WHAT IS COGSCI:
- An interdisciplinary field that comprises parts of psychology, philosophy. Linguists, AI, neuroscience, and anthropology.

COMPUTER METAPHOR:
- The mind is like a computer

- The brain has a computational structure to process info

- There is perception(input)

- Thought(processing)

- Memory(storage)

- Behavior(output)

- The mind

MULTIPLE REALIZABILITY: PAIN
- An octopus, human, and AI can experience pain.

- **EX:** Cutting of an octopus arm, burning your hand on a stove, which is external bodily harm that could manifest in similar ways.

- Pain is caused by similar stimuli, which have similar kinds of experiences and produce the same type of behavioral output.

- There is no underlying physical state or brain state that is common to different systems that experience pain

- However, different types of things or people can experience pain in their own way.

FUNCTIONALISM:
- What makes something a thought, desire, pain (or any other type of mental state) depends not on its internal constitution, but solely on its function, or the role it plays, in the cognitive system of which it is a part.

- Creatures with those internal states are able to be in pain
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- Creatures can fulfill the conditions of pain to fill the functional profile that can be characterized as pain.

- Mental states are defined by their function and can be multiple realizable and they can be realized by different kinds of physical substances.

- Creatures share the same functional profile and that's what makes us think it's a class of mental states pain.

- The functionalist theory might characterize pain as a state that tends to be caused by a bodily injury, to produce the belief that something is wrong with the body and the desire to be out of that state.

- **Brain states vs Mental State:**
    - **EX:** Different types of computers can run PowerPoint, but to run PowerPoint it is using a set of functional rules rather than the literal hardware you can swap out on a computer.

    - It's about those functional characteristics and not the kind of machine that's able to run PowerPoint.

    - It's not that any physical thing can instantiate pain and once we define mental states as separate from physical states, anything goes.

- If machines are ever to be conscious, it means we do have a shared belief that mental states can be instantiated in different kinds of physical states.

THE MULTIPLE REALIZABILITY THESIS:

- All mental kinds are multiplied realizable by distinct physical kinds

- If a given mental kind is multiplied realizable by distinct physical kinds, then it cannot be identical to any specific physical kind.

- No mental kind is identical to any specific physical kind.

MENTAL REPRESENTATIONS:

- The mind is just like a computer that is able to compute over things called representations.

- **Characteristics of mental representation:**
    - Bearer: Something that's doing the representing.

    - Referent: A thing in the world that's being represented.

    - Content: Something being shown.

    - Intentionality: Mental states represent objects, properties, and states of affairs in the world. The connection between the content and the thing in the world.

- **Example:**
    - I am looking at a cup so I would be the bearer.
    - The cup would be the referent.
    - The content is seeing the cup or in your head, if someone is telling you they are looking at a cup.
    - Intentionally is the relationship between the content and the referent.
    - The picture of the cup I am thinking of has some relationship with the actual cup on the table.
- Mental representations are useful to us because they allow us to represent in sentences like facts in our world.
- Can help us describe things in our head
- **Example:**
    - You can use different maps to prioritize different information.
    - There are many ways to represent New York.
    - You can represent New York by the subway map to show all the routes.
    - You can also use a tourist map to show all the great locations such as the empire state, the statue of liberty, or simply by its geography.
    - You can also represent New York by population density in different areas.
    - Depending on what you want to show, you must sacrifice other information for the information your graphic is being utilized for.
    - You can also represent New York with just straight-up true facts.

IMAGISTIC/PICTORIAL REPRESENTATION:

- Represent in virtue of resembling (in part or whole) the referent in the world.
- Imagistic representations where something in a drawing can be broken down into pieces and you can say a certain piece of a drawing corresponds to something real in the world.

- The pictures you see in your head allow you to represents and see things in the real world.

- You can imagine your bedroom and picture where all your furniture is.

- Imagistic representation is how we engage with objects and the perceptual here and how we build maps with mental imagery.

- **Isomorphism:** There's a similar structure between representation and the reference (the thing in your head or in the world).

- **Caricature (counterexample to isomorphism):** We are able to recognize people with distorted faces and funny-looking drawings. The imagistic representation will prioritize certain information about a person's physical appearance.

- Some people are good at mental rotation when looking at an image, which is a very complicated process for your brain when it comes to imagistic representations.

- **Case Study: Aphantasia:**
  - People are not able to picture things in their minds.

  - Some people have to rely on propositional representation since they can't picture things and use sentences

DIGITAL AND ANALOGUE REPRESENTATION:

- **Digital representations:**
  - Involves discrete representational units.

  - **EX:** A digital clock shows the hours, minutes, and seconds.

  - Letters and symbols are discrete and can be combined with a certain set of words in a rule-like way.

- **Analog representation:**
  - Something that is continuous and goes forever.

  - **EX:** A analog clock's needles/hands are always moving in a loop forever.

  - Represents continuous types of specification.

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CASE STUDY - ANALOGUE NUMBER REPRESENTATION:

- **Weber's Law:** The discriminability of any two analog magnitudes (loudness, brightness, length, etc) is a function of ratio.

- Brightness and loudness can be represented discretely on computers, but in our minds, it's analog because it's how we are seeing things or hearing things.

- 1 and 2 should be more discriminable visually than 7 and 8 (what is called the **magnitude effect).** It should be easier to discriminate 1 - 3 than 2 -3, which is called the **distance effect.**

- There is a system where we represent numbers not as being digital, but in an analog way by comparing 2 different ratios.

- Eventually, when we can get the concept of natural numbers, we get more complicated representations of numbers that we think are discrete and exact.

- Babies and animals have a number system that is analog.

- They take in a bunch of a number of things in the world and doing computations that looks like ratios.

SYMBOLIC REPRESENTATION:

- A symbol stands for an idea or object but does not have a genuine resemblance.

- **EX:** a $ sign looks nothing like a dollar bill, but it is very recognizable and represents a dollar bill.

PROPOSITIONAL REPRESENTATION:

- Sentence-like structures

- Bearers of truth value (can be true or false)

- Objects of propositional attitudes (belief, desire, etc)

- Specify some way in which the world could be

- Allow us to entertain counterfactual statements in virtue of understanding the logical relationship

- **Examples:**
    - Toronto is in Mexico (false).

    - Toronto is in Canada (true).

    - New Brunswick is in New Jersey (true).

- You have to think something true of the world and the thing it represents of the world is the proposition.
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- **Ex:** If you believe your cat needs more food, then you are thinking something is true of the world

- You can have attitudes toward propositional representation that make you believe they're true of the world or false.

- **Example:**
  - Represents logical relationships.

  - Sentence: "Mary loves John."

  - [Relationship between elements] ([Subject], [Object])

  - L(m,j)

  - It allows us to entertain counterfactual statements in virtue of understanding the logical relationship

  - Maybe it's true in the real world "John loves Mary", but maybe Mary does not love John.

  - Or "Mary loves John" could be true and can be a counterfactual world and how the world could be.

- As long as you understand the structure of a sentence, you can imagine the possible world a statement can be true.

PROPOSITIONAL VS IMAGISTIC REPRESENTATION:
- **Proposition**: "The cup is on the table."

- **Imagistic:** An actual picture of a cup.

MENTAL REPRESENTATIONS:
- Allows us to picture objects and situations

- Reason about objects and abstract ideas

- Plan and carry out appropriate actions.

- Communicate with others.

- Engage in forms of social cooperation.

- Are the buildings blocks of the mind.

COMPUTATION:

- Mind performs computations over representations.

- Computations get grouped (addition, subtraction, multiplication, and division which can be group as mathematical reasoning).

- **Examples of Mental computational operations:**
    - Perception
    - Attention
    - Memory
    - Language
    - Mathematical reasoning
    - Logical reasoning
    - Decision making
    - Problem-solving

MARR'S THREE LEVELS:

- If one hopes to achieve a full understanding of a system as complicated as a nervous system, a developing embryo, a set of metabolic pathways, a bottle of a gas or even a large computer program.

- One must be prepared to contemplate different kinds of explanations at different levels of description that are linked.

- At least in principle, into a cohesive whole, even if linking the levels in complete detail is impractical.

- There are level of explanations to understand anything

- **Example:**
    - There are many ways to represent the number 37

    - Arabic numeral (3*10) + (5*1) = 37_{10}

    - Binary numeral: 100101 (Binary numbers are represented in base 2) - (1*32) + (0*16) + (0*8) + (1*4) + (0*2) + (1*1) = 100101_2

    - Roman numeral: XXXVII - 10 + 10 + 10 + 5 + 1 + 1 = XXXVII

    - 37 = 100101 = XXXVII

REPRESENTATIONAL TRADE-OFF:

- There is a trade-off; any particular representation makes certain information explicit at the expense of information that is pushed into the background and might be hard to recover

- Makes certain information explicit at the expense of other information being pushed into the background and might be hard to recover.

- How information is presented affects what you can do with it.

- **Examples:**
    - Arabic and binary numerals are easy to add, subtract and multiply. Roman numerals are not.

    - On a New York map you give up the scale and size of the geography representative, but the routes of the subway are priortized

    - On a tourist map, they give up the locations about the map in favor of the general landmarks.

COMPUTATIONAL LEVEL: THE WHAT AND THE WHY:

- **A very abstrcal level asking questions about the What and the Why:**
    - What is the goal of the computation?

    - Why is it appropriate?

    - What is the logic of the strategy by which it can be carried out?

- **Example - Cash Register:**
    - The machine adds

    - Addition is denoted by ‘+’ and involves mapping pairs of numbers onto a single number (3 + 4 = 7).

      Theory of Addition:
        - **Commutativity:** (3+4) and (4+3) both equal 7, does not matter the order because they both = 7.

        - **Associatvity:** 3 + (4+5) is the same as (3+4) + 5.

        - **What for Commutativity:**
            - Community: (3+4) and (4+3) both equal 7

        - **But Why:**
            - The order of numbers shouldn't matter on the cash register when adding.

    - **What for Associativity:**
        - Associativity: 3 + (4+5) is the same as (3+4) + 5

        - **But Why:**
            - Arranging goods into different piles shouldn't affect how much you pay.

- This is computational for **What** and **Why** cash registers compute addition and why do cash registers follow these series of addition.

VISION: COMPUTATIONAL LEVEL:

- What and the why is deriving properties of the world from perceptual information.

- Vision involves getting an image of things such as a tree from perceiving a tree.

- The idea is that the **What** of vision is building this driving property from perceptual information and the **Why** is how we interact with it in the real world.

ALGORITHMIC LEVEL: THE HOW:

- For a computational process to run:
    - Representation (for the input and output of the process)
    - What do you do to the representation to get you from the input to the output
    - Algorithm (by which the transformation may actually be accomplished)

- Often a lot of choice in the representation

- But algorithm will depend a lot on the sort of representation (but even so there's almost always a choice)

- **Example: Cash Register:**
    - Representation: Arabic numerals

    - Algorithm: Rules like adding the least significant digits first and carrying the 1 if the sum exceeds 9.

    - At this level when your specifying these computational components, you still have not said anything at all committal to the physical aspects of the system.

- Often a lot of choice in the representation

- But algorithm will depend a lot on the sort of representation (but even so there's always a choice)

- Once you choose the representation, your choices of the algorithm will be limited.

- There will be multiple algorithms you want your system to do after your choose your representation.

- **Things to consider in an algorithm:**
    - Efficiently: Doing something fast

    - Robustness: Being sensitive to different accuracies.

- Cog sci takes place with this level of representation and algorithm and to be neutral to the system is being represented.

SERIAL VS PARALLEL ALGORITHMS:
- Serial algorithm: executed sequentially once through from start to finish

- Parallel algorithm: executed concurrently

- The brain is like a parallel algorithm because a bunch of things is happening concurrently at the same time.

IMPLEMENTATIONAL LEVEL:
- How the process is physically realized.

- **Example:**
    - A giant tinker toy that can play the perfect game of tic-tac-toe developed by Hillis and Silverman

    - Another computer can also play the perfect tic-tac-toe game.

    - They both play tic-tac-toe using the same algorithm, but they do it different substances, which is multiple realizability

- You can represent different substances that can represent the same algorithm.

- **Marr's levels of analysis:**
    - Why (goal)
    - What (algorithm)
    - How (implementation)

- **Example:**
    - Top level: Adding to a cash machine
    - Middle level: Adding arabic numeral and the rules of addition
    - Bottom level: The physical stuff that makes the adding machine such as the metal that makes up an adding machine.
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- The levels limit each other to one extend but are causily restricted and related to each other

MARR'S LEVELS:

- Computation
- Algorithmic
- Implementation
- Some phenomena are only explained at certain levels.
- Trying to understand perception by studying only neutrons is like trying to understand bird flight by studying only feathers; it just cannot be done.
- The idea is that you have to understand aerodynamics and why bird fly. You have to understand much more than just the implementation.
- We specify the kinds of representations and algorithms the mind is doing and the computations are doing.
- Marr's 3 levels aren't definitive enough and that there are different levels of implementation the information being accessible at different levels is very different.
- There are different levels of explanation that correspond with the different questions
- It's useful to ask how the levels relate to one another because there is some degree of constraint at the different levels and in the way we represent the information and the algorithms used.