# Wrap-Up
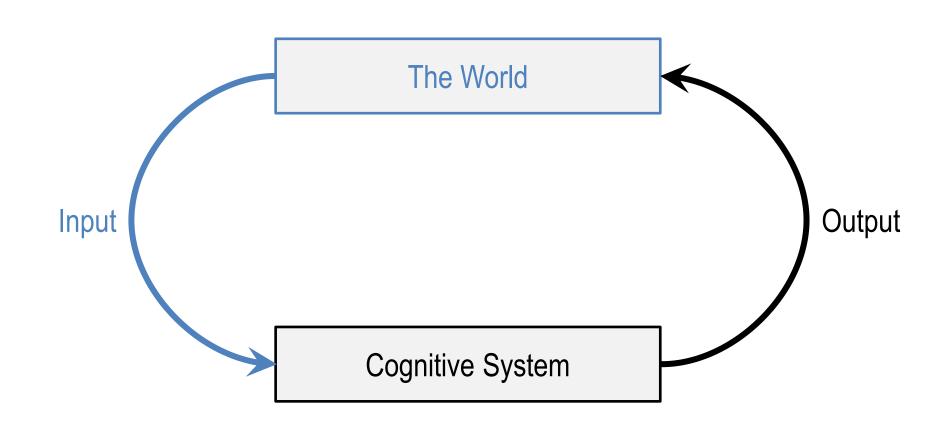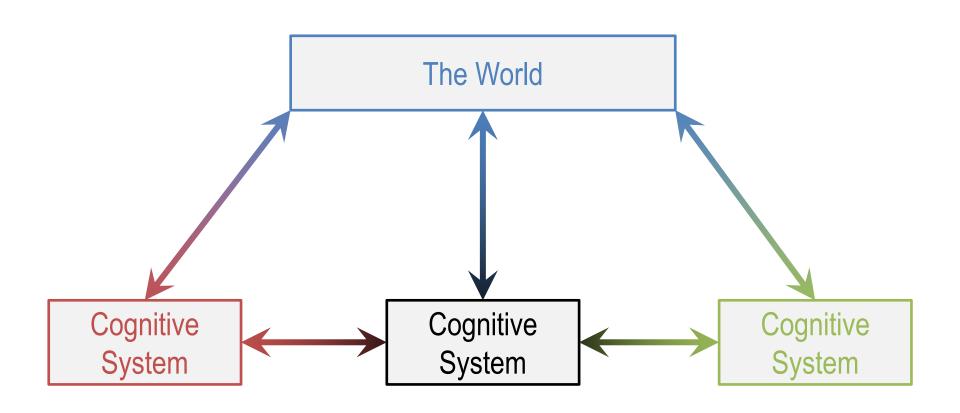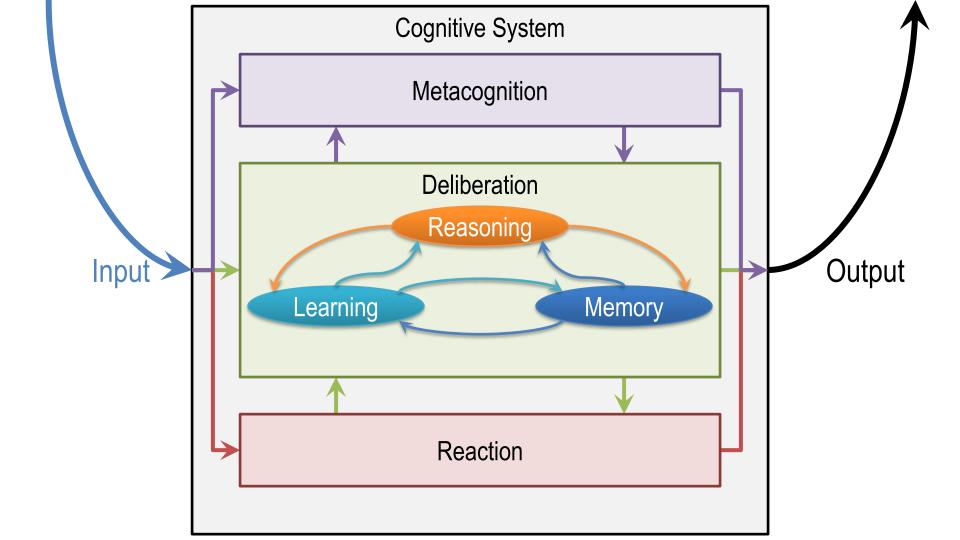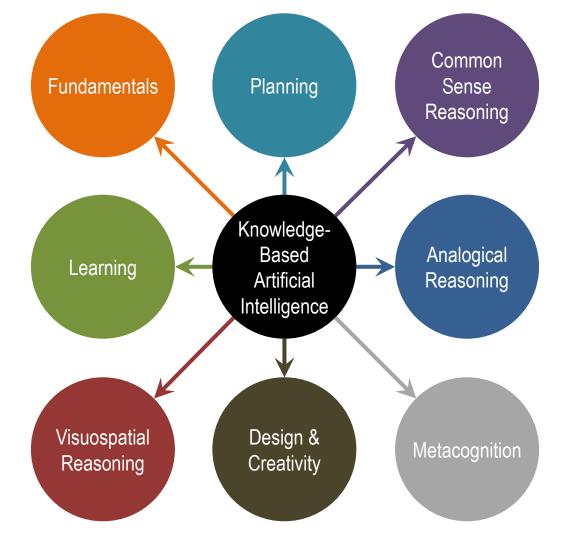
# Lesson Preview

- Major topics revisited

- Principles of KBAI revisited

- Modern KBAI research

- Final thoughts

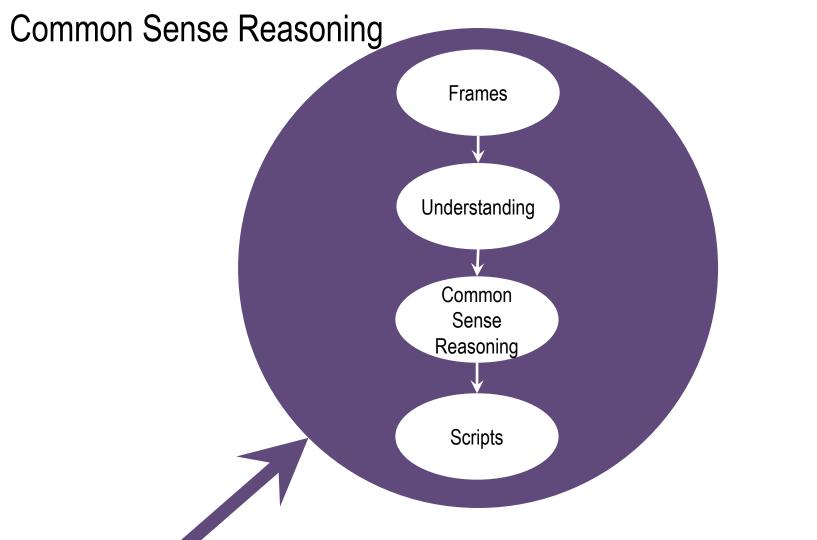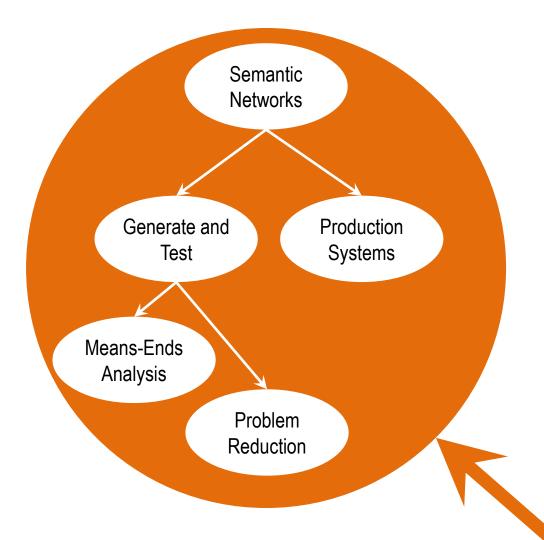# Fundamentals

# Planning

# Common Sense Reasoning

# Learning

# Analogical Reasoning

Visuospatial Reasoning

# Design & Creativity

Metacognition

Learning by Correcting Mistakes

Meta-Reasoning

Ethics in Artificial Intelligence

**Sentence 1:** A serious earthquake killed 25 people in Lower Slabovia.

**Sentence 2:** The President of Lower Slabovia killed 25 proposals for earthquake prediction.

kill. *verb.* /kil/

- to cause the death of

- to put an end to

```
kill1
agent :
victim :
```

```
kill2
agent :
object :
```

S = Ashok; P = Olive Garden; W = Andrew

```
Action Frame
 prim. : move-body-part
 agent : Ashok
 part : body
 destination : sitting
```

```
Action Frame
 prim. : move-object
 agent : Andrew
 object : Andrew
 destination : Ashok
```

```
Action Frame
 prim. : see
 agent : Andrew
 object : Ashok
```

```
Action Frame
 prim. : move-object
 agent : Andrew
 object : menu
 destination : Ashok
```

# Principle #2: Learning in KBAI agents is often incremental.



Given new problem **a**

Retrieve most similar prior problem, **b**, from memory

Apply **b**'s solution to problem **a**

| Route | Destination$_X$ | Destination$_Y$ |
|-------|-----------------|-----------------|
| A | $10_E$ | $8_N$ |
| B | $1_E$ | $8_N$ |
| C | $10_E$ | $4_N$ |
| D | $2_E$ | $1_N$ |
| X | $8_E$ | $2_N$ |
| Y | $8_E$ | $2_N$ |
| Z | $1_E$ | $9_N$ |

# Principle #2: Learning in KBAI agents is often incremental.



Current Concept

An Arch

New Concept

# Principle #2: Learning in KBAI agents is often incremental.

Visit3
**restaurant** : Sam's
**meal** : lunch
**day** : Saturday
**cost** : cheap

| Sam's breakfast Friday cheap | → | Sam's [any] [any] cheap |

[any]
Breakfast
[any]
[any]

Sam's
[any]
[any]
[any]

[any]
[any]
[any]
[any]

[any]
[any]
[any]
cheap

*Specific*                                                    *General*

# Principle #2: Learning in KBAI agents is often incremental.

# Principle #3: Reasoning in KBAI agents is top-down as well as bottom-up.

Angela ate lasagna with her dad last night at Olive Garden.

```
Ate
    subject : Angela
    object : lasagna
    location : Olive Garden
    time : night
    utensils :
    object-alive : false
    object-is : in-subject
    subject-mood : happy
```

# Principle #3: Reasoning in KBAI agents is top-down as well as bottom-up.

**Sentence 1:** A serious earthquake killed 25 people in Lower Slabovia.

**Sentence 2:** The President of Lower Slabovia killed 25 proposals for earthquake prediction.

kill. *verb.* /kil/

- to cause the death of →

```
kill1
agent :
victim :
```

- to put an end to →

```
kill2
agent :
object :
```

# Principle #3: Reasoning in KBAI agents is top-down as well as bottom-up.

S = Ashok; P = Olive Garden; W = Andrew

Action Frame
 **prim.** : move-body-part
 **agent** : Ashok
 **part** : body
 **destination** : sitting

Action Frame
 **prim.** : move-object
 **agent** : Andrew
 **object** : Andrew
 **destination** : Ashok

Action Frame
 **prim.** : see
 **agent** : Andrew
 **object** : Ashok

Action Frame
 **prim.** : move-object
 **agent** : Andrew
 **object** : menu
 **destination** : Ashok

# Principle #3: Reasoning in KBAI agents is top-down as well as bottom-up.

# Principle #3: Reasoning in KBAI agents is top-down as well as bottom-up.

**Fill this order:**
A chair that costs at most $16 to make and has a 100g metal seat.

Chair
  **mass** :
  **cost** :<$16
  **legs** :
  **seat** :
  **arms** :
  **back** :

Chair Legs
  **count** : 4
  **size** : 10g
  **material** : metal
  **cost** : $4.00

Chair Seat
  **size** : 100g
  **material** : metal
  **cost** : $10.00

Chair Arms
  **size** : 0g
  **material** : N/A
  **cost** : $0.00

Chair Back
  **size** : 20g
  **material** : metal
  **cost** : $2.00

Materials Table

| Material | Cost per gram |
|----------|---------------|
| Plastic | $0.01 |
| Wood | $0.05 |
| Metal | $0.10 |

**Methods**

Generate & Test
Means-Ends Analysis
Problem Reduction
Production Systems
Case-Based Reasoning
Planning
Analogical Reasoning

**Tasks**
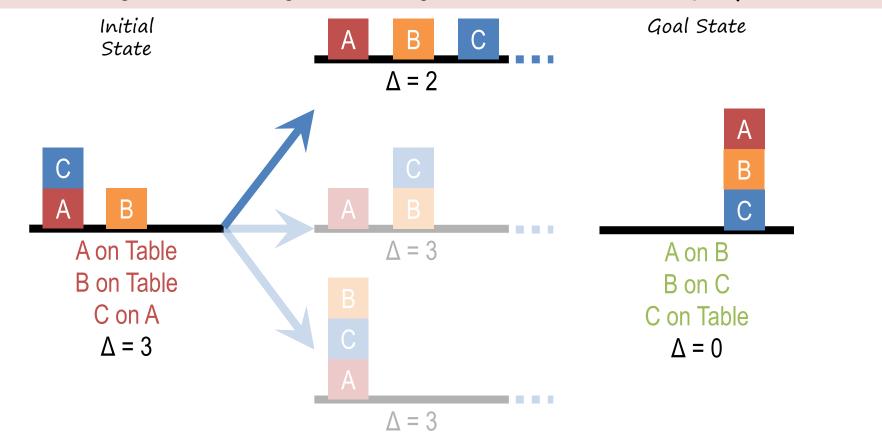
Configuration
Diagnosis
Design
Meta-Reasoning
Creativity
Classification
Systems Thinking

**Principle #5:** KBAI agents use heuristics to find solutions that are good enough, though not necessarily optimal.

Current Concept

Not an Arch

New Concept

Brick

supports

supports

Brick

left-of

Brick

Brick

Brick

left-of

Brick

Brick

must-support

must-support

Brick

left-of

Brick
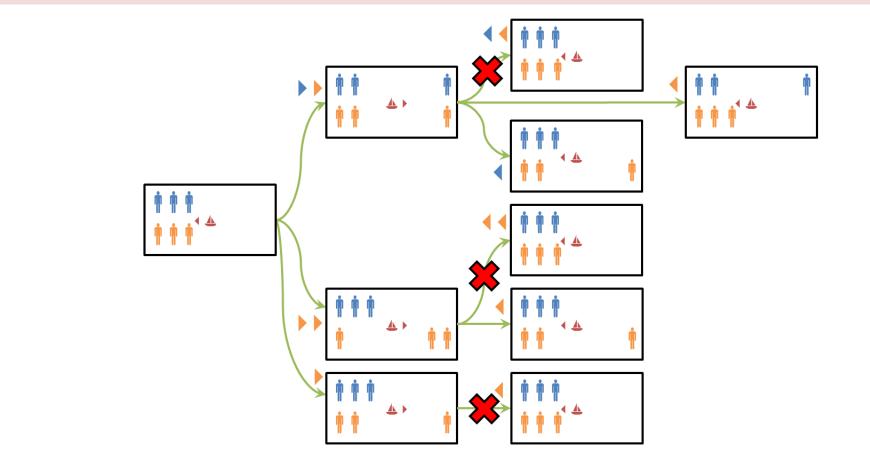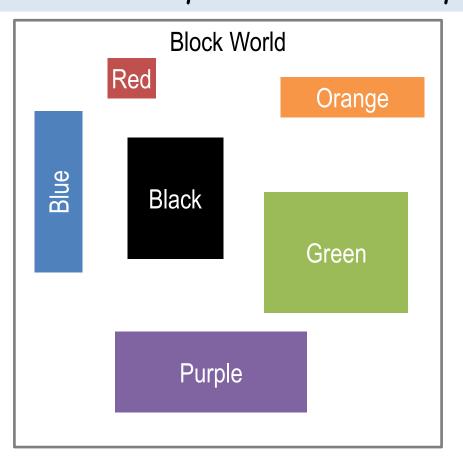
"require-link" heuristic

**Principle #5**: KBAI agents use heuristics to find solutions that are good enough, though not necessarily optimal.

Initial State

A on Table
B on Table
C on A
Δ = 3

Δ = 2

Δ = 3

Δ = 3

Goal State

A on B
B on C
C on Table
Δ = 0

**Principle #6:** KBAI agents make use of recurring patterns in the problems they solve.

Block World

Red

Orange

Blue

Black

Green

Purple

What color is this block?

?

Target

Source

# Principle #6: KBAI agents make use of recurring patterns in the problems they solve.

**Fill this order:**
A chair that costs at most $16 to make and has a 100g metal seat.

```
Chair
  mass :
  cost :<$16
  legs :
  seat :
  arms :
  back :
```

```
Chair Legs
  count : 4
  size : 10g
  material : metal
  cost : $4.00
```

```
Chair Seat
  size : 100g
  material : metal
  cost : $10.00
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Chair Arms
  size : 0g
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```

```
Chair Back
  size : 20g
  material : metal
  cost : $2.00
```

## Materials Table

| Material | Cost per gram |
|----------|---------------|
| Plastic  | $0.01         |
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| Metal    | $0.10         |

S = Ashok; P = Olive Garden; W = Andrew

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Action Frame
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 agent : Andrew
 object : Andrew
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```

```
Action Frame
 prim. : see
 agent : Andrew
 object : Ashok
```

```
Action Frame
 prim. : move-object
 agent : Andrew
 object : menu
 destination : Ashok
```

# Principle #7: The architecture of KBAI agents enables reasoning, learning, and memory to support and constrain each other.

```
inning : 5th
portion : bottom
game : 131
weather : windy
runners : 1st, 3rd
outs : 1
batter : Pierzynski
average : .283
bats : left-handed
score : 1-4
goal : pitch
pitch : throw-fast-ball
result : homerun
```

(r8) If two operators selected and one has an episode with **result** *homerun*

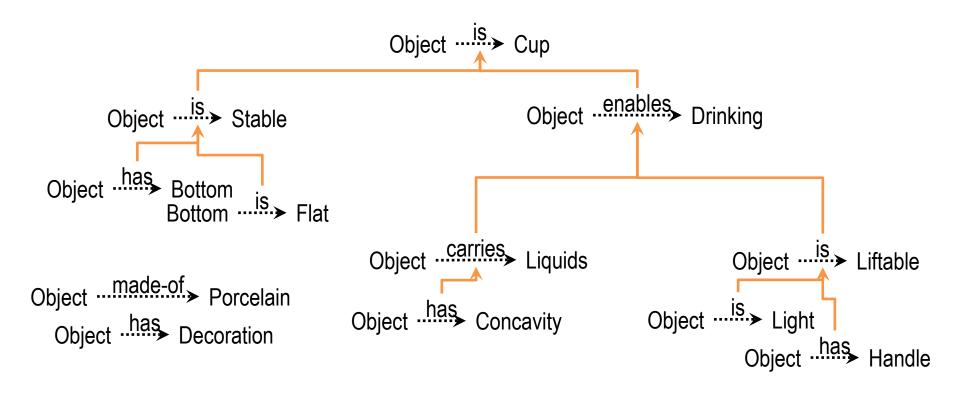then prefer other operator

"chunking"

**Principle #7:** The architecture of KBAI agents enables reasoning, learning, and memory to support and constrain each other.

If an animal flies and is not a bird, it is a bat.
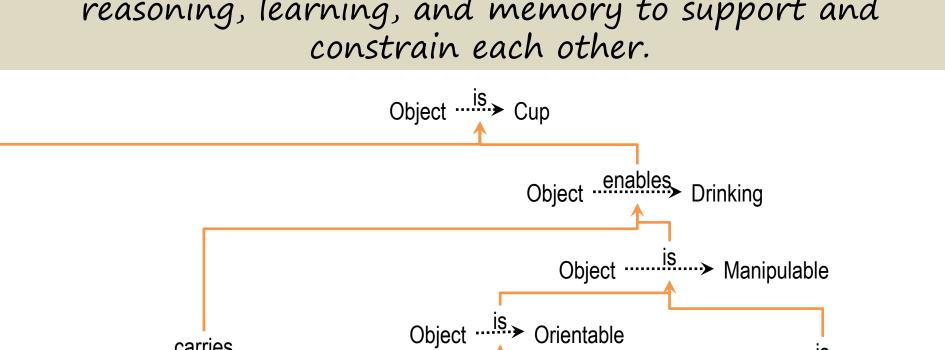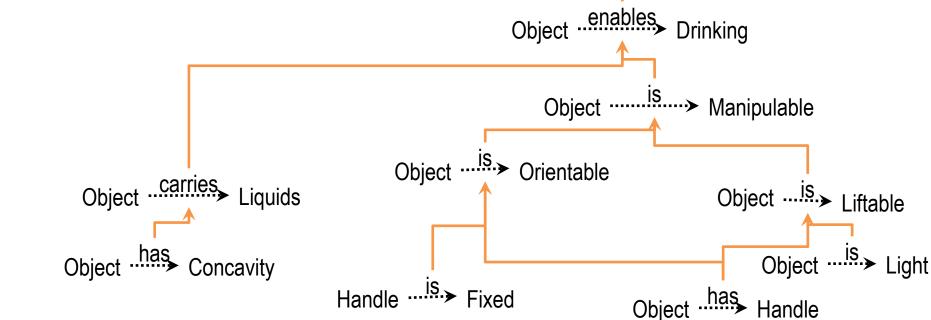
```
Flies(animal)
      ∧
¬Bird(animal)
```

```
If Flies(animal) ∧
  ¬Bird(animal):
Then Bat(Animal)
```

**Principle #7:** The architecture of KBAI agents enables reasoning, learning, and memory to support and constrain each other.

**CALO:**
"Cognitive Assistant that Learns and Organizes"

**Cyc and OMCS:**
Knowledgebases of everyday common sense knowledge

**Wolfram Alpha:**
A computational knowledge and answer engine.

**VITA:**
A computational model of visual thinking in autism, based on RPM.

**Dramatis:**
A computational model of suspense and drama in stories.

**DANE:**
Support for design based on analogies to natural systems.

What are some things Watson must be able to do to participate in Jeopardy? Write each on its own line below.

Read the clue

Search its knowledge base

Decide on an answer

Properly phrase that answer

# Fundamental Conundrums of Artificial Intelligence

- Intelligent agents have limited resources.

- Computation is local, but problems have global constraints.

- Logic is deductive, but many problems are not.

- The world is dynamic, but knowledge is limited.

- Problem solving, reasoning, and learning are complex, but explanation and justification are even more complex.

# Characteristics of AI Problems

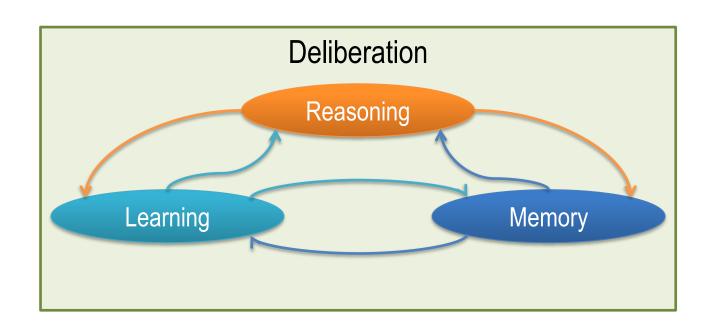- Knowledge often arrives incrementally.

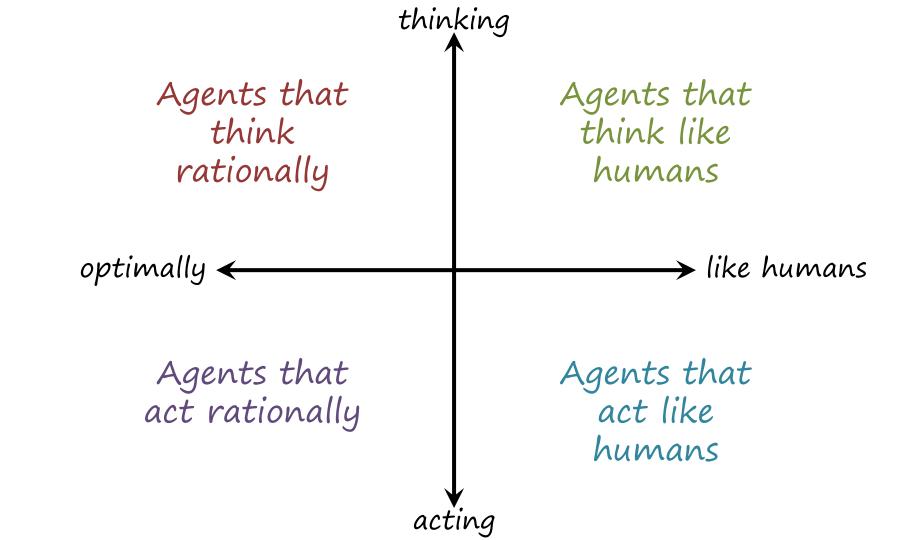- Problems exhibit recurring patterns.

- Problems have multiple levels of granularity.

- Many problems are computationally intractable.

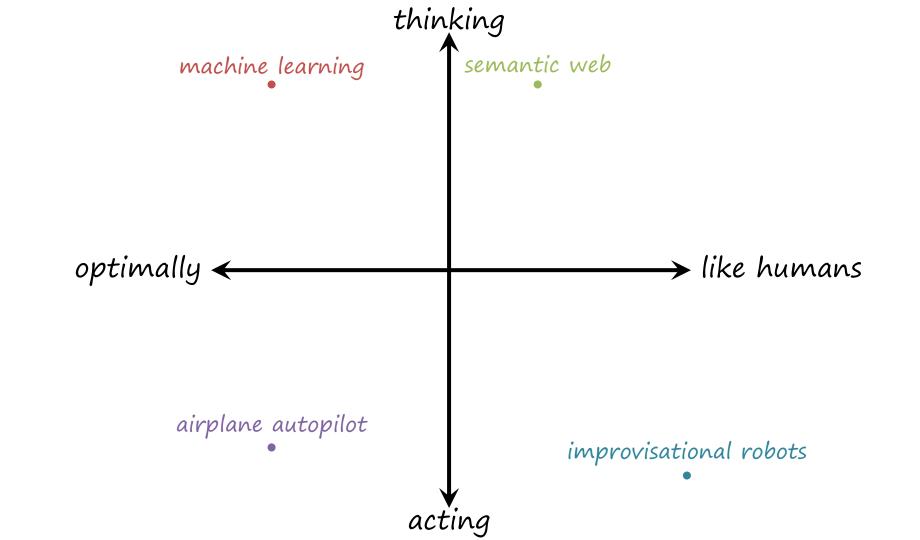- The world is dynamic, but knowledge of the world is static.

- The world is open-ended, but knowledge is limited.

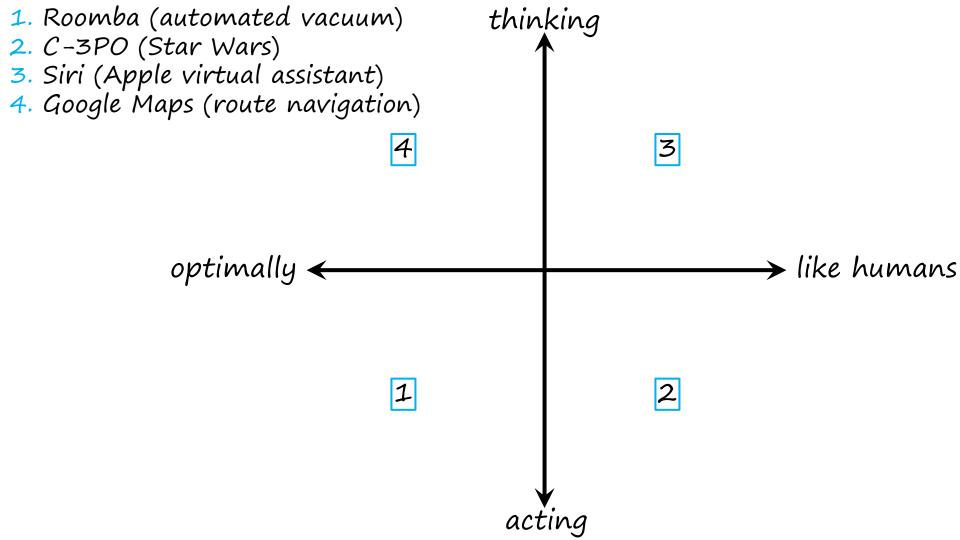# Characteristics of AI Agents

- Agents have limited computing power.

- Agents have limited sensors.

- Agents have limited attention.

- Computational logic is fundamentally deductive.

- AI agents' knowledge is incomplete relative to the world.

|                          | thinking                        |                                 |
|--------------------------|---------------------------------|---------------------------------|
| Agents that think rationally |                             | Agents that think like humans   |
| optimally ←              |                                 | → like humans                   |
| Agents that act rationally |                               | Agents that act like humans     |
|                          | acting                          |                                 |

1. Roomba (automated vacuum)
2. C-3PO (Star Wars)
3. Siri (Apple virtual assistant)
4. Google Maps (route navigation)

thinking

4

3

optimally ← → like humans

1

2

acting

# What are cognitive systems?

Cognitive: dealing with human-like intelligence.
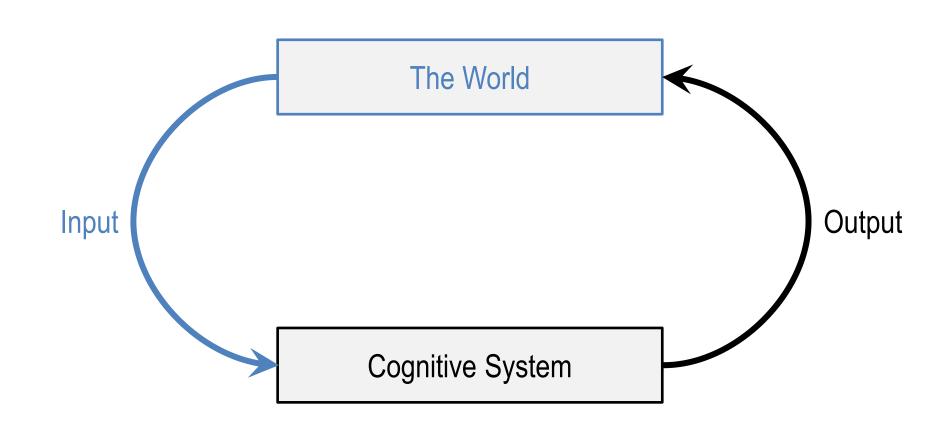
Systems: multiple interacting components such as learning, reasoning, and memory.

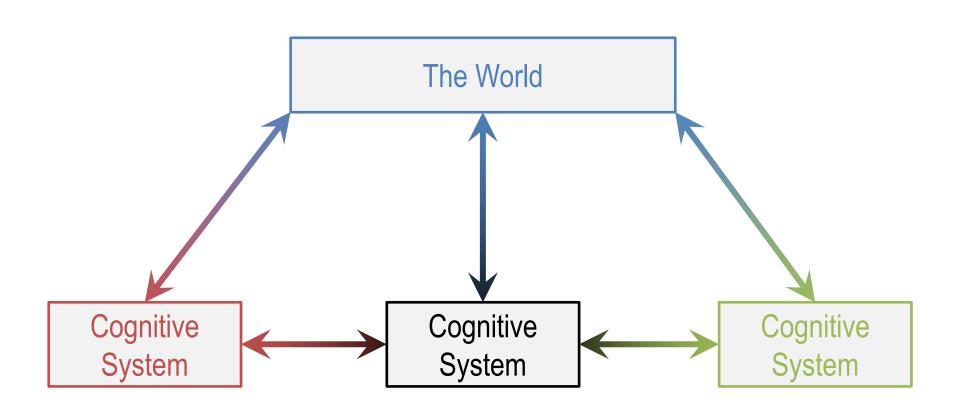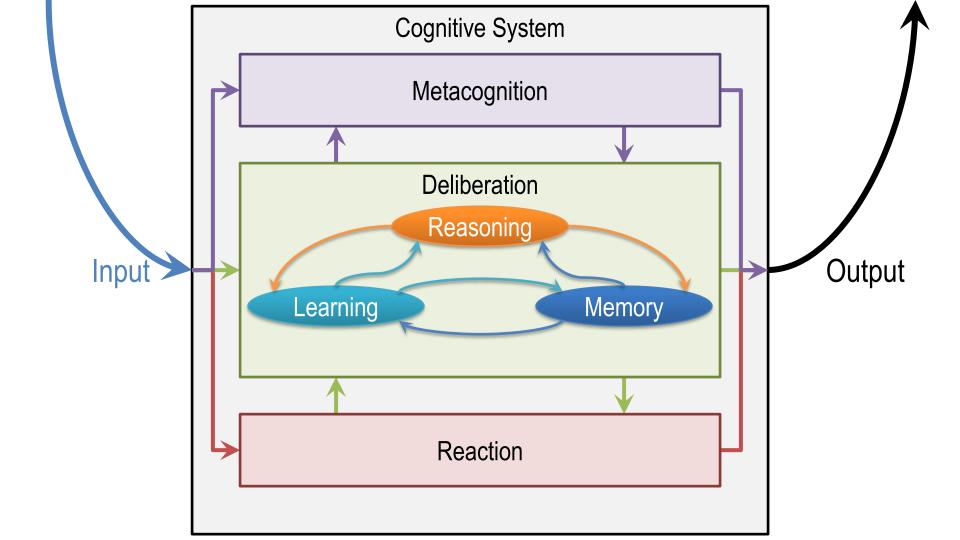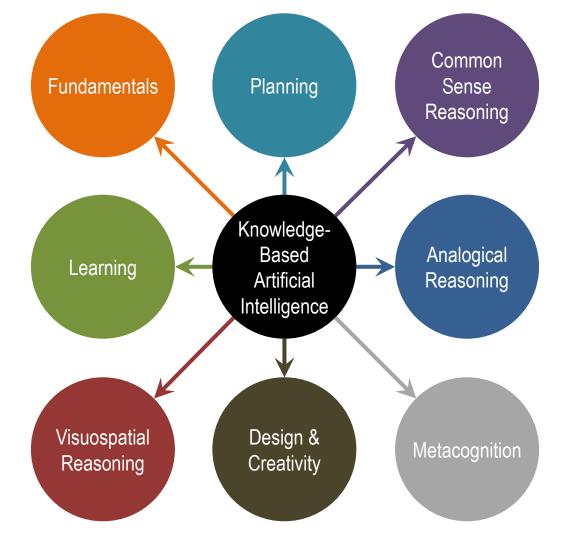**Cognitive Systems:** Systems that exhibit human-like intelligence through processes like learning, reasoning, and memory.
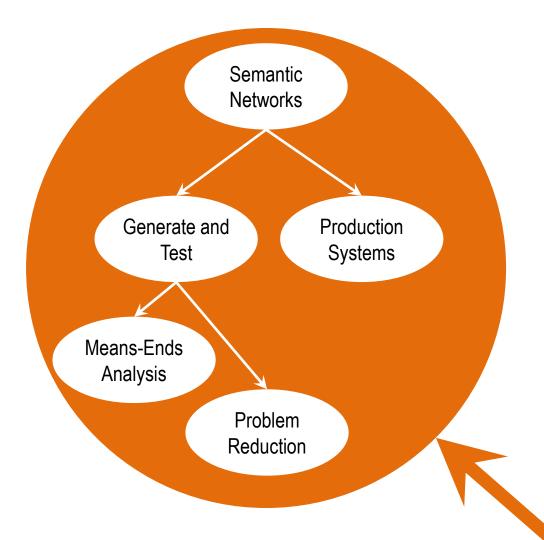
# Fundamentals

# Planning
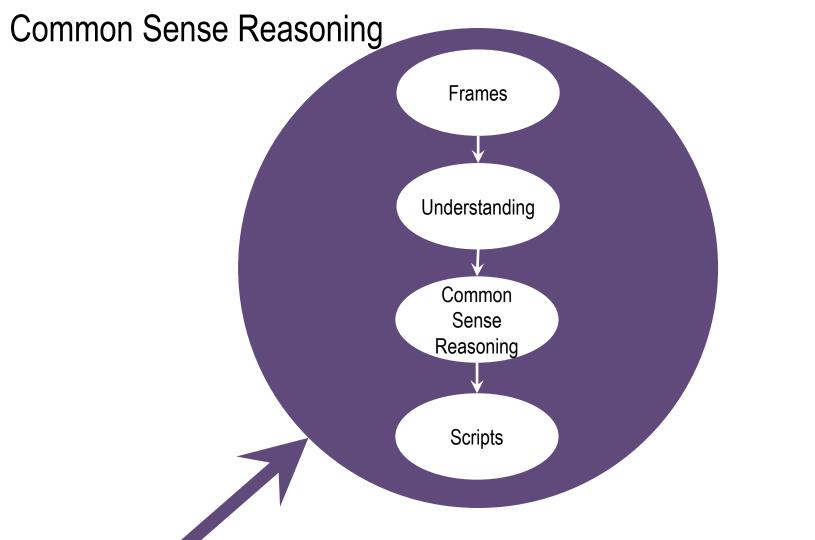
# Common Sense Reasoning

# Learning

# Analogical Reasoning

# Visuospatial Reasoning

# Design & Creativity

Metacognition

Learning by Correcting Mistakes

Meta-Reasoning

Ethics in Artificial Intelligence

Knowledge-Based Artificial Intelligence

**Semantic Networks** (orange)
- Semantic Networks
- Generate and Test
- Production Systems
- Means-End Analysis
- Problem Reduction

**Logic** (teal)
- Logic
- Planning

**Frames** (purple)
- Frames
- Understanding
- Common Sense Reasoning
- Scripts

**Learning by Recording Cases** (green)
- Learning by Recording Cases
- Incremental Concept Learning
- Classification
- Scripts

**Case-Based Reasoning** (blue)
- Learning by Recording Cases
- Case-Based Reasoning
- Explanation-Based Reasoning
- Analogical Reasoning

**Constraint Propagation** (red)
- Constraint Propagation
- Visuospatial Reasoning

**Configuration** (dark)
- Configuration
- Diagnosis
- Design
- Computational Creativity

**Learning by Correcting Mistakes** (gray)
- Learning by Correcting Mistakes
- Meta-Reasoning
- Ethics in Artificial Intelligence
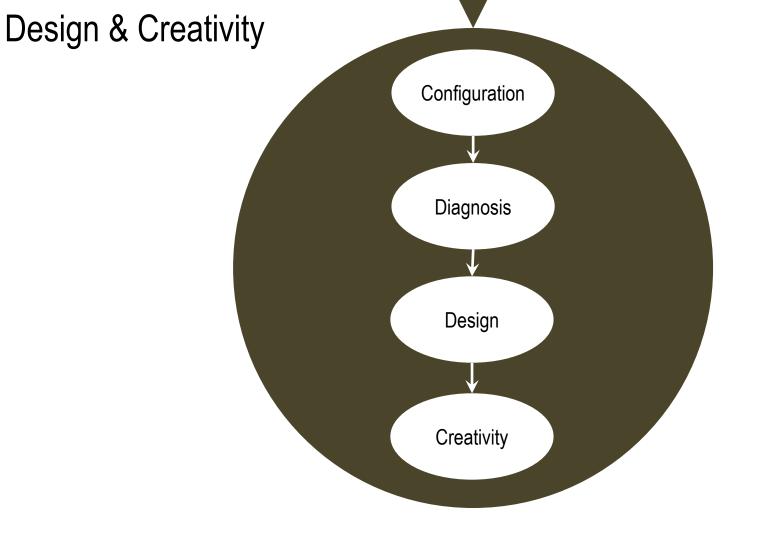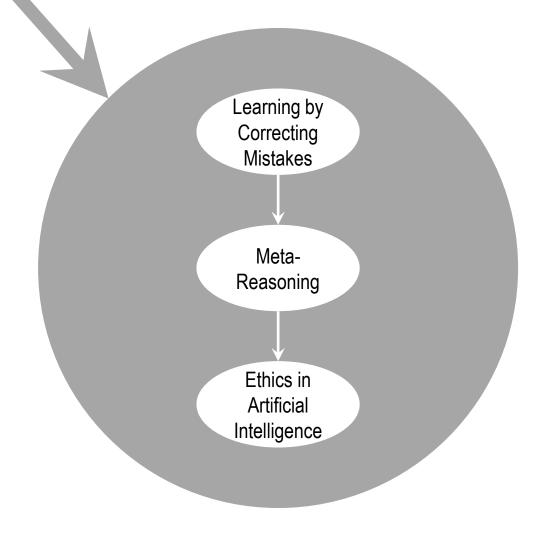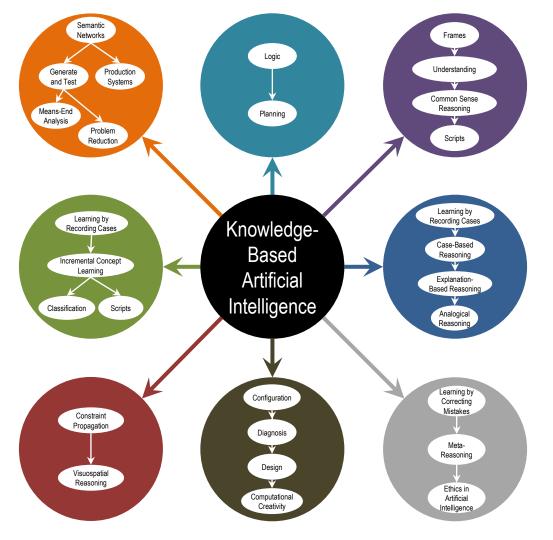
# To recap…

- Conundrums and characteristics

- Four schools of AI

- What is KBAI?

- Cognitive Systems

- Topics in AI

Introduction to CS7637

# Lesson Preview

- Class goals, outcomes, and strategies
- Class projects and assessments
- Computational psychometrics
- Raven's Progressive Matrices
- Principles of CS7637

# You will learn...

- Core methods of knowledge-based AI

- Tasks addressed by knowledge-based AI

- How knowledge-based AI agents use these methods to address these tasks

- The relationship between AI and human cognition

# You will be able to...

- Design and implement a knowledge-based AI agent

- Use these strategies and agents to address complex, practical problems

- Use the design and results of these agents to reflect on human cognition

# You will learn by...

- Learning by Example

- Learning by Doing

- Project-Based Learning

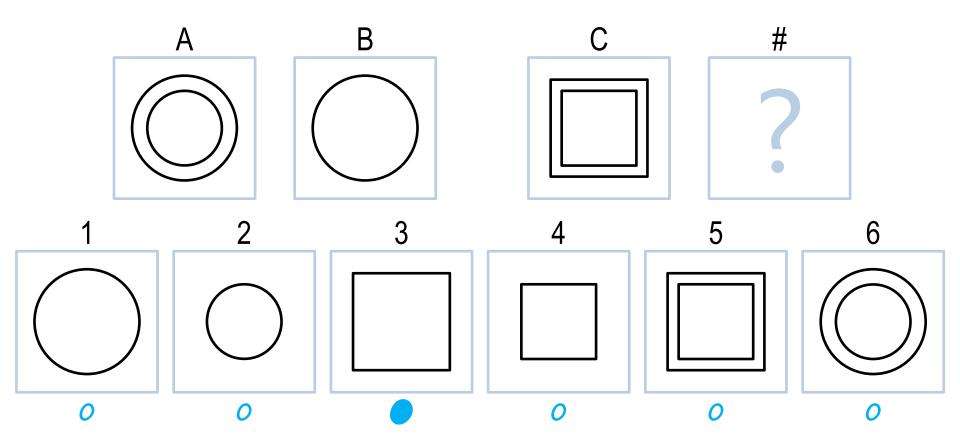- Personalization

- Learning by Reflection

# You will complete…

- Projects
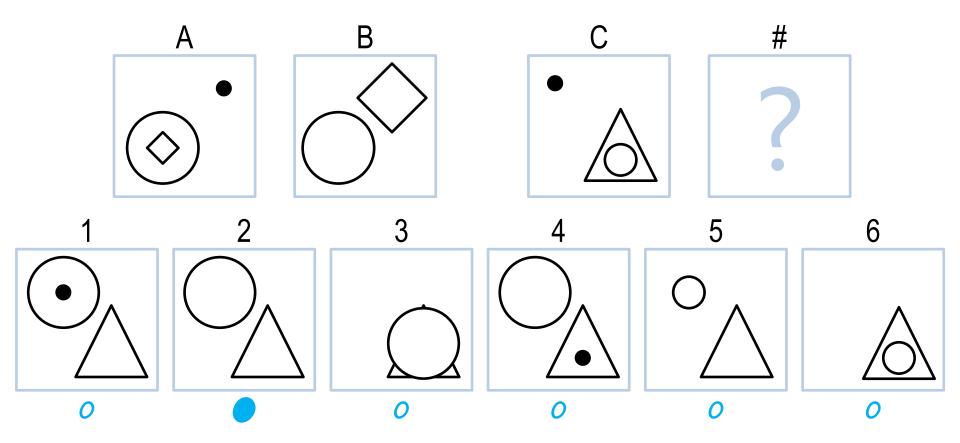
- Short assignments

- Tests

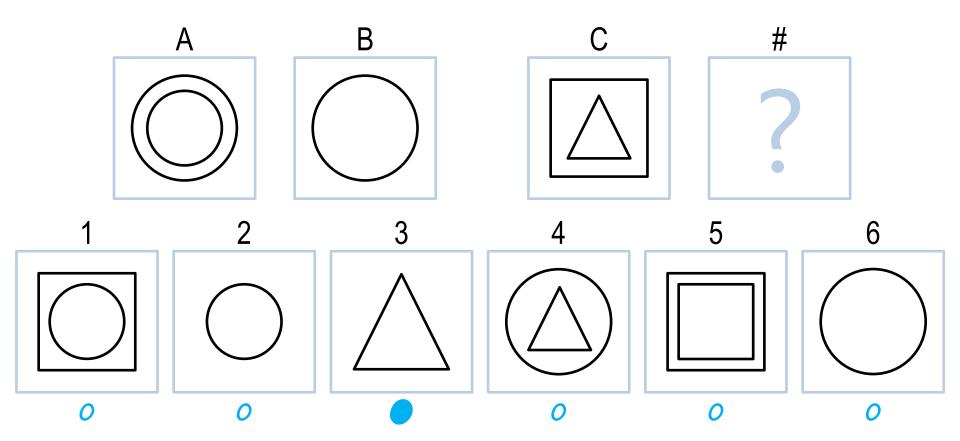- Exercises

- Discussions

# Raven's Progressive Matrices

- Test written in the 1930s to examine general intelligence.

- Consists of 60 multiple-choice visual analogy problems.

- Unique in that problems are strictly visual.
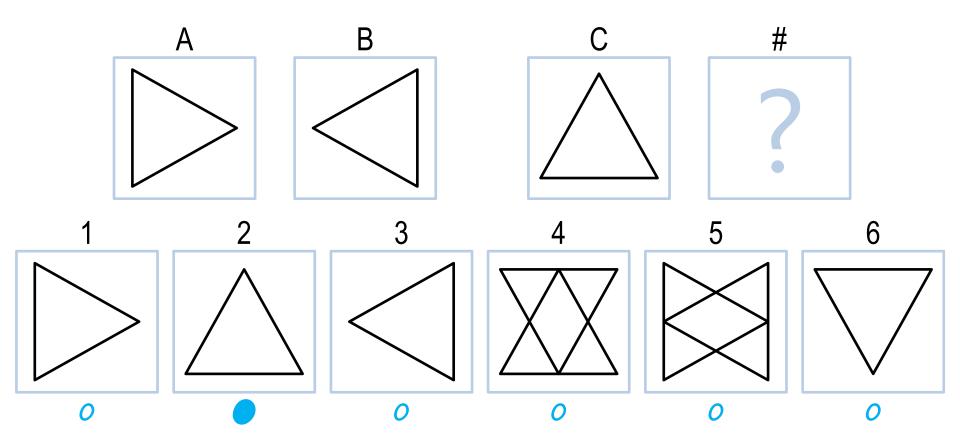
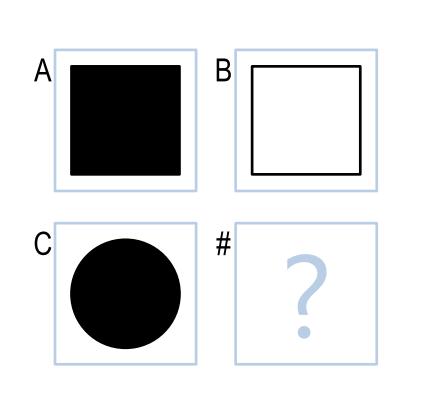- Widespread usage as a valid test for intelligence.

# Problems

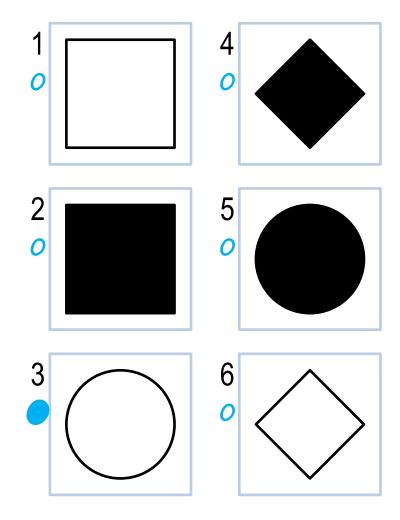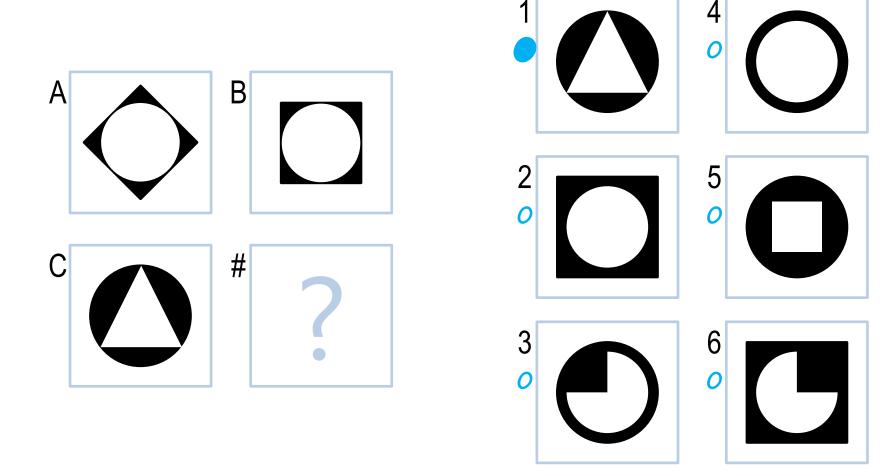- 2x1 matrix problems

- 2x2 matrix problems

- 3x3 matrix problems

A

B

C

#

?

1

2

3

4

5

6

A     B          C          #

?

1     2     3     4     5     6

A       B       C       #

?

1       2       3       4       5       6

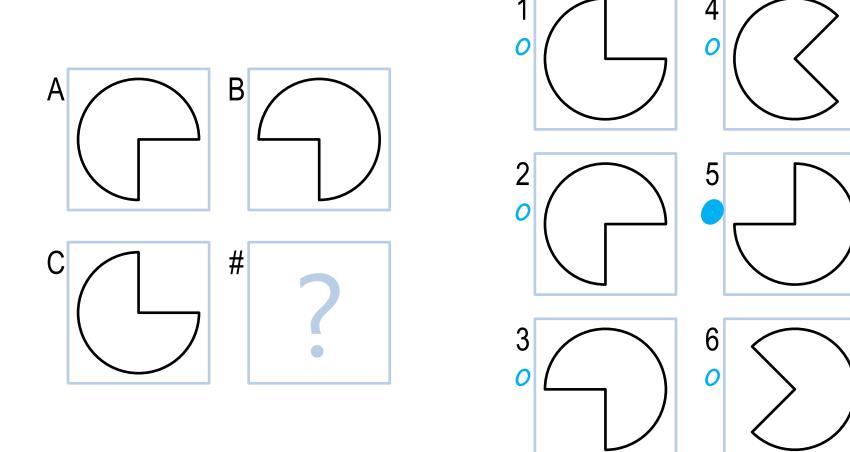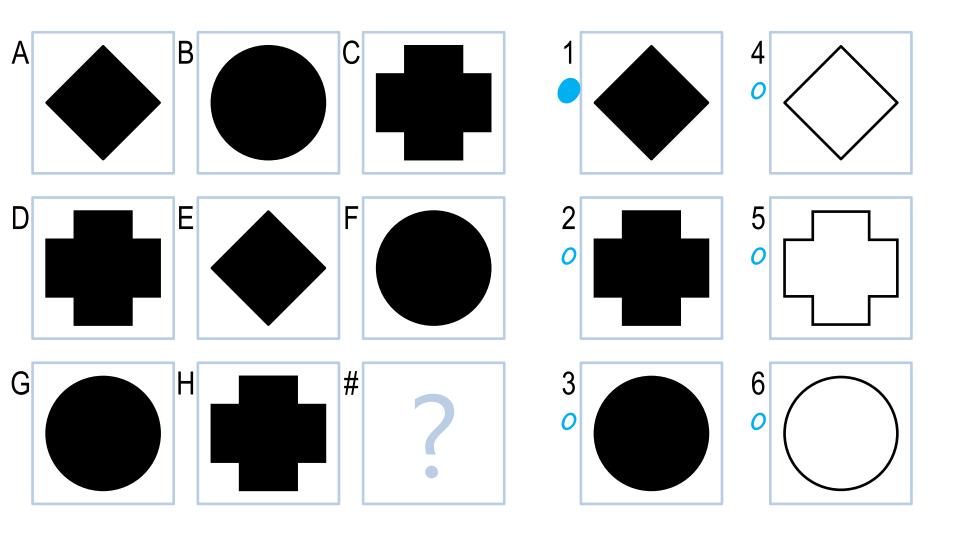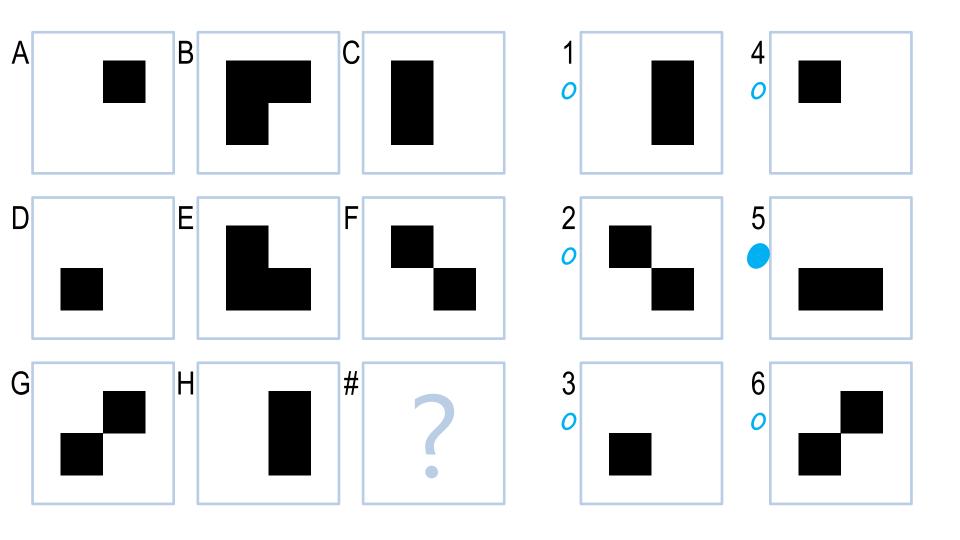O       O       ●       O       O       O

A

B

C

#  ?

1

4

2

5

3

6

# Principles of CS7637

1. KBAI agents represent and organize knowledge into knowledge structures to guide and support reasoning.

2. Learning in KBAI agents is often incremental.

3. Reasoning in KBAI agents is top-down as well as bottom-up.

4. KBAI agents match methods to tasks.

5. KBAI agents use heuristics to find solutions that are good enough, though not necessarily optimal.

6. KBAI agents make use of recurring patterns in the problems they solve.

7. The architecture of KBAI agents enables reasoning, learning, and memory to support and constrain each other.

# Frequently-used readings

- Artificial Intelligence by Patrick Winston

- Knowledge Systems by Mark Stefik

- Artificial Intelligence by Elaine Rich and Kevin Knight

- Artificial Intelligence: A Modern Approach by Stuart Russell and Peter Norvig

# To recap…

- Class goals, outcomes, and strategies
- The Project: Raven's Progressive Matrices
- Principles of CS7637