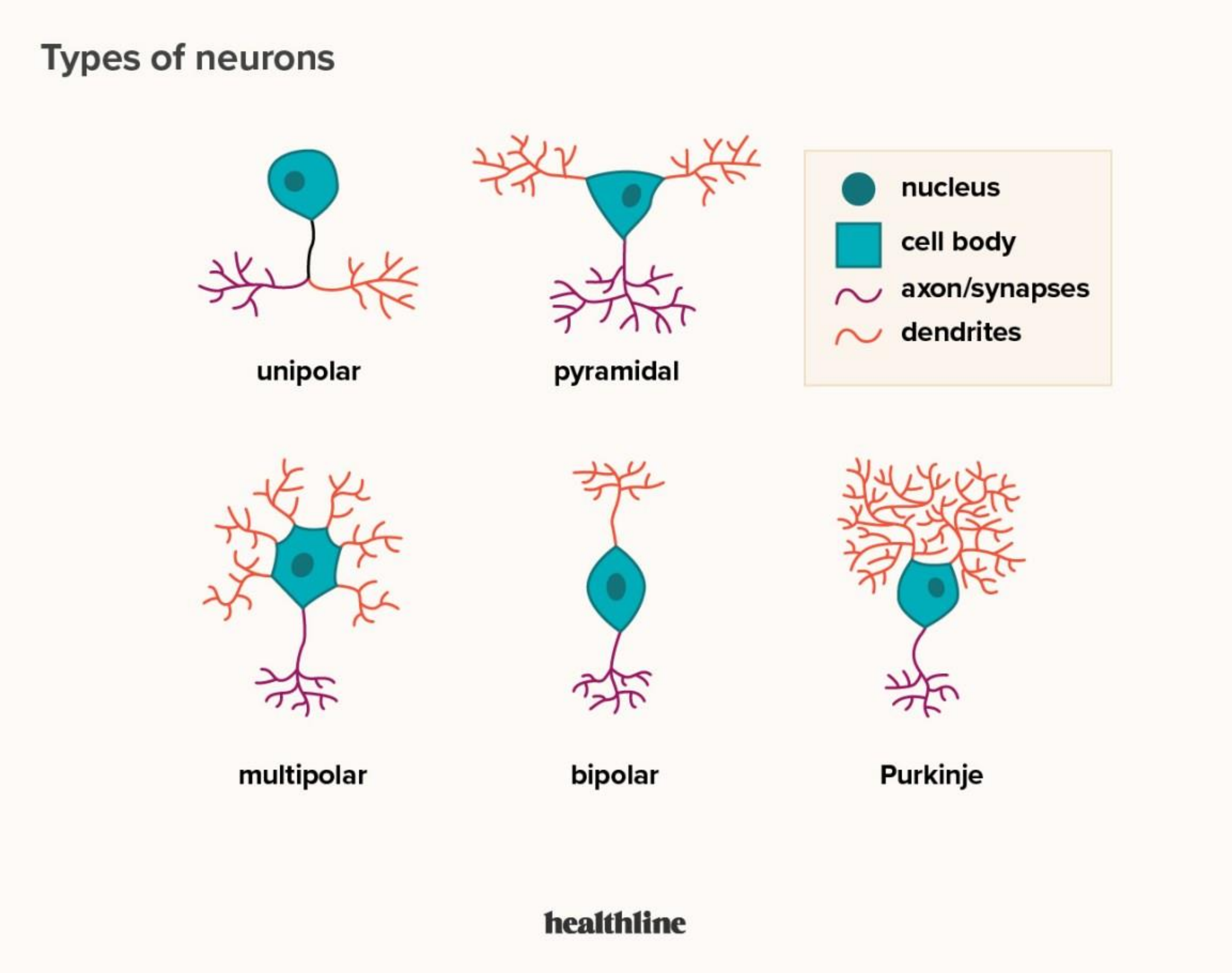
Axon

An axon is a long, tail-like structure. It joins the cell body at a specialized junction called the axon hillock. Many axons are insulated with a fatty substance called myelin. Myelin helps axons to conduct an electrical signal.

Neurons usually have one main axon.

Dendrites

Dendrites are fibrous roots that branch out from the cell body. Like antennae, dendrites receive and process signals from the axons of other neurons. Neurons can have more than one set of dendrites, known as dendritic trees.



Types of neurons

Neurons vary in structure, function, and genetic makeup. Given the sheer number of neurons, there are thousands of different types, much like there are thousands of species of living organisms on Earth.

However, there are five major neuron forms. Each combines several elements of the basic neuron shape.

- Multipolar neurons. These neurons have a single axon and symmetrical dendrites that extend from it. This is the most common form of neuron in the central nervous system.
- Unipolar neurons. Usually only found in invertebrate species, these neurons have a single axon.
- Bipolar neurons. Bipolar neurons have two extensions extending from the cell body. At the end of one side is the axon, and the dendrites are on the other side. These types of neurons are mostly found in the retina of the eye. But they can also be found in parts of the nervous system that help the nose and ear function.
- Pyramidal neurons. These neurons have one axon but several dendrites to form a pyramid type shape. These are the largest neuron cells and are mostly found in the cortex. The cortex is the part of the brain responsible for conscious thoughts.
- Purkinje neurons. Purkinje neurons have multiple dendrites that fan out from the cell body. These neurons are inhibitory neurons, meaning they release neurotransmitters that keep other neurons from firing.

In terms of function, scientists classify neurons into three broad types: sensory, motor, and interneurons.

Sensory neurons

Sensory neurons help you:

- taste
- smell
- hear
- see
- feel things around you

Sensory neurons are triggered by physical and chemical inputs from your environment. Sound, touch, heat, and light are physical inputs. Smell and taste are chemical inputs.

For example, stepping on hot sand activates sensory neurons in the soles of your feet. Those neurons send a message to your brain, which makes you aware of the heat.

Motor neurons

Motor neurons play a role in movement, including voluntary and involuntary movements. These neurons allow the brain and spinal cord to communicate with muscles, organs, and glands all over the body.

There are two types of motor neurons: lower and upper. Lower motor neurons carry signals from the spinal cord to the smooth muscles and skeletal muscles. Upper motor neurons carry signals between your brain and spinal cord.

When you eat, for instance, lower motor neurons in your spinal cord send signals to the smooth muscles in your esophagus, stomach, and intestines. These muscles contract, which allows food to move through your digestive tract.

Interneurons

Interneurons are neural intermediaries found in your brain and spinal cord. They're the most common type of neuron. They pass signals from sensory neurons and other interneurons to motor neurons and other interneurons. Often, they form complex circuits that help you to react to external stimuli.

For instance, when you touch something sharp like a cactus, sensory neurons in your fingertips send a signal to interneurons in your spinal cord. Some interneurons pass the signal on to motor neurons in your hand, which allows you to move your hand away. Other interneurons send a signal to the pain center in your brain, and you experience pain.

How do neurons work?

Neurons send signals using action potentials. An action potential is a shift in the neuron's potential electric energy caused by the flow of charged particles in and out of the membrane of the neuron. When an action potential is generated, it's carried along the axon to a presynaptic ending.

Action potentials can trigger both chemical and electrical synapses. Synapses are locations where neurons can pass these electrical and chemical messages between them. Synapses are made up of a presynaptic ending, a synaptic cleft, and a postsynaptic ending.

Chemical synapses

In a chemical synapse, the neuron releases of chemical messengers called neurotransmitters. These molecules cross the synaptic cleft and bind to receptors in the postsynaptic ending of a dendrite.

Neurotransmitters can trigger a response in the postsynaptic neuron, causing it to generate an action potential of its own. Alternatively, they can prevent activity in the postsynaptic neuron. In that case, the postsynaptic neuron doesn't generate an action potential.

Electrical synapses

Electrical synapses can only excite. These synapses form when two neurons are connected by a gap junction. This gap is much smaller than a chemical synapse and is made up of ion channels that help transmit a positive electrical signal.

Because of the way these signals travel, signals move much faster across electrical synapses than chemical synapses. However, these signals can diminish from one neuron to the next. This makes them less effective at transmitting repeated signals.

Unit 1 - Session 1

SLO 2: Glial Cells

Glial cells are smaller than neurons but are greater in number than nerve cells in the brain. Glial cells do not have axon and dendrites. However, they come into play during neural development or recovery from neural injury and during modulation of synaptic action and propagation of nerve signals.

Glial cells are found in the central nervous system (CNS) and peripheral nervous system (PNS). The important CNS glial cells are astrocytes, microglia, oligodendrocytes, radial glial cells, and ependymal cells. Schwann cells, enteric glial cells, and satellite glial cells are part of the PNS. Each type of glial cell is distinct in their origin, composition, morphology, and anatomy.

Astrocytes have a star-like appearance and are involved in neuronal signaling by maintaining the right chemical environment to regulate local blood flow and enhance oxygenation. They also play an important role in maintaining brain homeostasis by regulating the ion concentration. In addition, astrocytes play an important role in synapse formation and function.

Microglial cells participate not only in normal brain development but also in defense mechanisms, wherein the microglial cells migrate, release cytokines at the injury site, and also remove debris and dead cells by phagocytosis. Oligodendrocytes are responsible for producing the fatty substance, myelin, which acts as a protective sheath around axons thereby allowing faster travel of electrical impulses.

The radial glial progenitor cells are multipurpose cells involved in many areas of brain developments and are precursor cells for generating oligodendrocytes, astrocytes, and neurons. Ependymal cells are subtype of glial cells that form the epithelial lining of the brain ventricles and spinal cord. Like astrocytes, ependymal cells also maintain brain homeostasis and are involved in the development of the blood-cerebrospinal fluid barrier and the blood-retina barrier.

In the PNS, Schwann cells are also involved in myelination of neurons. The satellite cells are small cells that surround the neurons in the sensory ganglia in the autonomic nervous system and are involved in regulation of the exterior chemical environment. The enteric glial cells are majorly involved in regulation of the gastrointestinal system, and contribute significantly to the maintenance of the neuronal system.

Unit 1 - Session 2

SLO 1-2: Brain and its parts

The brain is composed of three main structures, the cerebrum, cerebellum, and brain stem. The brain sends chemical and electrical signals throughout the body to regulate different biological functions and sense environmental changes. The brain communicates with the majority of the body through the spinal cord. To do this, it uses billions of nerve cells throughout the CNS.

Cerebrum

The cerebrum is the front part of the brain and includes the cerebral cortex.
This part of the brain is responsible for many processes, including:

- initiating and controlling movement
- thinking
- emotion
- problem-solving
- learning

The cerebrum is responsible for personality. If a person experiences trauma to the cerebrum, in particular the frontal lobe, their friends and family may notice changes in their demeanor, mood, and emotions.

Cerebral cortex

The cerebral cortex covers the cerebrum and has many folds. Due to its large surface area, the cerebral cortex accounts for 50% of the brain's total weight.
The cerebral cortex has four lobes:

- Frontal lobe: This area is responsible for language, motor function, memory, personality, and other cognitive functions.
- Temporal lobe: The temporal lobe contains the Wernicke area, which is responsible for understanding language. It also processes memories and emotions and plays a major part in hearing and visual perception.
- Parietal lobe: The parietal lobe processes what a person sees and hears. It also interprets other sensory information.
- Occipital lobe: The occipital lobe interprets visual information and contains the visual cortex.

The cerebral cortex is made of grey matter, which is where the brain processes information. It also has ridges (gyri) and folds (sulci). The folds and ridges accommodated the rapid brain growth humans experienced over years of evolution.
The right side of the cerebral cortex, or hemisphere, controls the left side of the body, and the left hemisphere controls the right side of the body. Each hemisphere communicates with the other through the corpus callosum, which is a bridge of white matter.

Cerebellum

The cerebellum, or "little brain," is tucked underneath the cerebrum at the back of the head. It regulates balance and learned movements, such as walking and fastening buttons, but it cannot initiate movement.
Because the cerebellum is sensitive to alcohol, people will experience problems with balance and walking when they consume too much.

Brainstem

The brainstem is made up of the midbrain, pons, and medulla. It connects the cerebrum to the spinal cord.

Midbrain

The midbrain is responsible for several important functions that include hearing and movement. It also helps formulate responses to environmental changes, which include potential threats.

Pons

The pons enables a range of bodily functions, such as the production of tears, blinking, focusing vision, balance, and facial expressions. 10 cranial nerves arise from the pons. These connect to the face, neck, and trunk.

Medulla

The medulla regulates biological functions that are essential for survival, such as heart rhythm, blood flow, and breathing. This part of the brain also detects changes in blood oxygen and carbon dioxide levels. Reflexive responses such as vomiting, swallowing, and coughing also originate from the medulla.

Unit 1 - Session 3

SLO 1-2: Artificial Neural Networks

A neural network is a series of algorithms that endeavors to recognize underlying relationships in a set of data through a process that mimics the way the human brain operates. In this sense, neural networks refer to systems of neurons, either organic or artificial in nature.

Neural networks can adapt to changing input; so the network generates the best possible result without needing to redesign the output criteria. The concept of neural networks, which has its roots in artificial intelligence, is swiftly gaining popularity in the development of trading systems.

Types of Neural Networks

Feed-Forward Neural Networks

Feed-forward neural networks are one of the more simple types of neural networks. It conveys information in one direction through input nodes; this information continues to be processed in this single direction until it reaches the output mode. Feed-forward neural networks may have hidden layers for functionality, and this type of most often used for facial recognition technologies.

Recurrent Neural Networks

A more complex type of neural network, recurrent neural networks take the output of a processing node and transmit the information back into the network. This results in theoretical "learning" and improvement of the network. Each node stores historical processes, and these historical processes are reused in the future during processing.

This becomes especially critical for networks in which the prediction is incorrect; the system will attempt to learn why the correct outcome occurred and adjust accordingly. This type of neural network is often used in text-to-speech applications.

Convolutional Neural Networks

Convolutional neural networks, also called ConvNets or CNNs, have several layers in which data is sorted into categories. These networks have an input layer, an output layer, and a hidden multitude of convolutional layers in between. The layers create feature maps that record areas of an image that are broken down further until they generate valuable outputs. These layers can be pooled or entirely connected, and these networks are especially beneficial for image recognition applications.

Deconvolutional Neural Networks

Deconvolutional neural networks simply work in reverse of convolutional neural networks. The application of the network is to detect items that might have been recognized as important under a convolutional neural network. These items would likely have been discarded during the convolutional neural network execution process. This type of neural network is also widely used for image analysis or processing.

Modular Neural Networks

Modular neural networks contain several networks that work independently from one another. These networks do not interact with each other during an analysis process. Instead, these processes are done to allow complex, elaborate computing processes to be done more efficiently. Similar to other modular industries such as modular real estate, the goal of the network independence is to have each module responsible for a particular part of an overall bigger picture.

Unit 1 - Session 4

SLO 1-2: Uses of ANN

Neural networks are broadly used, with applications for financial operations, enterprise planning, trading, business analytics, and product maintenance. Neural networks have also gained widespread adoption in business applications such as forecasting and marketing research solutions, fraud detection, and risk assessment.

A neural network evaluates price data and unearths opportunities for making trade decisions based on the data analysis. The networks can distinguish subtle nonlinear interdependencies and patterns other methods of technical analysis cannot. According to research, the accuracy of neural networks in making price predictions for stocks differs. Some models predict the correct stock prices 50 to 60% of the time, while others are accurate in 70% of all instances. Some have posited that a 10% improvement in efficiency is all an investor can ask for from a neural network.

Specific to finance, neural networks can process hundreds of thousands of bits of transaction data. This can translate to a better understanding of trading volume, trading range, correlation between assets, or setting volatility expectations for certain investments. As a human may not be able to efficiently pour through years of data (sometimes collected down second intervals), neural networks can be designed to spot trends, analyze outcomes, and predict future asset class value movements.

Unit 1 - Session 5

SLO 1-2: Machine learning

Machine learning (ML) is a type of artificial intelligence (AI) that allows software applications to become more accurate at predicting outcomes without being explicitly programmed to do so. Machine learning algorithms use historical data as input to predict new output values.
Recommendation engines are a common use case for machine learning. Other popular uses include fraud detection, spam filtering, malware threat detection, business process automation (BPA) and Predictive maintenance.

Machine learning importance

Machine learning is important because it gives enterprises a view of trends in customer behavior and business operational patterns, as well as supports the development of new products. Many of today's leading companies, such as Facebook, Google and Uber, make machine learning a central part of their operations. Machine learning has become a significant competitive differentiator for many companies.
What are the different types of machine learning?
Classical machine learning is often categorized by how an algorithm learns to become more accurate in its predictions. There are four basic approaches:supervised learning, unsupervised learning, semi-supervised learning and reinforcement learning. The type of algorithm data scientists choose to use depends on what type of data they want to predict.

- Supervised learning: In this type of machine learning, data scientists supply algorithms with labeled training data and define the variables they want the algorithm to assess for correlations. Both the input and the output of the algorithm is specified.
- Unsupervised learning: This type of machine learning involves algorithms that train on unlabeled data. The algorithm scans through data sets looking for any meaningful connection. The data that algorithms train on as well as the predictions or recommendations they output are predetermined.
- Semi-supervised learning: This approach to machine learning involves a mix of the two preceding types. Data scientists may feed an algorithm mostly labeled training data, but the model is free to explore the data on its own and develop its own understanding of the data set.
- Reinforcement learning: Data scientists typically use reinforcement learning to teach a machine to complete a multi-step process for which there are clearly defined rules. Data scientists

program an algorithm to complete a task and give it positive or negative cues as it works out how to complete a task. But for the most part, the algorithm decides on its own what steps to take along the way.

Unit 1 - Session 6

SLO 1-2: Data mining in Biology

Data mining (DM) refers to the extraction or "mining" of knowledge from a large amount of data. Data mining is the science of finding new interesting patterns and relationships in large amounts of data. It is defined as "the process of discovering meaningful new associations, patterns and trends by mining a large amount of data stored in a warehouse". Data mining is sometimes called Knowledge Discovery in Database (KDD). It has been successfully applied in bioinformatics, which has abundant data and requires important discoveries such as gene expression, protein modeling, biomarker identification, drug discover and so on. The development of new data mining methods provides a useful way to understand rapidly expanding biological data. Now data mining methods are widely used in bioinformatics data analysis.

Data Mining in Bioinformatics

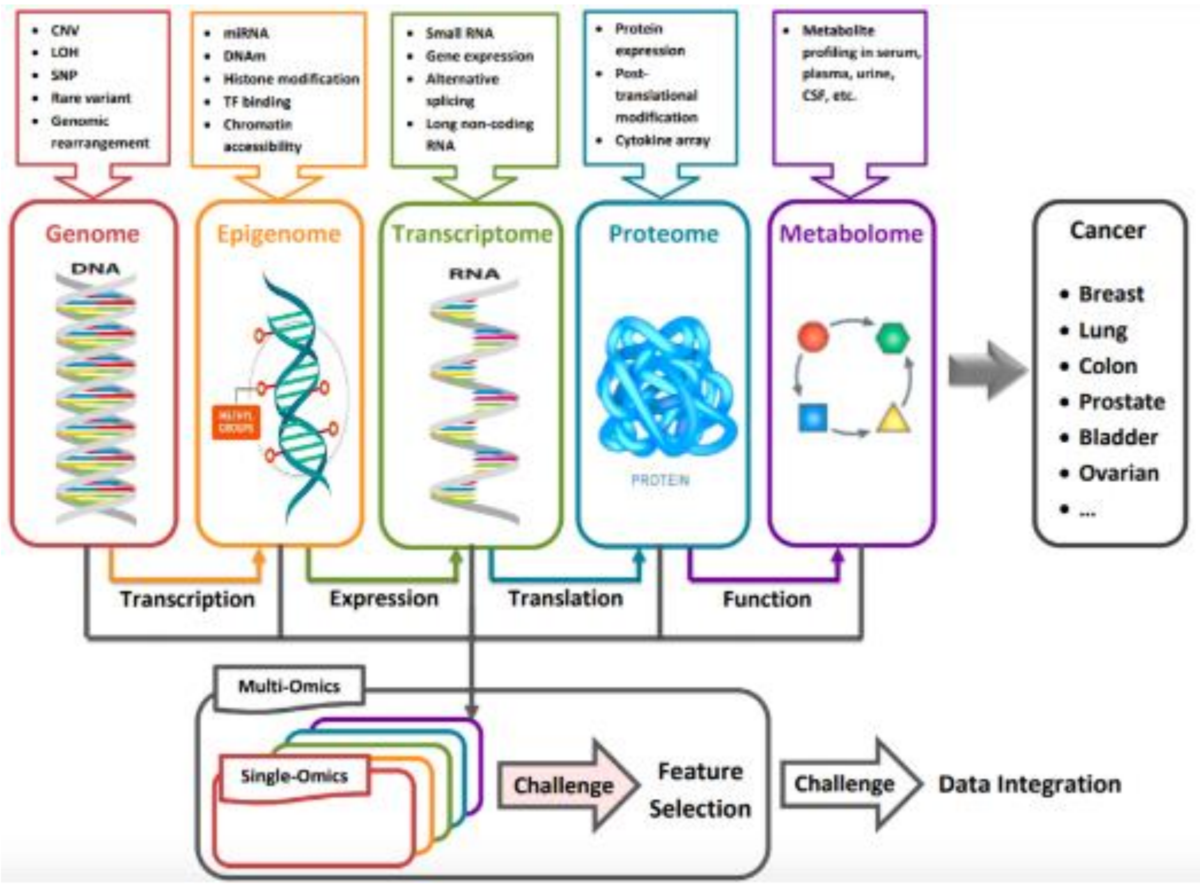


Fig 1. Data from different databases can be mined for single-omics and multi-omics joint analysis. (Momeni Z, *et al*2020)

Typical Data Mining Pipeline

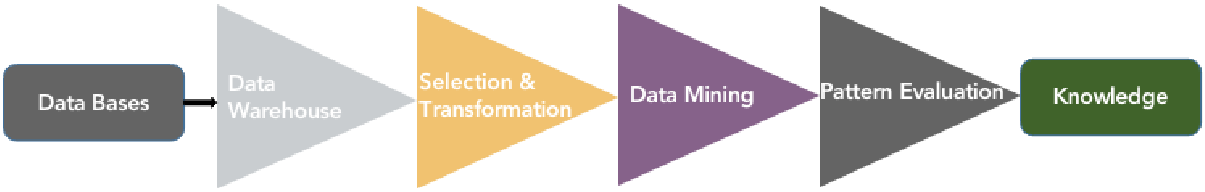


Fig 2. Process of knowledge discovery through data mining.

Application of Data Mining

With the development of sequencing technology and bioinformatics, more and more biological data and databases are generated, and a large amount of biological data is stored. Therefore, it is becoming more and more important to mine and effectively use existing data through data mining methods.

Biomedical field: Data mining techniques helps to propose proactive research within specific fields of the biomedical industry. And it enables researchers to better understand the biological mechanisms in order to discover new treatments in the fields of medical care and life knowledge.

Animal and plant research: Integrate and analyze data from different species databases to study the evolutionary relationship between different species. Integrate and analyze data from different omics databases of the same species, and conduct a comprehensive and systematic study of the biological mechanism of this species.