Knowledge Representation and Reasoning
Part-1

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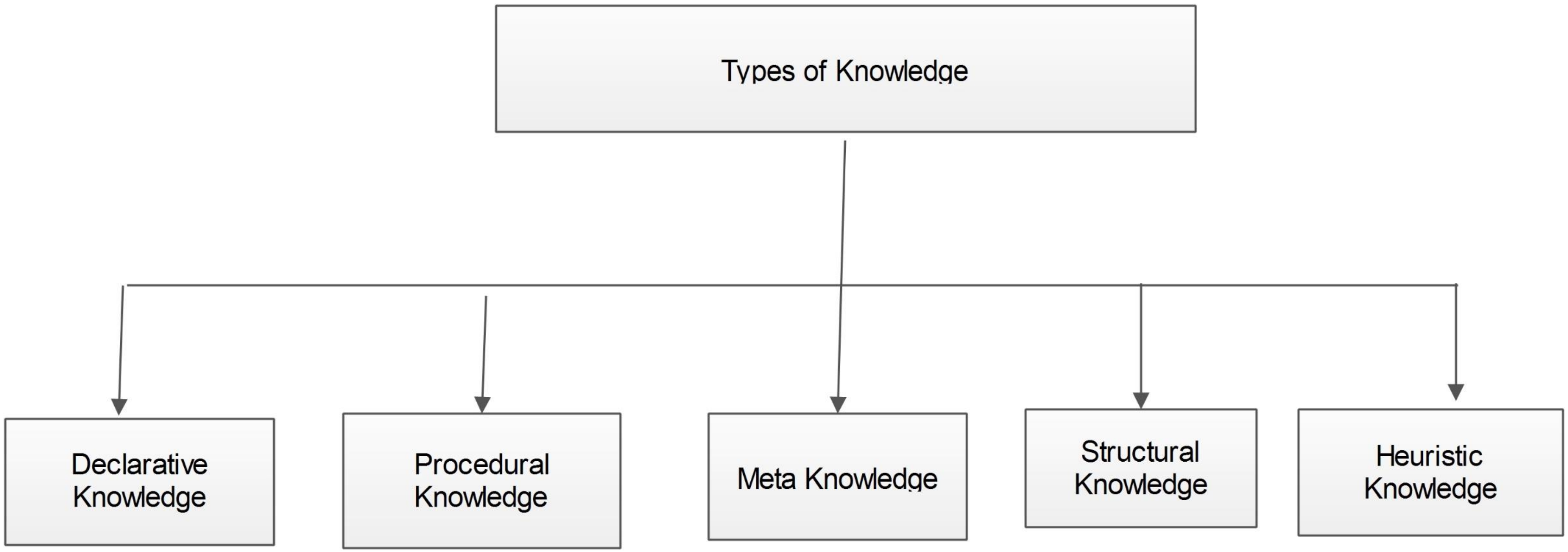
- **Knowledge** is the collection of facts, information, and skills acquired through experience or training or education.
- It is the theoretical or practical understanding of a subject/topic.
- **Reasoning** means processing of knowledge.
- **Intelligence** is the ability to use the knowledge.

- Humans are capable to understand, and interpret the knowledge.
- As per their knowledge, they perform various actions in the real world.
- How machines can do all these things?
  - It comes under knowledge representation and reasoning.
  - It is part of AI which concerned with AI agents thinking and how thinking contributes to their intelligent behavior.

Knowledge representation is not just storing data into some database, but it also enables an intelligent agent to learn from that knowledge and experiences so that it can behave intelligently like a human.

Knowledge representation can use this knowledge to solve the real world problems like diagnosis a medical condition or communicating with humans in natural language.


Types of Knowledge
Declarative Knowledge
Procedural Knowledge
Meta Knowledge
Structural Knowledge
Heuristic Knowledge

1**. Declarative Knowledge:**

- Declarative knowledge is to know about something like concepts, facts, and objects.
- It is also called descriptive knowledge and expressed in declarative sentences.
- It is static in nature.

For example: New Delhi is the capital of India.

2. Procedural Knowledge

- Procedural knowledge involves knowing how to do something.
- It can be directly applied to any task.
- It includes rules, strategies, procedures, agendas, etc.
- It is process-oriented in nature

For example- riding a bicycle. When someone was teaching you how to ride a bicycle, no matter what they said, you probably struggled to grasp it until you'd actually done it a few times. Once you figured it out, it quickly became implicit knowledge. That is, the type of knowledge that is hard to explain as it is subconsciously stored in your mind.

3. Meta-knowledge:

- Knowledge about the knowledge is called Meta-knowledge.
- It is used to describe things such as tags, models and taxonomies that describe knowledge.

For example: bibliography

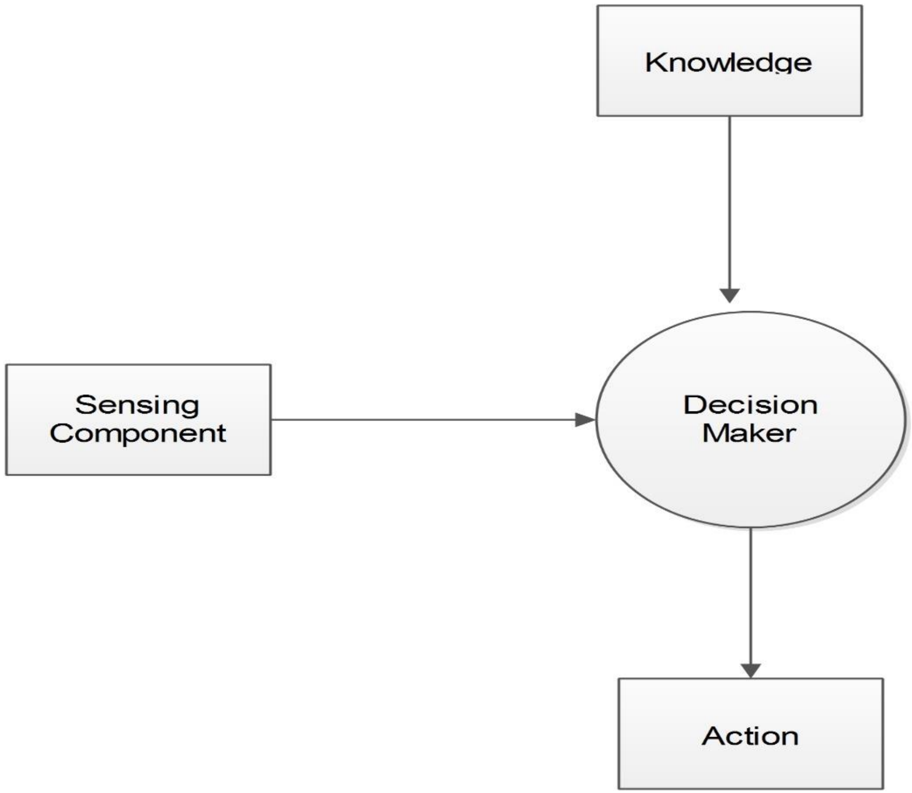
4. Heuristic knowledge:

- Heuristic knowledge is representing knowledge of some experts in a field or subject.
- Heuristic knowledge is rules of thumb based on previous experiences, awareness of approaches, and which are good to work but not guaranteed.

5. Structural knowledge:

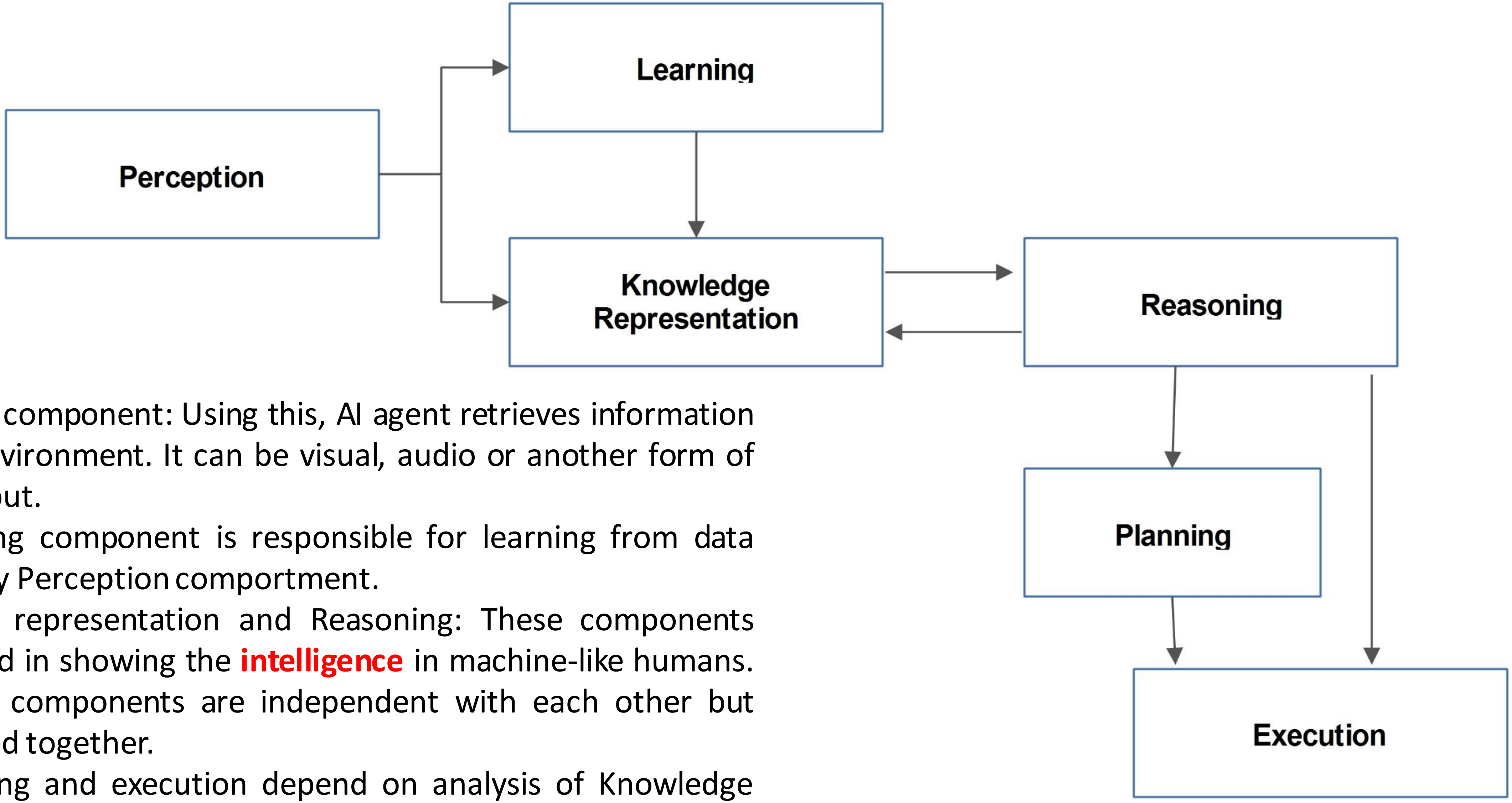
- Structural knowledge is basic knowledge to problem-solving.
- It describes relationships between various concepts such as **kind of**, **part of**, and **grouping of something**.
- It describes the relationship that exists between concepts and objects.

Relationship between Knowledge and Intelligence:



- There is one decision maker which act by sensing the environment as well as using its knowledge.
- If the knowledge part will not present then, it cannot display intelligent behavior.
- So for any intelligent system, we need knowledge.

Cycle of knowledge



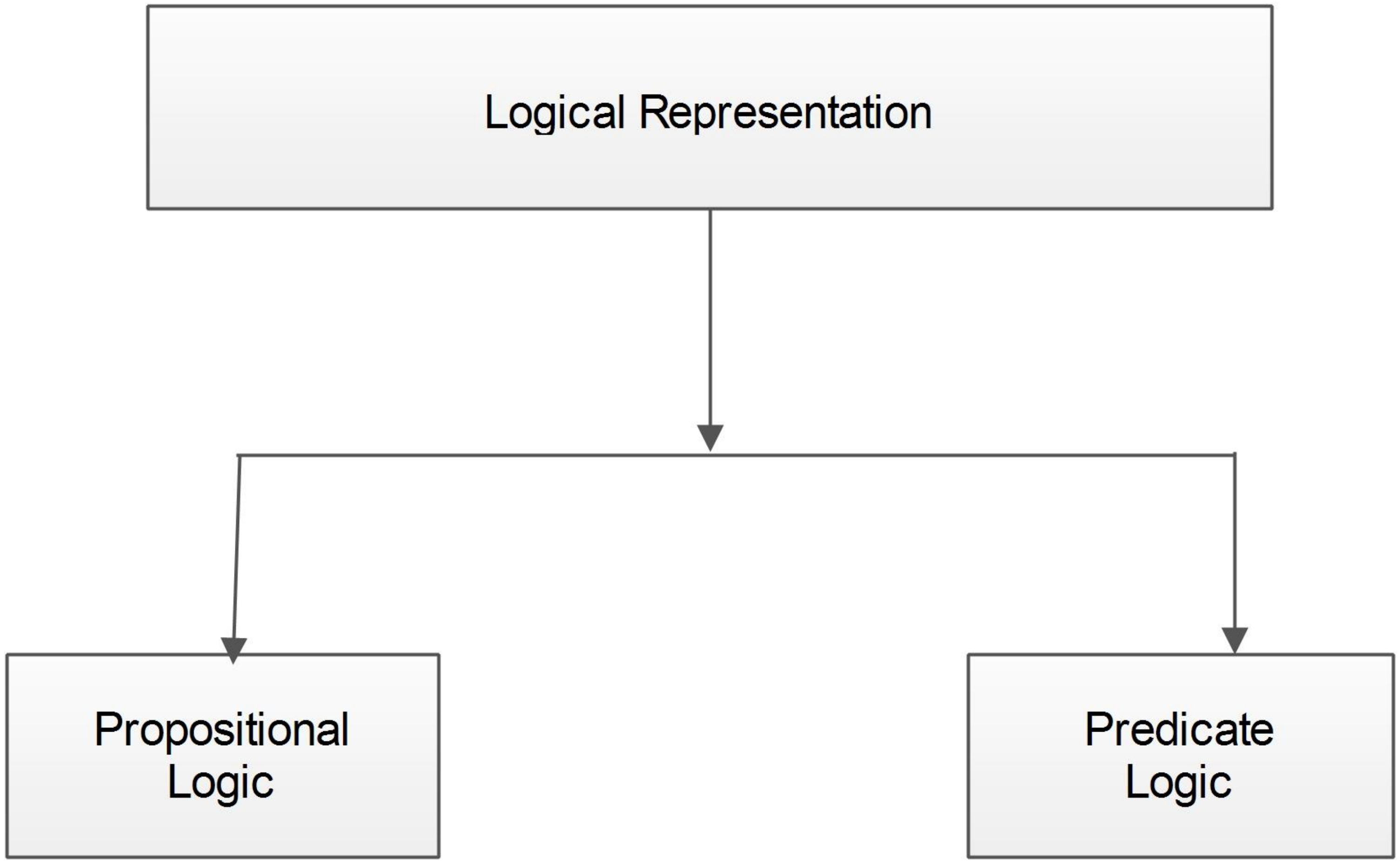
- Perception component: Using this, AI agent retrieves information from its environment. It can be visual, audio or another form of sensory input.
- The learning component is responsible for learning from data captured by Perception comportment.
- knowledge representation and Reasoning: These components are involved in showing the **intelligence** in machine-like humans. These two components are independent with each other but also coupled together.
- The planning and execution depend on analysis of Knowledge representation and reasoning.

Approaches of Knowledge Representation

- Logical Representation
- Semantic Network Representation
- Frame Representation
- Production Rules

1. Logical Representation: It is a language type representation with some definite rules which deals with the propositions and has no ambiguity. It represents a conclusion based on various conditions

Syntax	**Semantics**
Using syntax we can decide how we can construct legal sentences in a logic.	These are the rules by using which we can interpret the sentences.
It determines which symbol we can use in knowledge representation	It assigns a meaning to each sentences.
How to write those particular symbols	


Logical Representation
Propositional Logic
Predicate Logic

Propositional logic

- Propositional/Boolean logic is the simplest form of logical representation in which all the statements are represented by propositions.
- A proposition is a **declarative statement** which is **either true or false.**
- It is a technique of knowledge representation in logical and mathematical form.
- Propositional logic consists of an object, relations or function, and logical connectives/logical operators.

For example:

Sun rises from East (True)

7 is a prime number (True)

2+2 = 5 (False)

- A proposition formula which is always true is called **tautology,** and it is also called a valid sentence.
- A proposition formula which is always false is called **Contradiction**.
- Statements which are questions, commands, or opinions are not propositions such as "Where is Ram?", "How do you do?", "What is your name?", are not propositions.

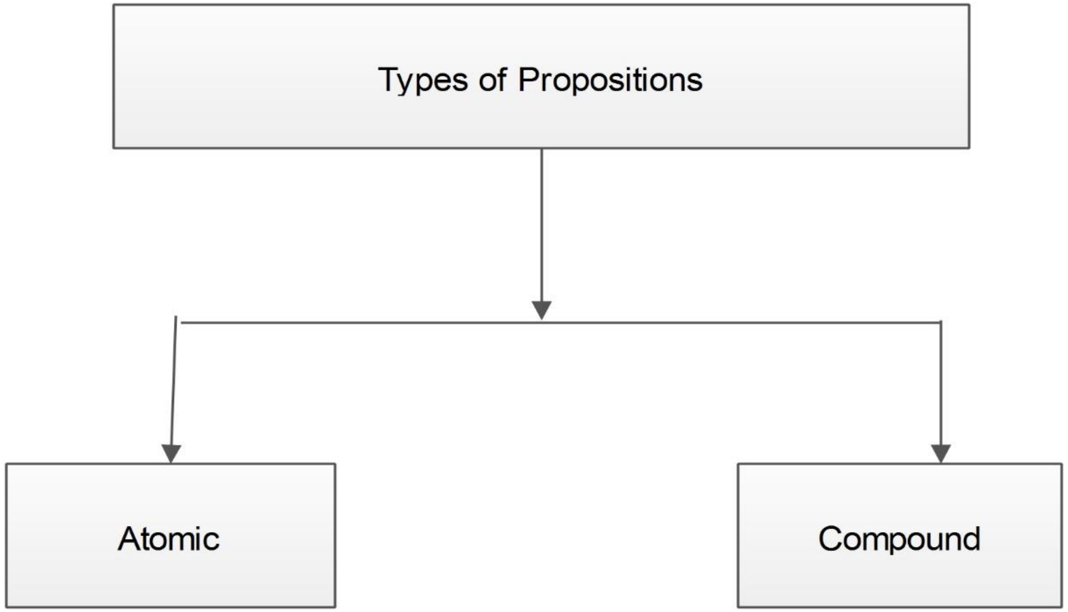
It consists of precisely defined syntax and semantics which supports the sound inference. Each sentence can be translated into logics using syntax and semantics.

Syntax:

- Syntaxes are the rules using which we can construct legal sentences in the logic.
- It determines which symbol we can use in knowledge representation.
- How to write those symbols.

Semantics:

- Semantics are the rules by which we can interpret the sentence in the logic.
- Semantic also involves assigning a meaning to each sentence.



- Atomic: These are the simple propositions consisting of single proposition symbol. For example 1+1 = 2 is an atomic proposition.
- Compound/complex/composite: These are constructed by combining atomic propositions, using parenthesis and logical connectives. For example: (It is not raining today in Patiala)

Logical Connectives

1. **Negation**: A sentence such as $\neg$ P is called negation of P. A literal can be either Positive literal or negative literal. For example: Today is not holiday can be represented as $\neg$ P , where P: Today is holiday.
2. **Conjunction**: A sentence which has $\wedge$ connective such as, $P \wedge Q$ is called a conjunction. For example: Ramu eats fries, **and** Aman drinks soda.
3. **Disjunction**: A sentence which has $\vee$ connective, such as $P \vee Q$. is called disjunction, where P and Q are the propositions. For example- The clock is slow **or** the time is correct can be represented as $P \vee Q$.
4. **Implication**: A sentence such as $P \rightarrow Q$, is called an implication. Implications are also known as if-then rule. For example: If there is a rain then the streets are wet.
5. **Biconditional**: A sentence such as $P \Leftrightarrow Q$ is a Biconditional sentence, For example If I am breathing, then I am alive

Truth Tables of Logical Connectors

For Negation:

P	¬ P
True	**False**
False	**True**

For Conjunction:

P	Q	P∧ Q
True	True	**True**
True	False	**False**
False	True	**False**
False	False	**False**

For disjunction:

P	Q	P ∨ Q.
True	True	**True**
False	True	**True**
True	False	**True**
False	False	**False**

For Implication:

P	Q	P→ Q
True	True	**True**
True	False	**False**
False	True	**True**
False	False	**True**

"If you get an A+, then your father will give you a gift."

The statement will be true if your father keep his promise and false if he does n't.

Suppose it's true that you get an A+ and it's true that your father give you a gift. Since he kept his promise, the implication is true. This corresponds to the first row in the table.

Suppose it's true that you get an A+ but it's false that your father give you a gift. Since he didn't keep his promise, the implication is false. This corresponds to the second row in the table.

What if it's false that you get an A+? Whether or not your father give you a gift, he has n't broken his promise. Thus, the implication can't be false, so (since this is a two-valued logic) it must be true. This explains the last two rows of the table.

For Biconditional:

P	Q	$P \Leftrightarrow Q$
True	True	**True**
True	False	**False**
False	True	**False**
False	False	**True**

Note: We can create truth table for more than three propositions

Construct a truth table for ¬ P ∧(P →Q)

P	Q	$\neg P$	$P \rightarrow Q$	$\neg P \wedge (P \rightarrow Q)$
T	T	F	T	F
T	F	F	F	F
F	T	T	T	T
F	F	T	T	T

Show that $(P \rightarrow Q) \vee (Q \rightarrow P)$ is a tautology.

P	Q	$P \rightarrow Q$	$Q \rightarrow P$	$(P \rightarrow Q) \vee (Q \rightarrow P)$
T	T	T	T	T
T	F	F	T	T
F	T	T	F	T
F	F	T	T	T

Truth table for (P →Q) ∧ (Q →R)

P	Q	R	$P \to Q$	$Q \to R$	$(P \to Q) \wedge (Q \to R)$
T	T	T	T	T	T
T	T	F	T	F	F
T	F	T	F	T	F
T	F	F	F	T	F
F	T	T	T	T	T
F	T	F	T	F	F
F	F	T	T	T	T
F	F	F	T	T	T

Examples

It is hot

It is humid

It is raining

Write down the proposition logic for

1. If it is humid then it is hot

2. If it is hot and humid then it is not raining

Take A= **It is hot.**
B = It is humid.
C= It is raining.

1. **B** $\rightarrow$ A

2. $(A \land B) \rightarrow \neg C$

P: Good mobile phones are not cheap
Q: Cheap mobile phones are not good

L: P implies Q
M: Q implies P
N: P is equivalent to Q
Which one of the following about L, M, and N is CORRECT?
(A) Only L is TRUE.
(B) Only M is TRUE.
(C) Only N is TRUE.
(D) L, M and N are TRUE

Let a and b be two proposition
a: Good Mobile phones.
b: Cheap Mobile Phones.

P and Q can be written in logic as
P: $a \rightarrow \sim b$
Q: $b \rightarrow \sim a$.

Truth Table

a	b	~a	~b	P	Q
T	T	F	F	F	F
T	F	F	T	T	T
F	T	T	F	T	T
F	F	T	T	T	T

It clearly shows P and Q are **equivalent**.
so option D is Correct

First-order logic does not only assume that the world contains facts like propositional logic but also assumes the following things in the world:

- Objects: A, B, people, numbers, colors etc.
- Relations: It can be **unary** relation such as: red, round, is adjacent, or **n-any** relation such as: the sister of, brother of, has color, comes between
- Function: Father of, best friend, third inning of, end of, ...

Predicate Logic/First Order Logic

In Propositional Logic(PL), we can represent statements/facts which are either **true** or **false.**

PL is not sufficient to represent the **complex sentences** or **natural language statements**. The propositional logic has very limited expressive power.

For example we cannot represent following sentences using PL logic.

"Some employees are hard workers“

or

“All boys like cricket."

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- Function: Father of, best friend, third inning of, end of, ...

As a natural language, first-order logic also has two main parts:

- Syntax
- Semantics

Basic Elements of First-order logic

Constant	1, 2, A, John, Mumbai, cat,....
Variables	x, y, z, a, b,....
Predicates	Brother, Father, >,....
Function	sqrt, LeftLegOf, ...
Connectives	∧, ∨, ¬, ⇒, ⇔
Equality	==
Quantifier	∀, ∃

- **Atomic sentences:**

Atomic sentences are the most **basic sentences of first-order logic**. These sentences are formed from a predicate symbol followed by a parenthesis with a sequence of terms.

We can represent atomic sentences as Predicate (term1, term2, ..., term n).

Example: Ram and Shyam are brothers: => Brothers(Ram, Shyam).

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- **Complex Sentences:**

Complex sentences are made by combining atomic sentences using **connectives**.

First-order logic statements can be divided into two parts:

- Subject: Subject is the main part of the statement.
- Predicate: A predicate can be defined as a **relation**, which binds two atoms together in a statement.

For example: Ram is a batsman

Here Ram is Subject and is a batsman, is Predicate.

Quantifiers in First-order logic:

- Universal Quantifier, (for all, everyone, everything)
- Existential quantifier, (for some, at least one).

If there is a statement: All man play cricket.

It can be converted into FOL as

$\forall x : man(x) \rightarrow play(x, cricket)$.

Also if we have another statement- Some boys are intelligent.

$\exists x: boys(x) \wedge intelligent(x)$

Note:

- The main connective for universal quantifier ∀ is **implication** →.

- The main connective for existential quantifier ∃ is **and** ∧.

Example 1: Every house is a physical object

$\forall x$: house(x) $\rightarrow$ physical_object(x)

where house and physical_object are unary predicate symbols.

Example 2: Some physical objects are houses

$\exists x$: physical_object(x) $\wedge$ house(x)

Example 3: Every house has an owner

$\forall x$: house(x) $\rightarrow$ $\exists y$.owns(y, x)

here owns is a binary predicate symbol.

Example 4: “Everybody owns a house” is translated as

$\forall x.\exists y.(owns(x, y) \wedge house(y))$

Example 5: “Ram owns a house” is translated as

$\exists x.(owns(Ram, x) \wedge house(x))$

where Ram is an individual constant symbol.

Example 6: "Ram does not own a house" is translated as

$\neg \exists x.(owns(Ram, x) \land house(x))$

Example 7: "Somebody does not own a house" is translated as

$\exists x. \forall y.(owns(x, y) \rightarrow \neg house(y))$

Advantages	Disadvantages
Logical representation help to perform logical reasoning	Logical representations have some restrictions and are challenging to work with.
This representation is the basis for the programming languages	This technique may not be very natural and inference may not be very efficient.