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BLIA: Bayesian–LLM Intelligent Assistant in Medicine

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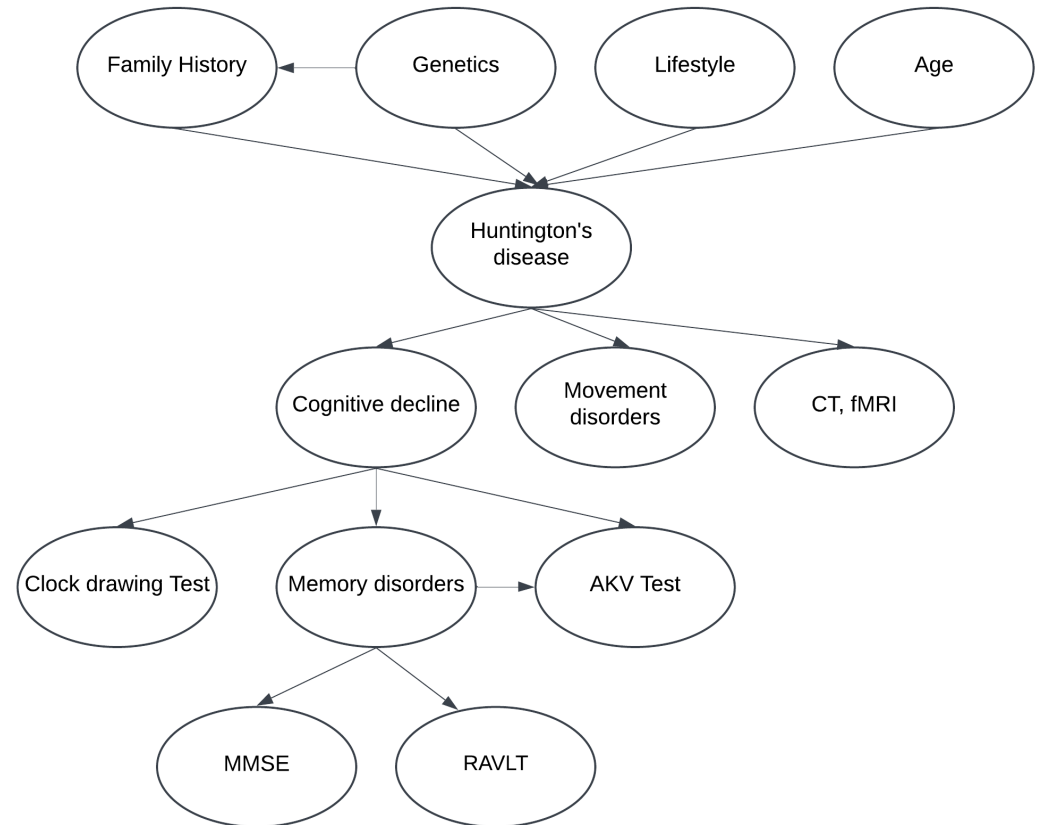
Outline

- Bayesian Networks and Large Language Models
- Introduction of the method
- Prototype
- Evaluation
- **Use-cases**



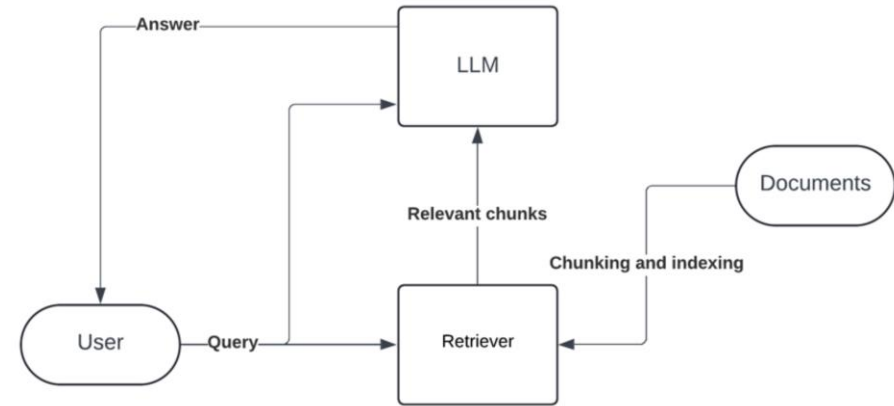
Bayesian Networks in medical diagnostics

- Model diagnosis well
- Combine expert knowledge and machine learning
- Difficult for expert to understand
 - Explanatory solutions



Large Language Models

- **Benefits**
 - Simple interaction
 - Dynamic
 - Approachable
- **Disadvantages**
 - „Hallucinations”
 - Retrieval Augmented Generation
 - Unreliable reasoning
 - Fine-tuning



Goals

Extending Bayesian Networks with LLMs



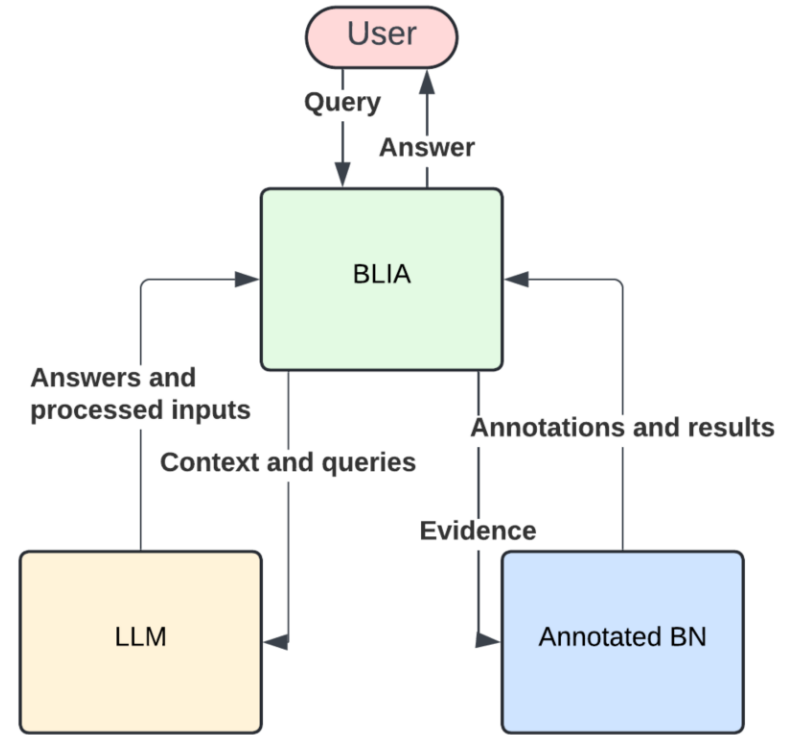
Making Bayesian Networks accessible

Mitigating the problems of LLMs

Diagnostic assistants

Fundamentals of the method


- Bayesian Network inference and its semantic explanation
 - Using explanatory algorithms similar to RAG
 - Semantic extension with RAG
- Components:
 - Annotated Bayesian Network
 - Bayesian-LLM Intelligent Assistant (BLIA)
 - Large Language Model
- Bayes-LLM Intelligent Assistant
 - Natural language evidence processing
 - Explanation of Bayesian Network and its results
 - Explanation of the domain
 - Dynamic interaction
 - Relies on LLM and Bayesian Network



Prototype

main page


bayes net screen

Chat page 


Patient Information

Factors


Family History

Dementia was present at a you... 


Age

middle aged 

History Of Vascular Diseases


no 

Lifestyle

High risk 

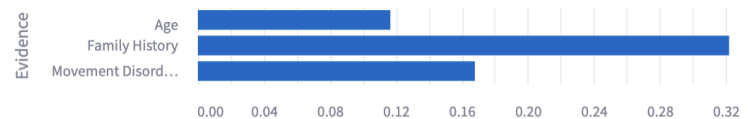
Symptoms

Memory Disorders


yes 

 Is Huntington's disease likely?

Significant Evidence for Huntington's Disease




Impact of Evidence (Hellinger distance between probability of Huntington's Disease with and without the individual evic

 Based on the provided information, Huntington's disease is highly likely for the individual in question due to the following key factors:

- Family History:** There is a known presence of dementia in the family at a young age, which is a significant risk factor for Huntington's disease, as it is inherited in an autosomal dominant manner.
- Movement Disorders:** The individual exhibits movement disorders, which are common symptoms associated with Huntington's disease.
- Age:** The individual is middle-aged, which aligns with the typical onset age for Huntington's disease, usually between 30 and 50 years.

Given these factors, it would be prudent to consider further diagnostic evaluations, including genetic testing and a thorough medical assessment to confirm the diagnosis of Huntington's

What would you like to know? 

Evaluation

- Is the Bayesian Network made approachable?
- Is it semantic?
- Is it based on its inner knowledge?
- Is it well formulated?

Consistency	Answer Relevancy	Medical Language	Narrative Explanation	Handeling uncertainty
100%	100%	100%	100%	100%

Answer Relevancy	Semantic Similarity	Faithfulness
91%	95%	91%

Query:

Given the patient lives a high risk lifestyle and is middle-aged and has a family history of early dementia what is the likelihood of Huntington's disease?

Answer:

Based on the provided information, the likelihood of the patient having Huntington's disease is assessed as high. This conclusion is drawn from the following key factors:

Family History: A family history of early dementia significantly increases the risk of genetic conditions like Huntington's disease, which is inherited in a dominant manner...

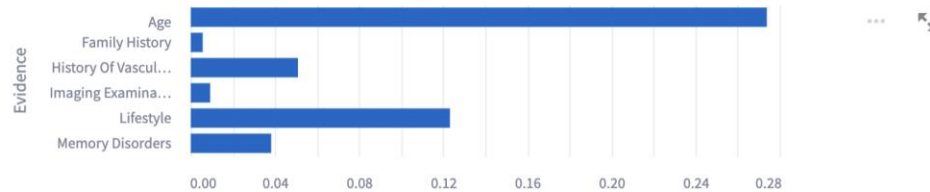
Hennessy et al. (2020). Explaining Bayesian Networks in Natural Language. NL4XAI Workshop, ACL.

Reiter (2019). NLG Challenges for Explainable AI. NL4XAI Workshop, ACL.

Diagnosis

👤 Is vascular dementia likely? Why? Answer in a short paragraph but give details!

Significant Evidence for Vascular Dementia



Impact of Evidence (Hellinger distance between probability of Vascular Dementia with and without the individual evid)

👤 Vascular dementia is likely in this individual due to several interconnected risk factors. Firstly, advanced age is a significant risk factor, as the likelihood of developing dementia increases with age. Additionally, the individual has a high-risk lifestyle, which may include factors such as physical inactivity, poor diet, or smoking, all of which contribute to vascular health deterioration. A history of vascular diseases further elevates the risk, as conditions like hypertension and diabetes can impair blood flow to the brain, leading to cell death. The presence of memory disorders aligns with common symptoms of vascular dementia, reinforcing the diagnosis. Lastly, the absence of early-onset dementia in the family suggests that genetic predispositions are less influential, indicating that lifestyle and medical history are primary contributors to the risk of vascular dementia.

Sources:

- [Cleveland Clinic - Dementia](#)
- [Alzheimer Society of Canada - Vascular Dementia](#)



Advising



Based on the evidence provided, including the individual's age, presence of vascular lesions in imaging results, and the likelihood of positive laboratory test results, the next examination to conduct should be:

Neuroimaging Studies (e.g., MRI or CT scan): This will help assess the extent of vascular lesions and any other structural brain changes that could confirm or rule out Vascular Dementia or other types of dementia.

Neuroimaging is critical in understanding the structural aspects of the brain, which can guide further diagnostic and therapeutic decisions.

For more detailed information on the diagnostic process for dementia, you can refer to the following sources:

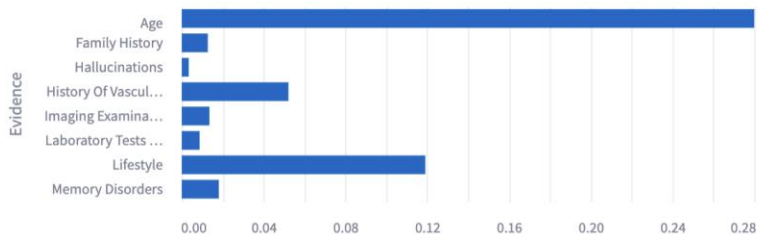
- [Alzheimer Society of Canada - What to expect while getting your diagnosis](#)
- [Alzheimer Society of Canada - Vascular Dementia](#)



Report generation

👤 Is vascular dementia likely? Why? Write a medical report in the format of a medical document!

Significant Evidence for Vascular Dementia



Impact of Evidence (Hellinger distance between probability of Vascular Dementia with and without the individual evid)

📄 Medical Report: Assessment of Vascular Dementia

Patient Information:

- **Age:** Old
- **Relevant Medical History:** History of vascular diseases
- **Lifestyle:** High-risk lifestyle for developing dementia
- **Symptoms:** Memory disorders
- **Laboratory Test Results:** Negative
- **Imaging Results:** Show vascular lesions
- **Family History:** No early-onset dementia

Assessment: Based on the comprehensive evaluation of the patient's medical history, lifestyle factors, symptoms, and imaging results, the likelihood of the individual having Vascular Dementia is assessed to be high. This conclusion is supported by several interconnected factors that significantly influence the diagnosis.

Connected Factors:

1. **History of Vascular Diseases:** The presence of vascular diseases is a critical risk factor for Vascular Dementia, as it directly impacts cerebral blood flow, leading to cognitive decline.
2. **Lifestyle:** The individual's high-risk lifestyle further compounds the risk of developing dementia, particularly vascular types, as lifestyle choices can exacerbate vascular health issues.
3. **Age:** Advanced age is a significant risk factor for various forms of dementia, including Vascular Dementia.
4. **Memory Disorders:** The presence of memory disorders is a common symptom associated with Vascular Dementia, indicating cognitive impairment.
5. **Imaging Results:** Imaging findings showing vascular lesions provide direct evidence of vascular damage, which is characteristic of Vascular Dementia.

Report generation

Supporting Evidence:

- The patient's advanced age increases susceptibility to dementia.
 - The combination of a history of vascular diseases and a high-risk lifestyle strongly supports the likelihood of Vascular Dementia.
 - Memory disorders align with the expected symptoms of Vascular Dementia.
 - Imaging results confirming vascular lesions substantiate the diagnosis.
-

Contradicting Evidence:

- Negative laboratory test results may suggest the absence of other types of dementia or conditions that could mimic Vascular Dementia.
- The absence of early-onset dementia in the family history may reduce the likelihood of hereditary factors influencing the current condition.

Conclusion: In summary, the analysis indicates that Vascular Dementia is likely in this individual due to the combination of age, history of vascular diseases, high-risk lifestyle, memory disorders, and imaging findings. While the negative laboratory results and lack of family history of early-onset dementia provide some counterpoints, they do not outweigh the strong supporting evidence for Vascular Dementia. Further evaluation and monitoring are recommended to confirm the diagnosis and guide appropriate management strategies.

Recommendations:

- Consider referral to a neurologist for comprehensive evaluation.
 - Implement lifestyle modifications to address high-risk factors.
 - Regular follow-up assessments to monitor cognitive function and adjust care as necessary.
-

Prepared by: [Your Name]

[Your Title]

[Date]

[Contact Information]

References:

- Alzheimer Society of Canada. (n.d.). Vascular Dementia. Retrieved from <https://alzheimer.ca/en/about-dementia/other-types-dementia/vascular-dementia>
- Cleveland Clinic. (n.d.). Dementia. Retrieved from <https://my.clevelandclinic.org/health/diseases/9170-dementia>

Electronic Health Record processing



Diagnose the patient based on this EHR:

Patient Information:

Age: Advanced Lifestyle: High-risk (including physical inactivity, poor diet, smoking) Medical History: Vascular Diseases: History of hypertension and diabetes Family History: No early-onset dementia Clinical Assessment:

Diagnosis: Vascular Dementia (suspected) Risk Factors: Advanced Age: Increased risk for dementia with aging. Lifestyle Factors: High-risk behaviors (inactivity, poor diet, smoking) contributing to vascular health deterioration. Vascular Disease History: Hypertension and diabetes contributing to impaired cerebral blood flow. Memory Impairment: Present, consistent with vascular dementia symptoms. Family History: No evidence of early-onset dementia, suggesting less genetic influence. Clinical Impression: The patient's advanced age, combined with lifestyle factors and a history of vascular diseases, elevates the likelihood of vascular dementia. Memory disorders further support this diagnosis. The absence of genetic predispositions from early-onset dementia in the family suggests that lifestyle and medical history are the primary risk factors.



Based on the provided patient information and clinical assessment, the diagnosis of Vascular Dementia is strongly supported. The key factors contributing to this diagnosis include:

1. **Advanced Age:** The patient is of advanced age, which is a significant risk factor for dementia, particularly vascular dementia.
2. **High-Risk Lifestyle:** The patient exhibits high-risk lifestyle behaviors such as physical inactivity, poor diet, and smoking. These factors are known to contribute to vascular health deterioration, which is critical in the development of vascular dementia.
3. **History of Vascular Diseases:** The documented history of hypertension and diabetes indicates compromised vascular health, leading to impaired cerebral blood flow, a primary factor in the development of vascular dementia.
4. **Memory Impairment:** The presence of memory disorders aligns with the typical symptoms associated with vascular dementia.
5. **Family History:** The absence of early-onset dementia in the family suggests that genetic factors may play a lesser role in this case, further emphasizing the influence of lifestyle and medical history.

In summary, the combination of advanced age, high-risk lifestyle factors, a history of vascular diseases, and memory impairment strongly indicates that the patient is likely to have Vascular Dementia. The clinical impression aligns with established diagnostic criteria for vascular dementia, reinforcing the need for further management and treatment strategies focused on addressing the identified risk factors.

Overview from conversations



Extract evidence from the conversation, assess all diseases in the Bayesian Network, and create a comparative report for me. Compare the probability of every disease!

Patient: Good morning, doctor. I've been feeling really strange lately, and it's starting to worry me.

Doctor: Good morning! I'm here to help. Can you tell me more about what you've been experiencing?

Patient: It's hard to describe, but I've been having these sudden, jerky movements in my arms and legs that I can't control. It's like my body is moving on its own.

Doctor: That sounds concerning. Have you noticed if these movements happen more often at certain times, or are they random?

Patient: They seem random, but they're happening more often now. At first, it was just a little twitch here and there, but now it's affecting my ability to write or hold things properly.

Doctor: I see. Have you experienced any other symptoms, like mood changes, memory problems, or difficulty focusing?

Patient: Yes, I've been feeling really down lately, like I can't enjoy things I used to. And I've been forgetting things—sometimes simple stuff, like appointments or even what I was just doing.

Doctor: That's helpful to know. Have you noticed any other unusual experiences, like seeing things that aren't there or hearing things that others can't hear?

Patient: Actually, yes. A few times, I've seen things out of the corner of my eye—like shadows or people who aren't really there. It's been pretty unsettling, but I thought maybe it was just stress.

Overview from conversations



Extracted Evidence from the Conversation:

1. **Movement Disorders:** The patient reports sudden, jerky movements in arms and legs that they cannot control, which have increased in frequency and severity.
2. **Memory Problems:** The patient mentions forgetting simple things, such as appointments and tasks.
3. **Hallucinations:** The patient describes seeing shadows or people that aren't there.
4. **Mood Changes:** The patient feels down and unable to enjoy activities they previously liked.
5. **Family History:** The patient has a father with Huntington's disease.

Comparative Report on Diseases:

1. **Huntington's Disease**
 - **Likelihood:** Moderate
 - **Supporting Evidence:** Family history of Huntington's disease.
 - **Contradicting Evidence:** The patient does not exhibit classic symptoms such as chorea or significant cognitive decline at this stage.
2. **Parkinson's Disease**
 - **Likelihood:** Moderate

Summary of Comparative Likelihoods:

- **Lewy Body Dementia:** High likelihood due to the combination of symptoms.
- **Huntington's Disease:** Moderate likelihood, primarily due to family history.
- **Parkinson's Disease:** Moderate likelihood based on movement disorders.
- **Alzheimer's Disease, Vascular Dementia, Other Dementias, NonOrganic Pseudodementia:** Low likelihood due to lack of supporting evidence or contradictory symptoms.

Conclusion:

The patient's symptoms are most consistent with **Lewy Body Dementia**, warranting further investigation to clarify the diagnosis and guide treatment options. The family history of Huntington's disease is a significant factor but does not align with the current presentation of symptoms.

Further diagnostic testing, including neurological assessments and imaging, is recommended to confirm the diagnosis and rule out other conditions.

References:

- [Lewy Body Dementia Symptoms](#)
- [Huntington's Disease Overview](#)
- [Parkinson's Disease Symptoms](#)
- [Alzheimer's Disease Information](#)

Education



Medical Student Test: Diagnosis and Management of Vascular Dementia

Patient Case Summary: A 72-year-old individual presents with memory disorders and exhibits several interconnected risk factors for vascular dementia. Key points include:

- **Age:** 72 years (advanced age)
- **Lifestyle Factors:** Physical inactivity, poor diet, and smoking
- **Medical History:** History of hypertension and diabetes
- **Family History:** No early-onset dementia reported

Questions:

1. Diagnosis:

- Based on the provided patient information, what is the most likely diagnosis?
 - A) Alzheimer's Disease
 - B) Vascular Dementia
 - C) Frontotemporal Dementia
 - D) Mixed Dementia

Correct Answer: B) Vascular Dementia

2. Risk Factor Analysis:

- Identify three modifiable risk factors present in this patient that could be addressed to reduce the risk of further cognitive decline.
 - A) Advanced age
 - B) Hypertension
 - C) Smoking
 - D) Family history of dementia

Correct Answers: B) Hypertension, C) Smoking, and any other lifestyle factor (e.g., poor diet, physical inactivity).

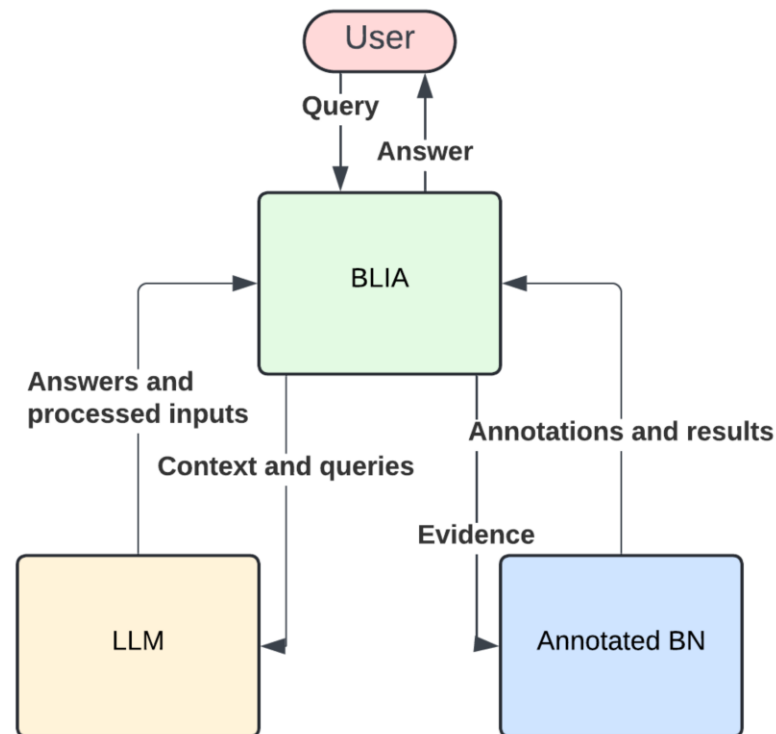
3. Management Strategies:

- Which of the following lifestyle modifications should be recommended to this patient to help manage their risk of vascular dementia? (Select all that apply)
 - A) Increase physical activity (e.g., regular exercise)
 - B) Implement a heart-healthy diet (e.g., Mediterranean diet)
 - C) Continue smoking to manage stress
 - D) Regular monitoring and management of blood pressure and diabetes

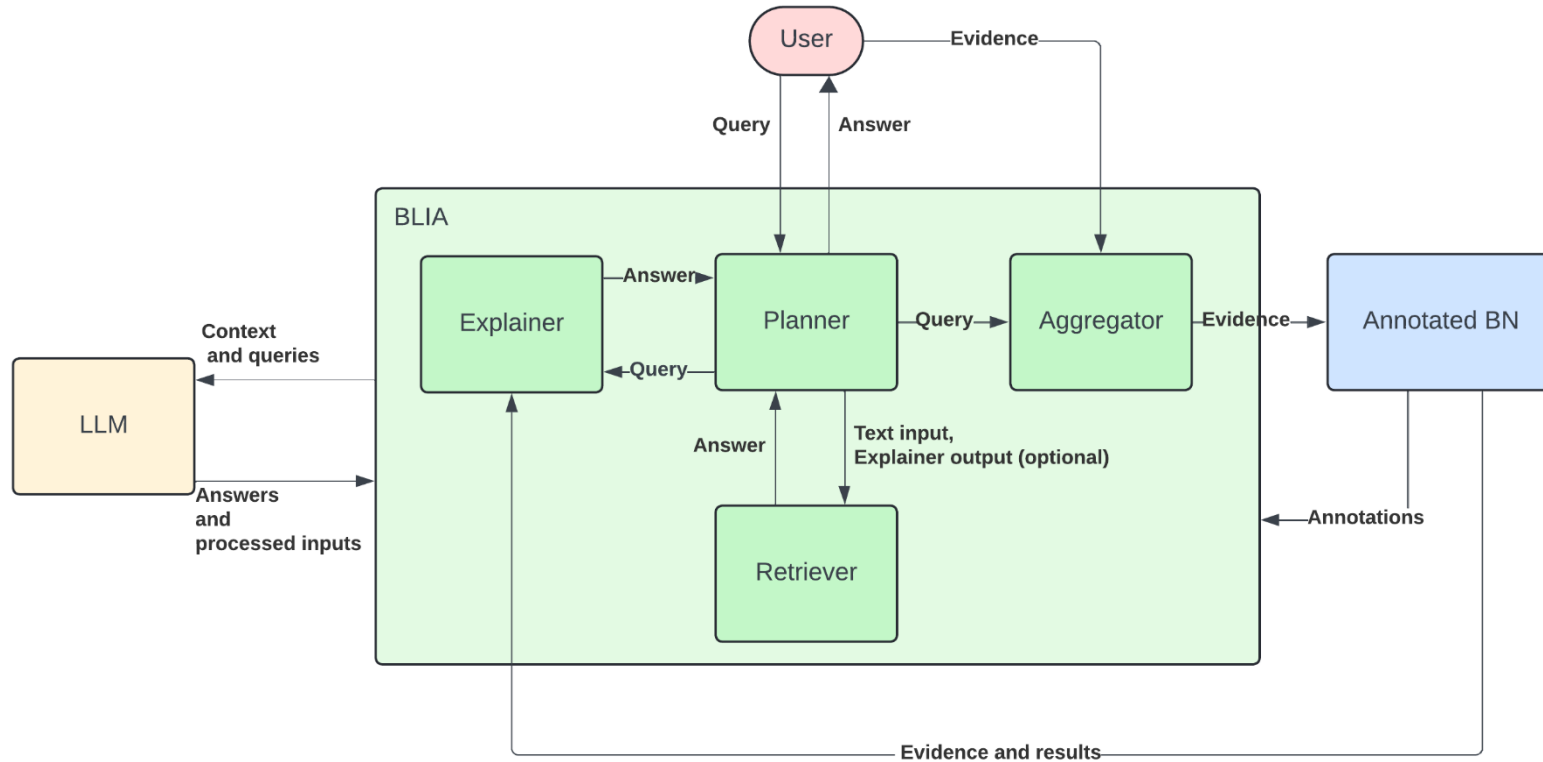
Correct Answers: A) Increase physical activity, B) Implement a heart-healthy diet, D) Regular monitoring and management of blood pressure and diabetes.

Conclusions

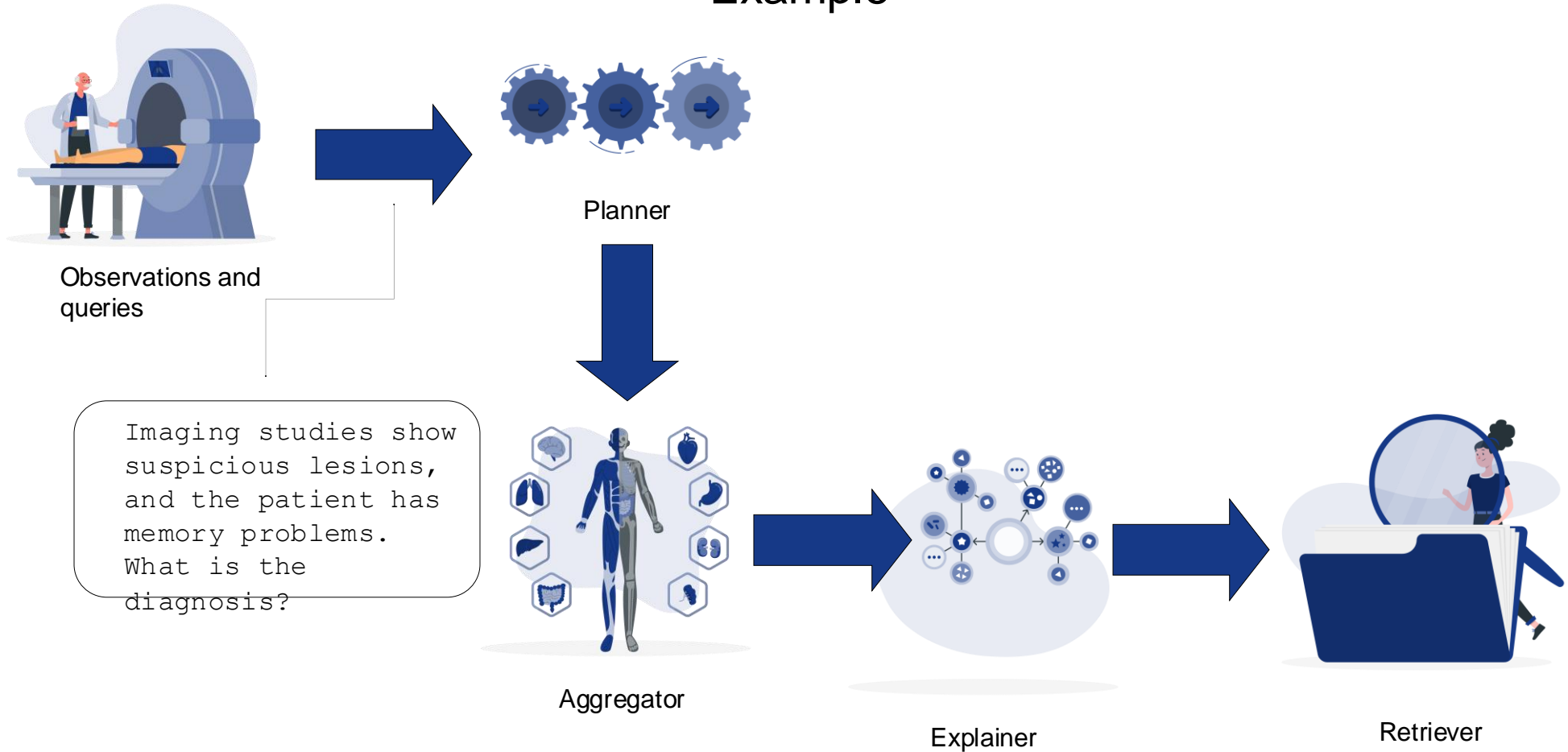
- Approachable Bayesian Networks for domain experts
- Wide array of applications
- Potentials of the method
 - Different white-box models
 - Alternative domains
 - Other modalities



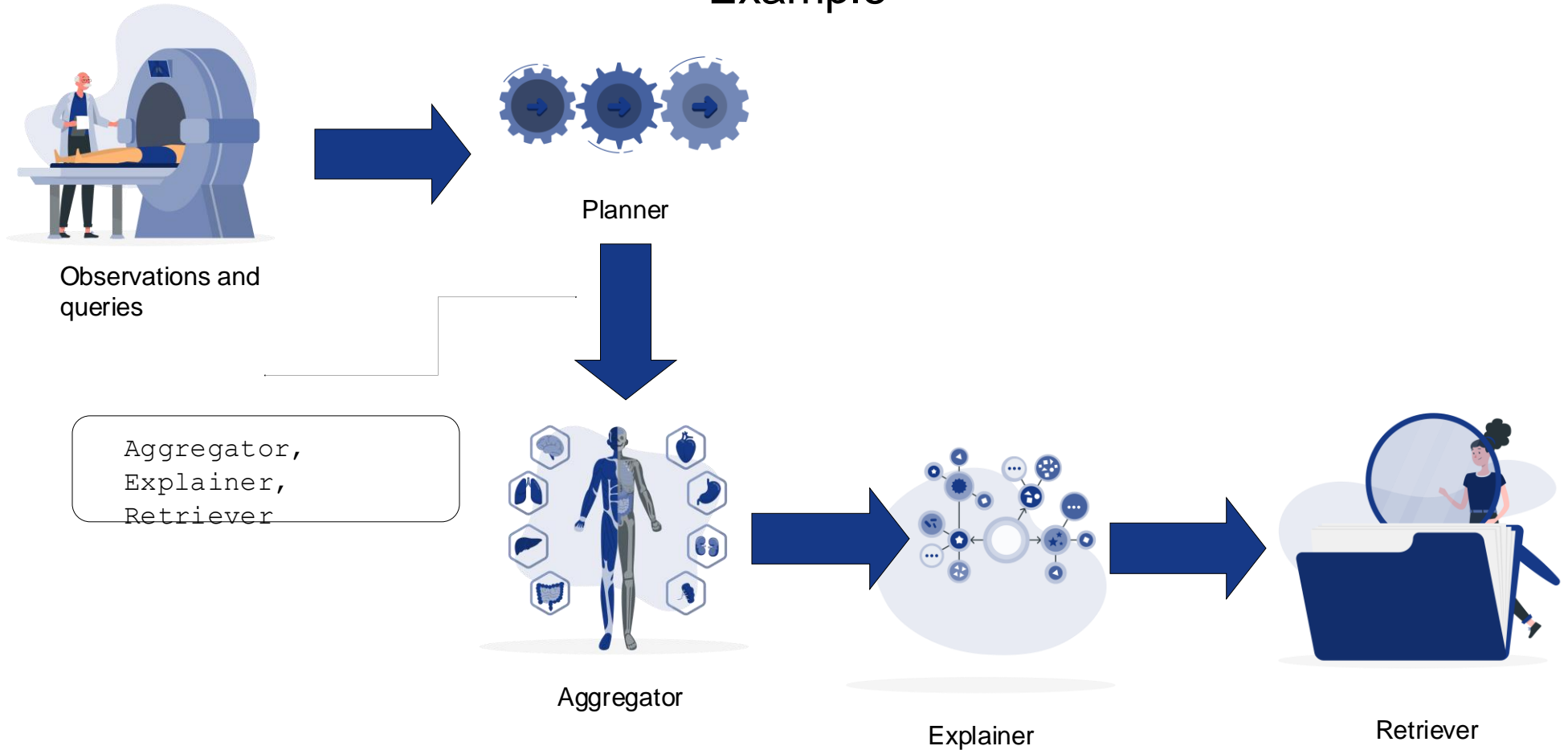
BLIA's architecture



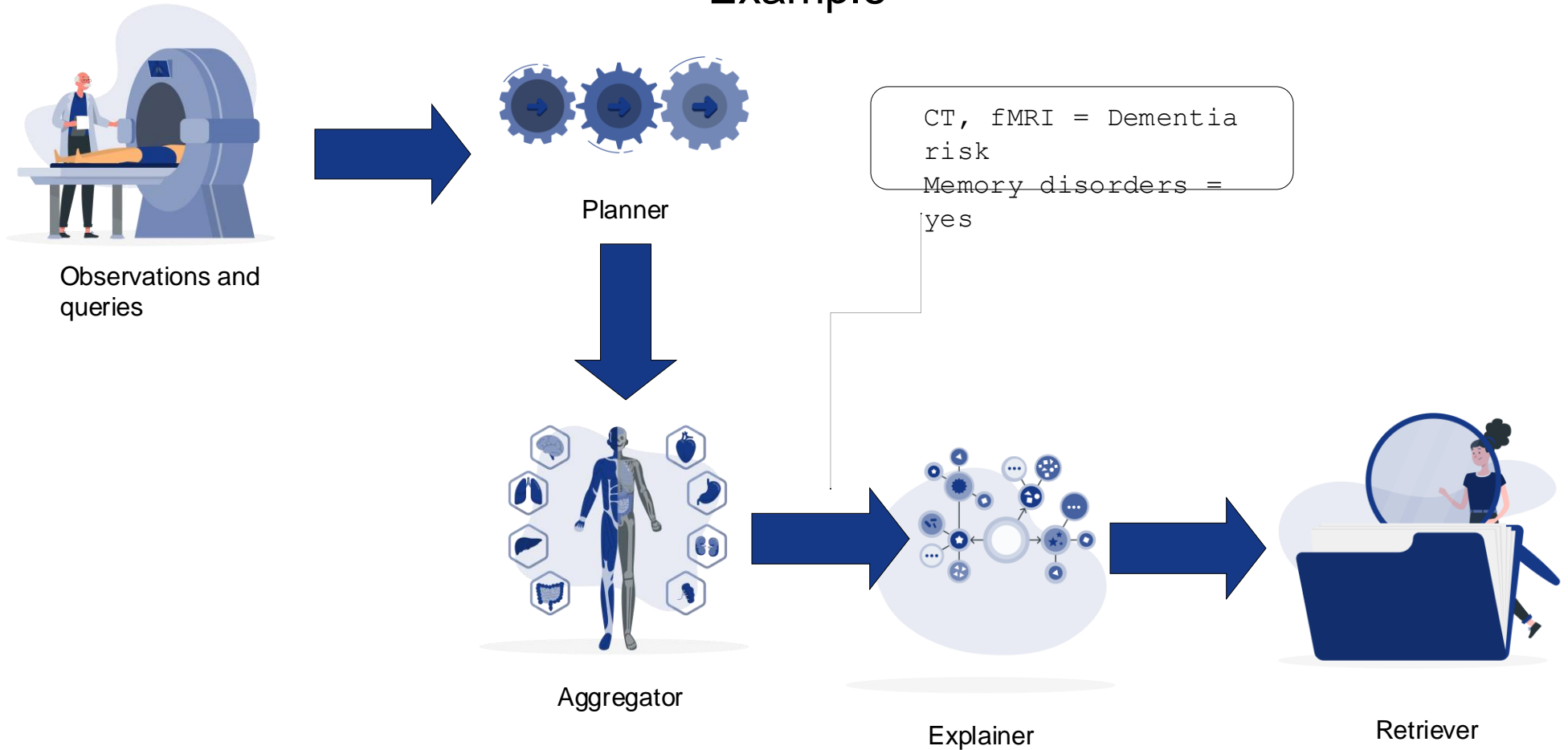
Example



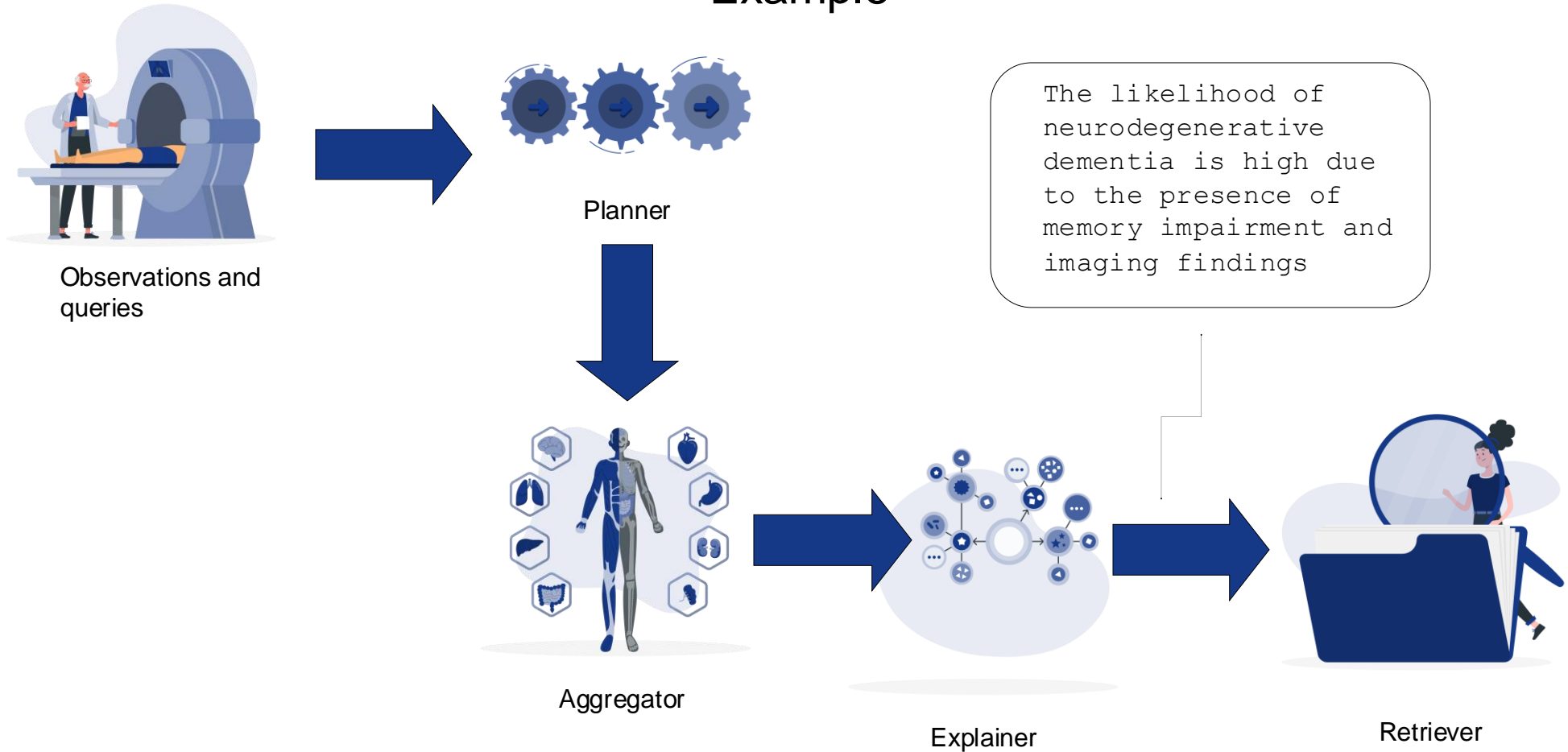
Example



Example



Example



Example

