AIAA2205

Section 2 What is Intelligence

第二节 什么是智能

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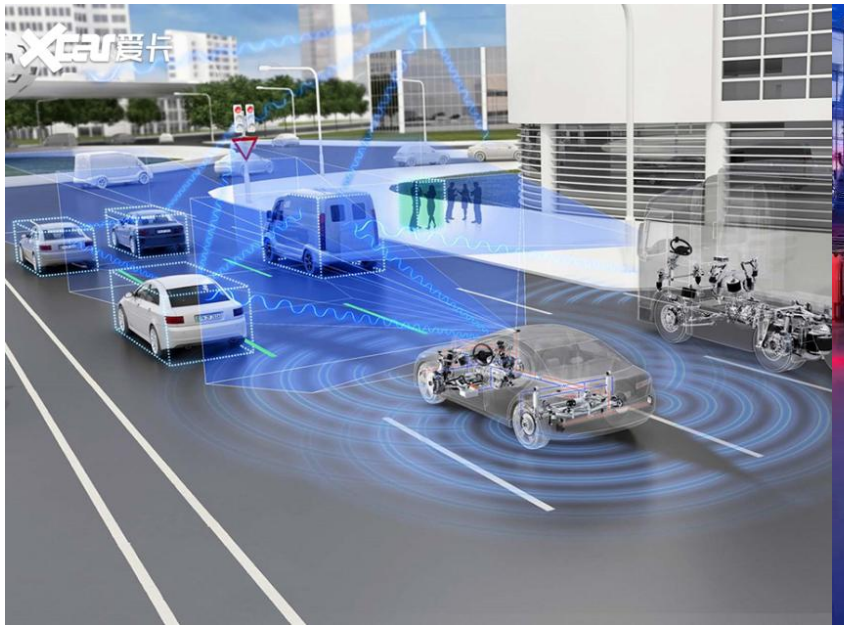
Flying 飞行

What is flying? 什么是飞行?

- Definition of Flight (飞行的定义)
  - Flight is a controlled locomotion process through gaseous medium (typically air) using aerodynamic forces, achieving sustained displacement against gravitational pull.
  - 飞行指通过气动力的运用在气体介质（通常为空气）中实现可控运动，持续克服重力作用产生位移的过程。
- Core Elements (核心要素):
  - 1. Lift Generation (升力产生)
    - Birds: Achieved via airfoil-shaped wings creating pressure differential (鸟类：翼型翅膀产生压力差)
    - Aircraft: Utilize Bernoulli's principle through fixed/moving wings (飞行器：应用伯努利原理的固定/旋转翼)
  - 2. Thrust Production (推力生成)
    - Biological: Muscle-powered wing flapping (生物：肌肉驱动的扑翼运动)
    - Mechanical: Engine/propeller systems (机械：发动机/螺旋桨系统)
  - 3. Controlled Navigation (可控导航)
    - Avian: Neuromuscular coordination adjusting wing morphology (鸟类：神经肌肉协调改变翼型)
    - Aviation: Flight control surfaces (aileron, rudder, elevator) (航空：副翼、方向舵、升降舵等控制面)

- Exceptions (例外情况):
  - Ballistic Motion (e.g., thrown objects) lacks sustained control 弹道运动（如投掷物）缺乏持续控制
  - Buoyant Flight (e.g., hot air balloons) relies on density differentials 浮力飞行（如热气球）依赖密度差
  - Dynamic Soaring (动态翱翔)
    - Albatrosses exploiting wind gradients (10,000km non-stop migration)信天翁利用风梯度（10,000公里不间断迁徙）
  - ……
- Principles
  - 伯努利原理Bernoulli‘s Principle：流体速度增加时，其静压降低
    - 飞机翼型上表面气流加速产生升力（典型升力贡献60-70%）
    - 鸟类翅膀的拱形截面设计
  - 克拉科夫机制 (Clap-and-Fling Mechanism): 双翼碰撞分离产生超常升力
    - 蜂类垂直起降时升力提升40%
  - ……

Intelligence 智能



How do we define “intelligence”?

Looked at in one way, everyone knows what intelligence is; looked at in another way, no one does.

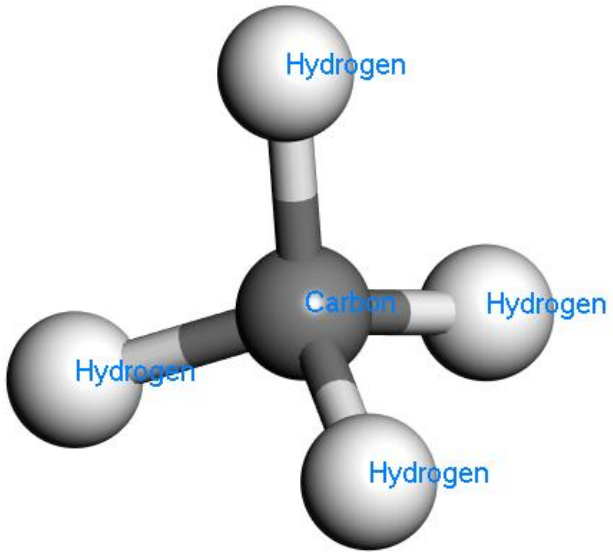
Robert J. Sternberg, 2000

- >70 “versions” of definitions
  - AI is the science of making machines capable of performing tasks that would require intelligence **if done by humans**. (Minsky, 1968)
  - AI is the science and engineering of making machines do tasks they have never seen and have **not been prepared for beforehand**. (McCarthy, 1987)
  - I want to consider intelligence **as a collective noun**. I want to see what we in AI have thought of it and review the multiple ways in which we've conceived of it. … to conceive of AI as the study of the design space of intelligences. (Davis, 1998)
  - It has been hypothesized that whatever intelligence is (and we obviously have not been able to fully define it so far), it is a **multidimensional thing**. … We must consider the integration and synergies of components in an overall system to really approach some form of artificial intelligence. (Brachman, 2006)
  - Intelligence is the capacity of an information-processing system to adapt to its environment while operating with **insufficient knowledge and resources**. (Wang P., 1995, rediscussed 2019 and 2021)
  - AI is a **branch of computer science**, which is the scientific study of what problems can be solved, what tasks can be accomplished, and what features of the world can be understood computationally, and then to provide algorithms to show how this can be done efficiently, practically, physically, and ethically. (Rapaport, 2020)

- What is intelligence and what is not?
- What might be the key properties of an intelligence system?

DeepSeek R1’s definition:

- Definition of Intelligence (智能的定义)
  - Intelligence is a system's capacity to achieve complex goals through adaptive information processing, involving perception, learning, reasoning, and decision-making in variable environments.
  - 智能是系统通过适应性信息处理（感知、学习、推理、决策）在变化环境中实现复杂目标的能力。
- Core Elements (核心要素)
  - Adaptive Goal Pursuit (适应性目标追求)
    - Humans: Transfer calculus knowledge to stock trading strategies
    - 人类：将微积分知识迁移至股票交易策略
    - AI: Adjust recommendation algorithms based on user feedback
    - AI：根据用户反馈调整推荐算法
  - Metacognition (元认知)
    - Biological: Prefrontal cortex monitoring decision-making processes
    - 生物：前额叶皮层监控决策过程
    - Artificial: Neural network attention visualization tools
    - 人工：神经网络注意力可视化工具
  - Uncertainty Management (不确定性管理)
    - Human pilots handling sudden turbulence using heuristic rules
    - 人类飞行员用启发式规则处理突发湍流
    - Autonomous vehicles making probabilistic predictions in rain
    - 自动驾驶在雨中做概率预测
  - Value Weighting (价值权衡)
    - Medical AI balancing diagnosis speed vs. accuracy (sensitivity 92% vs specificity 88%)
    - 医疗AI平衡诊断速度与准确度（敏感度92% vs 特异度88%）
    - Human judges considering legal principles & social impact
    - 人类法官权衡法律原则与社会影响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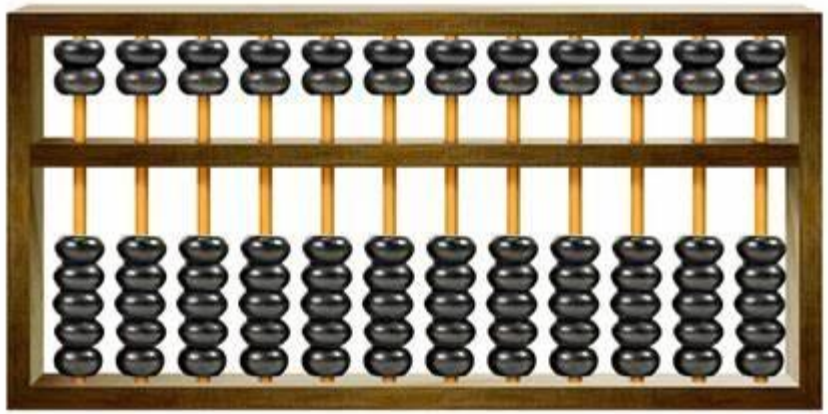


Which ones are intelligent systems – 2 ?

- Methane 甲烷分子
- Virus 病毒
- Paramecium 草履虫
- Ant 蚂蚁
- Turtle 乌龟
- Bird 鸟
- Dog 狗
- Gorilla 大猩猩
- Human 人
  - Birth 出生
  - 1 yo 1岁
  - 5 yo 5岁
  - 10 yo 10岁
  - 20 yo 20岁

- Abacus 算盘
- Calculator 计算器
- Automatic production line 自动化流水线
- Face Recognition access control system 人脸识别门禁系统
- Robot vacuum 扫地机器人
- Boston dynamics Atlas 人形机器人
- Tesla Model Y (半)自动驾驶汽车
- AlphaGo/AlphaZero
- AlphaFold
- IBM Watson
- BERT
- Bard
- ChatGPT
- …

What can an intelligent system do?

- Perception-decision-action 感知-决策-执行
- 推理、理解、计划、解决问题、抽象思维、表达意念
- 逻辑 （logical）
- 语言文字（linguistic）
- 空间（spatial）
- 音乐（musical）
- 肢体运作（kinesthetic）
- 内省（intra-personal）
- 人际（inter-personal）
- 自然探索（naturalist）
- Learning 学习

- Logical calculation 逻辑运算
- Programmed tasks (installation of a part)
- Localization 定位
- Route planning 路径规划
- Classification 分类
- Detection 检测
- Tracking 跟踪
- Segmentation 分割
- Language translating 翻译
- Generation 生成
- Reward hunting 生存（奖励最大化）
- Question answering 问答
- Giving advices 给出建议
- Complex task planning 复杂任务计划
- Drawing 画图
- Writing code 写代码

What are the mechanisms behind them?

- Natural selection
- Perception
  - Eye
  - Ear
  - Tactile
  - …
- Calculation
  - “ System 1” autonomous/unconscious
  - “ System 2” analytical/Factoring/conscious
- Action
  - Physical
  - Informational

- Hydraulic transmission 液压传动
- Motor controlling 电机控制
- UAV flight control algorithms (Kalman filter / PID) 无人机飞控算法
- Game of life (Ising model) 生命游戏（伊辛模型）
- Perceptron 感知机
- Back propagation 反向传播
- AlexNet
- Yolo 7
- LSTM
- Q-learning
- Attention mechanism / Transformer
- Next Token Prediction
- Python code training
- Reinforcement Learning from Human Feedback
- Proximal Policy Optimization

What is the main property of intelligence?

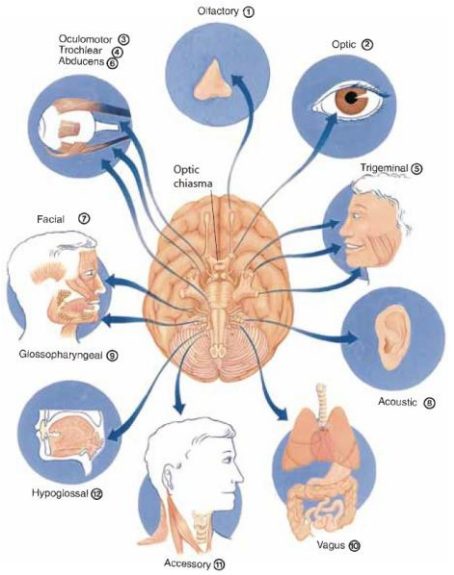
- Connectionism
  - Intelligence is in the connections of neurons
  - Typical:
    - CNN based cat-noncat classifier
    - Multi-layer neuron network
    - Supervised training
      - Back-propagation updating weights
    - Input-calculate-output
    - Multi-step feature transformation
      - On multiple granularities
- Symbolism
  - Intelligence is in the symbol-based Factorings
  - Typical:
    - MYCIN医疗诊断系统
    - Knowledge (based on symbol/language)
      - Rules
      - Factoring
      - 如果病人有发热，而且血液培养结果显示有革兰阴性菌，那么病人可能有败血症sepsis。
- Behaviorism
  - Intelligence is adjusting behavior to achieve goal by interacting with environment
  - Typical:
    - Q-learning (reinforcement learning)
    - State-Action-Reward
    - Q-value
      - Expected reward for a certain action on a certain state
    - Policy
      - epsilon-greedy

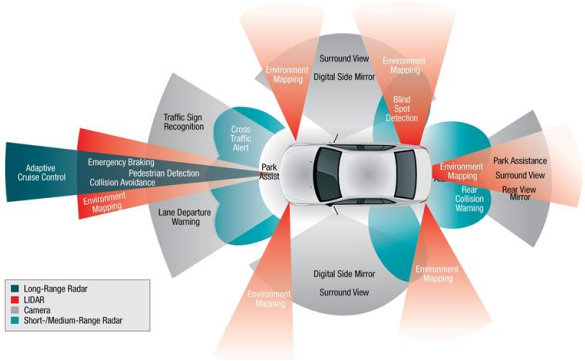
What is intelligence?

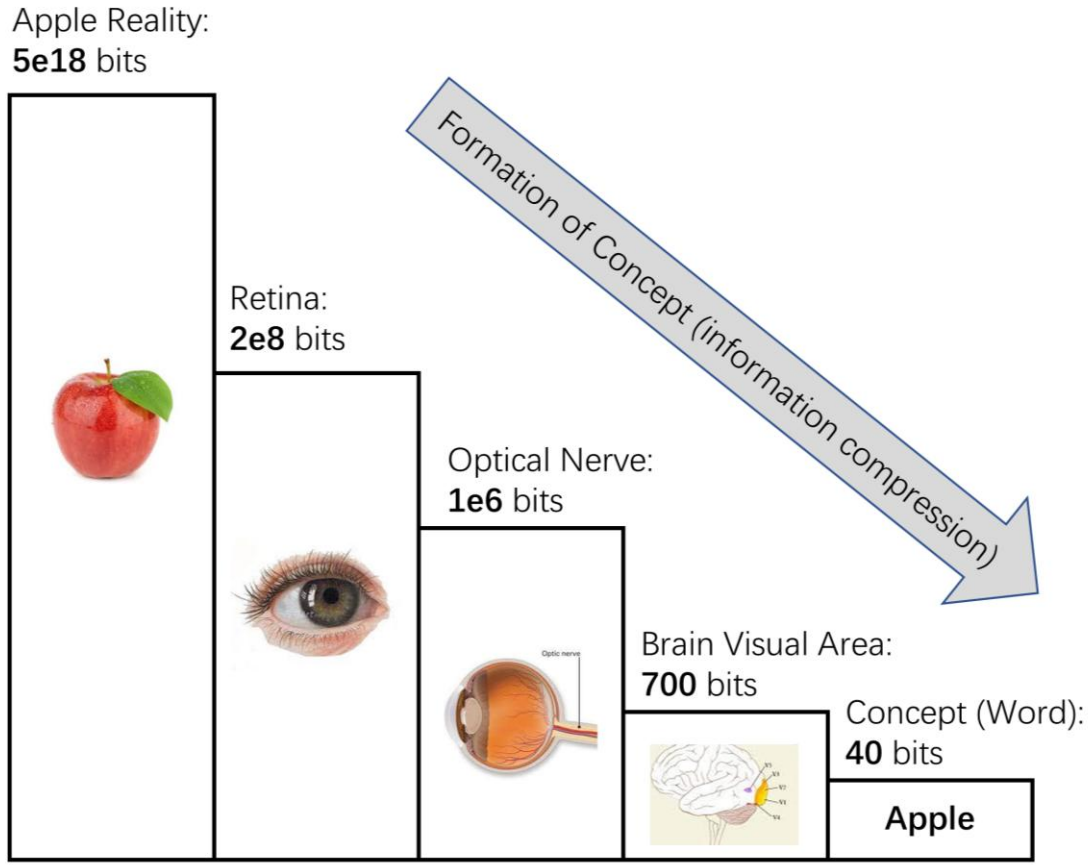
- Information compression
  - Convolution, feature extraction
  - World modelling, state representation
- Information transformation
  - Word embedding
- Pattern recognition
- Causal discovery / causal inference
- Learning
  - Supervised training of a classifier
  - NTP training of a LLM foundation model
  - Policy updating of an agent
- Meta-learning
- Reasoning
- Planning
- Problem solving
- …

1 element: Information compression

- Apple reality → …… → a word
- Intelligence model and the causality in it are based on coarse-graining







In physical reality, the approximate number of photons refracted by the apple can be given by:

$$N_p = \frac{SLtc}{h\lambda} \approx 5e18 \quad (2)$$

while S=0.02 m^2 is the apple's illuminated surface area, L=100 Lux is the average intensity of light refracted by the apple, λ=500nm is the average wavelength of light refracted by the apple, t=1 second is the time period for consideration (and eye observation), $h = 6.6.26e{-}14$ is the Planck constant. We assume here one photon carries 1 bit of information, although in principle it could be more than 1 bit. We can then roughly quantify the original information of the physical reality:

$$H_{real} \approx 5e18bits \quad (3)$$

The eye captures some of the photons and converts them into electrical signals by retina cells, the information is on the order of:

$$H_{retina} \approx 2e8bits \quad (4)$$

The information being transmitted to the brain via optical nerve cells is on the order of:

$$H_{nerve} \approx 1e6bits \quad (5)$$

The exact way the brain stores the features created by brain visual areas is not clear. To have a rough idea of the order of magnitude, here we assume 10 features are created, each with a probability of 0.01. The information is then on the order of:

$$H_{feature} \approx 700\ bits \quad (6)$$

Finally, the word "apple" is stored in brain language area. Assuming a regular encoding method, the word "apple" has information on the order of:

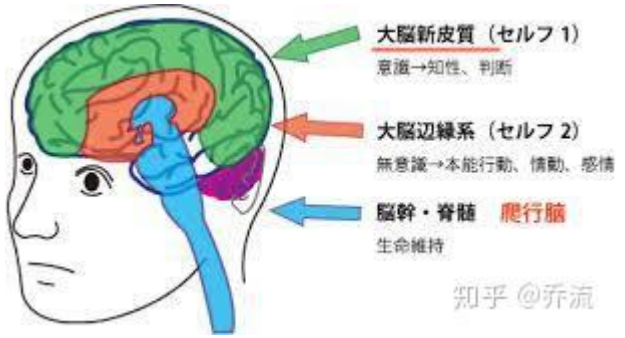
$$H_{concept} \approx 40\ bits \quad (7)$$

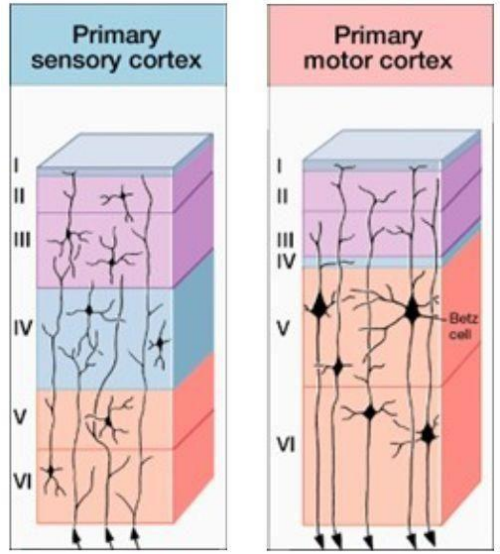
[Ref.]: Y. Yue, "A World-Self Model Towards Understanding Intelligence," in *IEEE Access*, vol. 10, pp. 63034-63048, 2022, doi: 10.1109/ACCESS.2022.3182389.

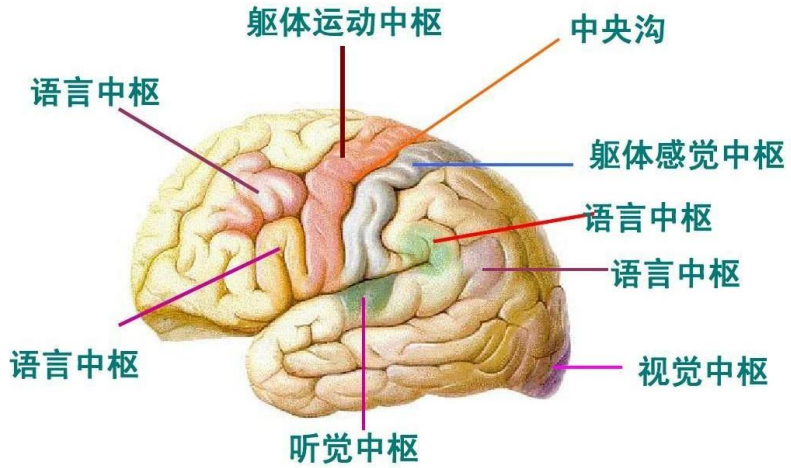
Other elements?

Some facts about the human brain: Basic information
关于人脑一些事实：基本情况

- Old brain and new brain旧脑与新脑
  - Old brain (reptilian brain)旧脑（爬行脑）
  - Limbic system (mammalian brain)边缘系统（哺乳脑）
  - New brain (higher brain)新脑（高级脑）
- Cerebral cortex大脑皮层
  - 400*400*3mm毫米
  - Stuffed inside the skull, wrinkled塞在脑壳里，挤皱了
  - 6 layers6层
  - Different locations不同位置
    - Highly similar structure结构高度相似
    - Highly different functions功能高度不同
- Strong plasticity可塑性强
  - Localized damage局部损伤
  - Hemispherectomy半脑缺失
  - Anencephaly大脑缺失







Some facts about the human brain: System 1 and System 2
关于人脑的一些事实：系统一与系统二

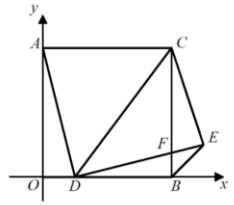
- System 1系统一
  - Automatic operation, uncontrolled, reflexive, fast, effortless, without subjective awareness自动运行，不受控制，条件反射，快，不费劲，无主观意识体验
  - Blinking, chewing, salivating, playing ball眨眼、咀嚼、流口水、打球
- System 2系统二
  - Requires attention, slow, effortful, with subjective awareness
    需要注意力，慢，费劲，有主观意识体验
  - Solving problems, scientific research, writing articles, imagining and counterfactual reasoning算题、科研、写文章、想象与反事实推理
- Intelligent behavior of the human brain
  人脑的智能行为
  - Cognitive science concepts: System 1, System 2
    认知科学概念：系统一、系统二
  - Spontaneous system, analytical system
    自发式系统、分析式系统
  - Unconscious, conscious
    无意识、有意识
  - Elephant, elephant rider
    大象、骑象人
- Most brain activities in humans are not consciously perceived
  人的绝大多数脑活动，自己并不能意识到
  - Eye movements, 3-4 times/second, 100,000 times/day
    转眼球，3~4次/秒，10万次/天
  - Subconscious, personality control, motivation control, social unconscious (e.g., "black people are dumb")
    潜意识，性格支配，动机支配，社会无意识（例如，黑人是笨的）

如图，在平面直角坐标系中，四边形 AOBC 为正方形，点 A(0，2)．点 D 为 OB 边上一动点，连接 AD，向上作 DE⊥AD 并在 DE 上取 DE=AD 交 BC 于点 F，连接 CD、CE 和 BE，设点 D 的坐标为(x，0)．

（1）填空：点 C 的坐标为____；

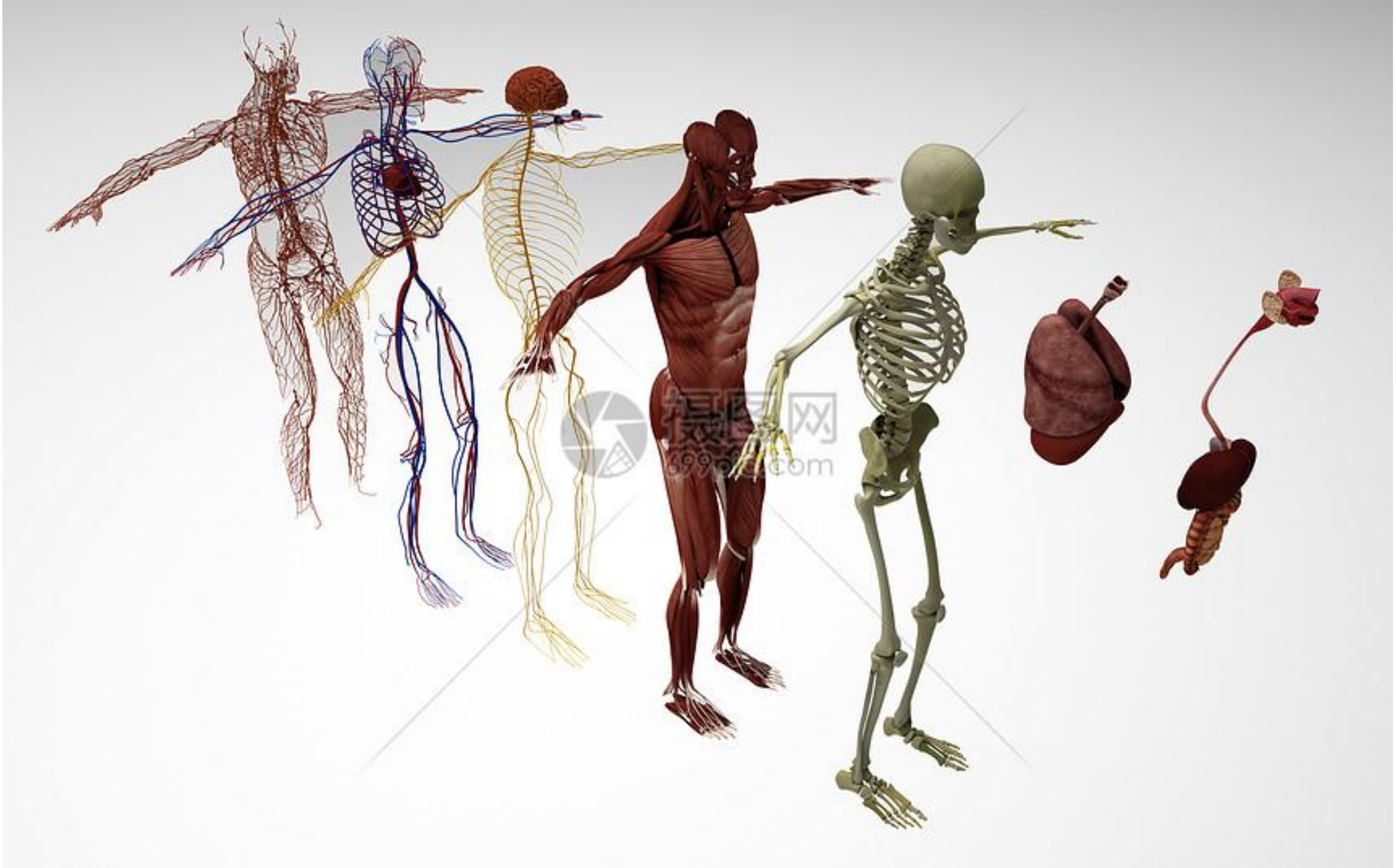
（2）设 $y=S_{\triangle CDE}$，求 y 关于 x 的关系式，并求 y 的最小值；

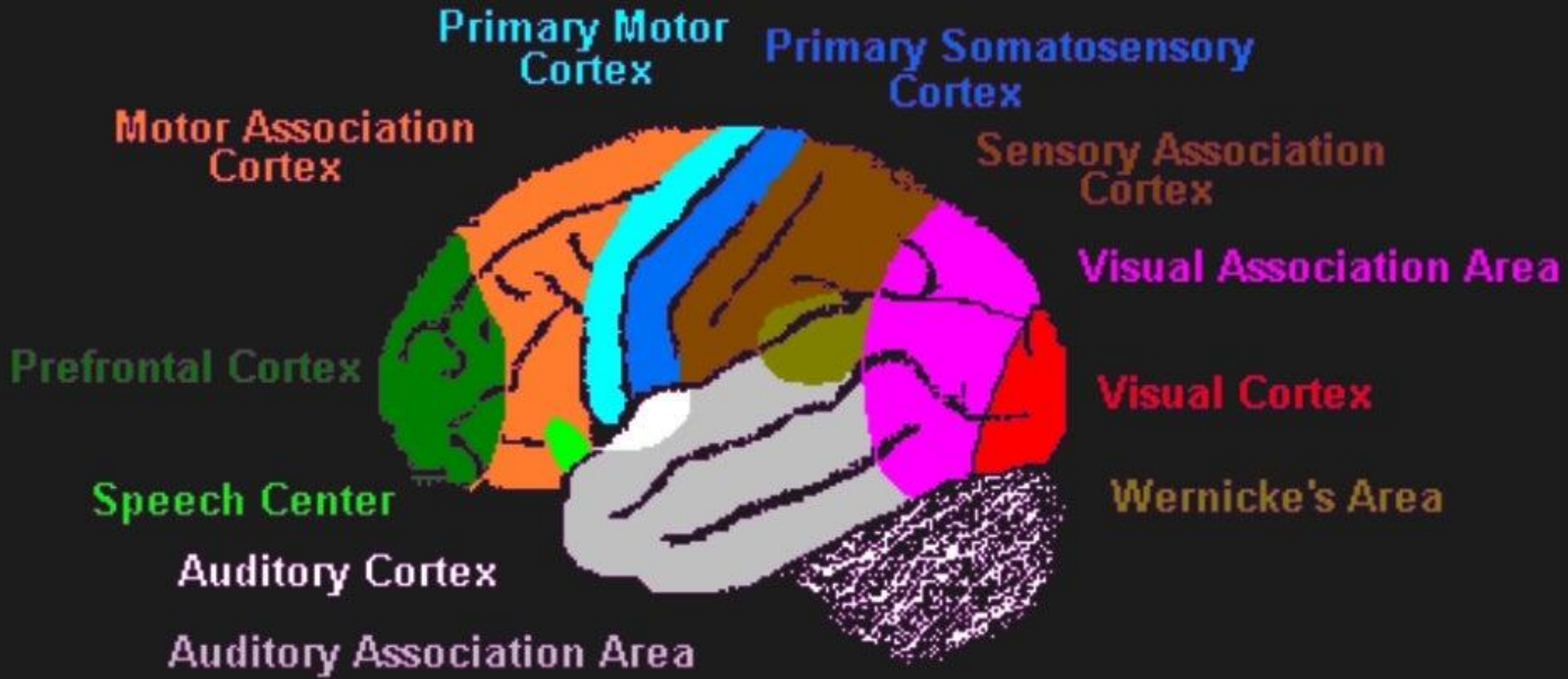
（3）是否存在这样的 x 值，使△CBE 为等腰三角形？若存在，求出对应的 x 值；若不存在，请说明理由．

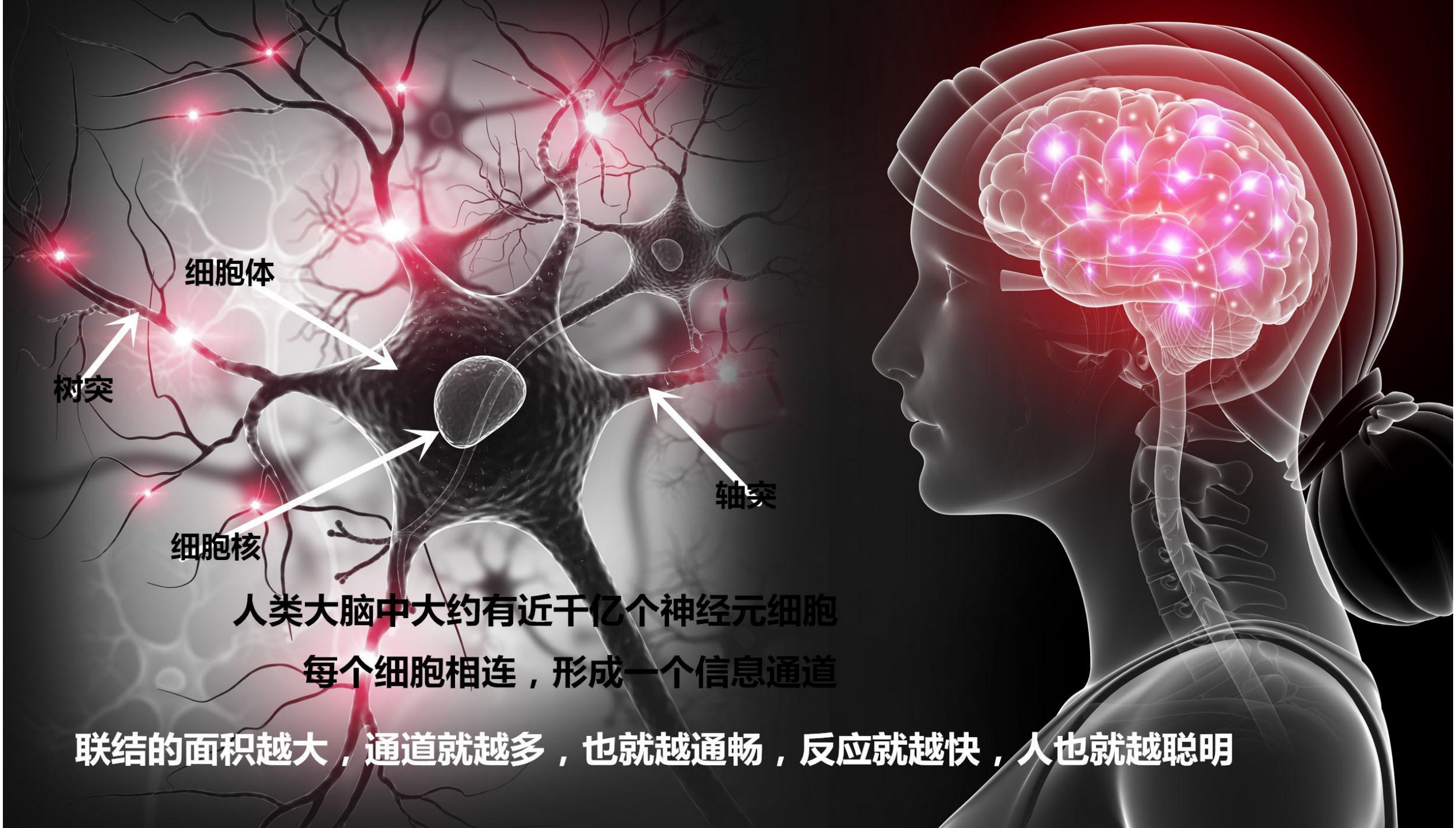


Some facts about the human brain: Energy supply and others
关于人脑的一些事实：供能与其他

- Elements governing system operation支配系统运转的要素
  - Material-energy:物质-能量
  - Time-space:时间-空间
  - Information信息
- Energy能量
  - Glucose, oxygen葡萄糖、氧
  - 2% of body weight, 20% of energy consumption2%体重，20%耗能
  - ~20W约20W
  - High baseline energy consumption, with little difference in energy consumption across different types of brain activity基础能耗大，不同类型大脑活动耗能有差异但不大
  - There is a significant difference in energy consumption between different processes in the brain: communication is 35 times more energy-consuming than computation大脑内不同过程的能耗差异很大：通信是计算的35倍
  - The thickness of axons is likely determined by the energy demands of the synaptic terminals, which account for 65% of energy consumption in the mammalian brain轴突的粗细很可能取决于突触终端的能耗需求，它占哺乳动物大脑能耗的65%
- Brain activity follows basic physical and chemical laws大脑活动遵循基本的物理化学规律
  - Energy能量
    - Energy utilization is a major constraint in biological evolution能量利用是生物进化的重大约束
    - The evolution of the brain is no exception大脑进化不会例外
    - The expensive brain was naturally selected and evolved to be quite large昂贵的大脑被自然选择留下来了，而且进化得很大
    - Constraints on brain activity by energy: ?能量对大脑活动的约束：？
  - Spatial granularity, temporal granularity空间粒度、时间粒度
  - Material: physical processes, chemical reactions, biochemical reactions物质：物理过程、化学反应、生化反应
    - NO, NOS, NOR一氧化氮（NO），一氧化氮合酶（NOS），一氧化氮还原酶（NOR）
  - **Environmental interaction:环境交互：**
    - Input of perceptual information, retrieval of (unconscious) memory感知信息的输入，（非意识）记忆的调取
    - Exchange of matter, energy, and information with the environment与环境的物质、能量、信息交换



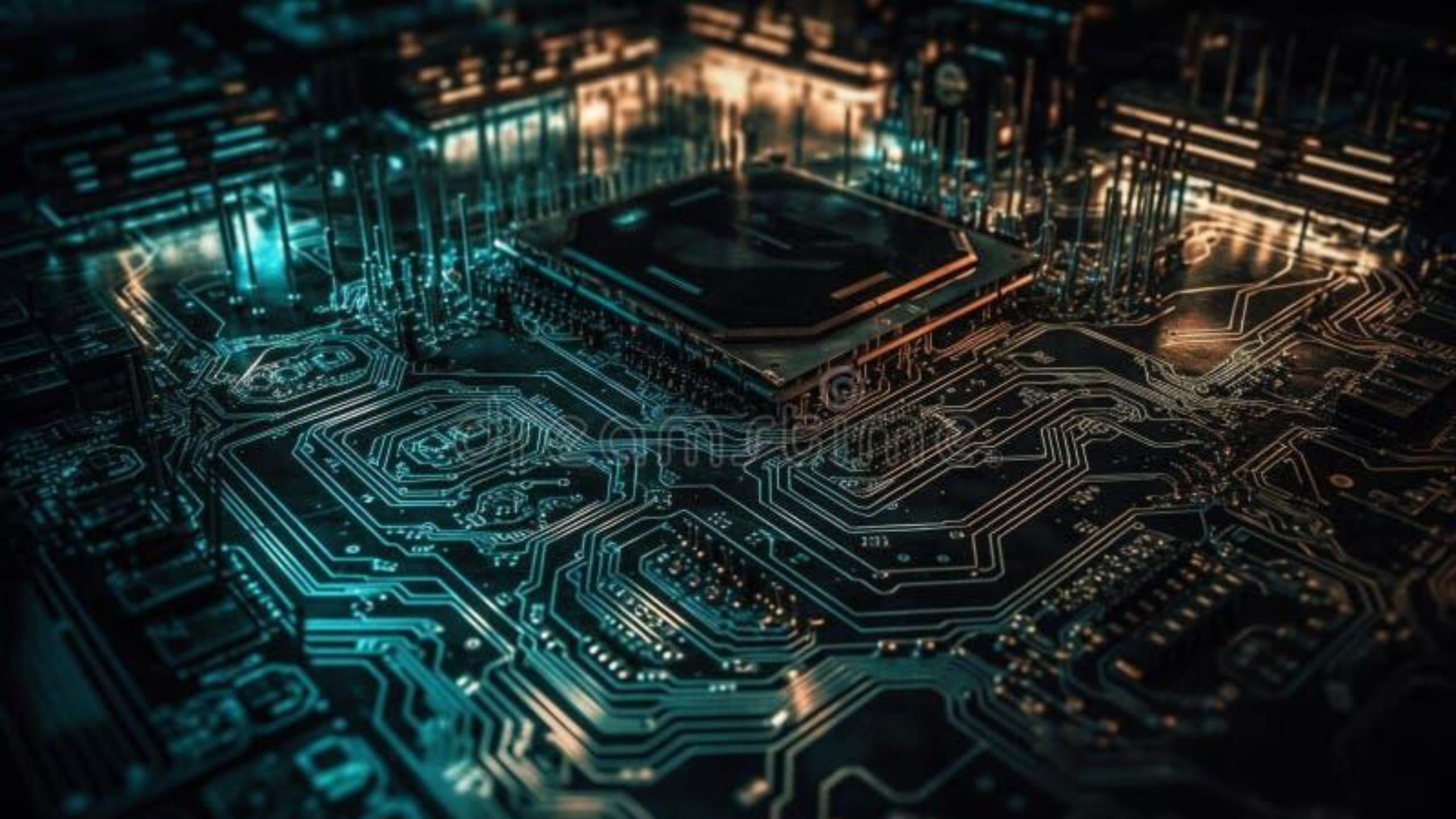

Primary Motor Cortex
Primary Somatosensory Cortex
Motor Association Cortex
Sensory Association Cortex
Visual Association Area
Prefrontal Cortex
Visual Cortex
Speech Center
Wernicke's Area
Auditory Cortex
Auditory Association Area



人类大脑中大约有近千亿个神经元细胞

每个细胞相连，形成一个信息通道

联结的面积越大，通道就越多，也就越通畅，反应就越快，人也就越聪明



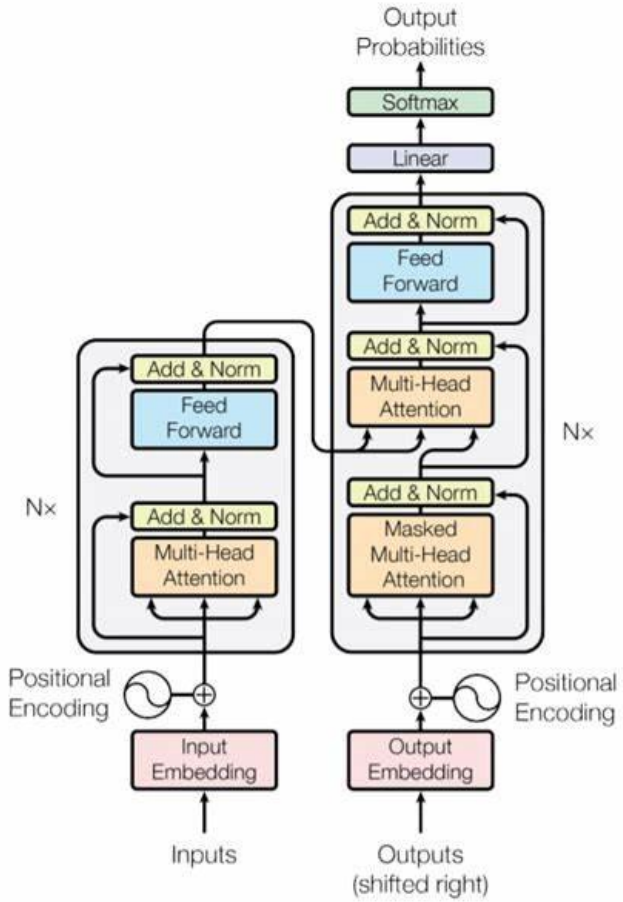
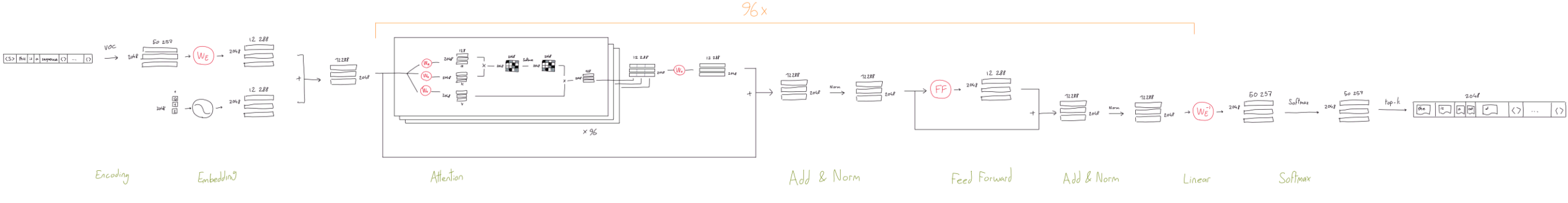
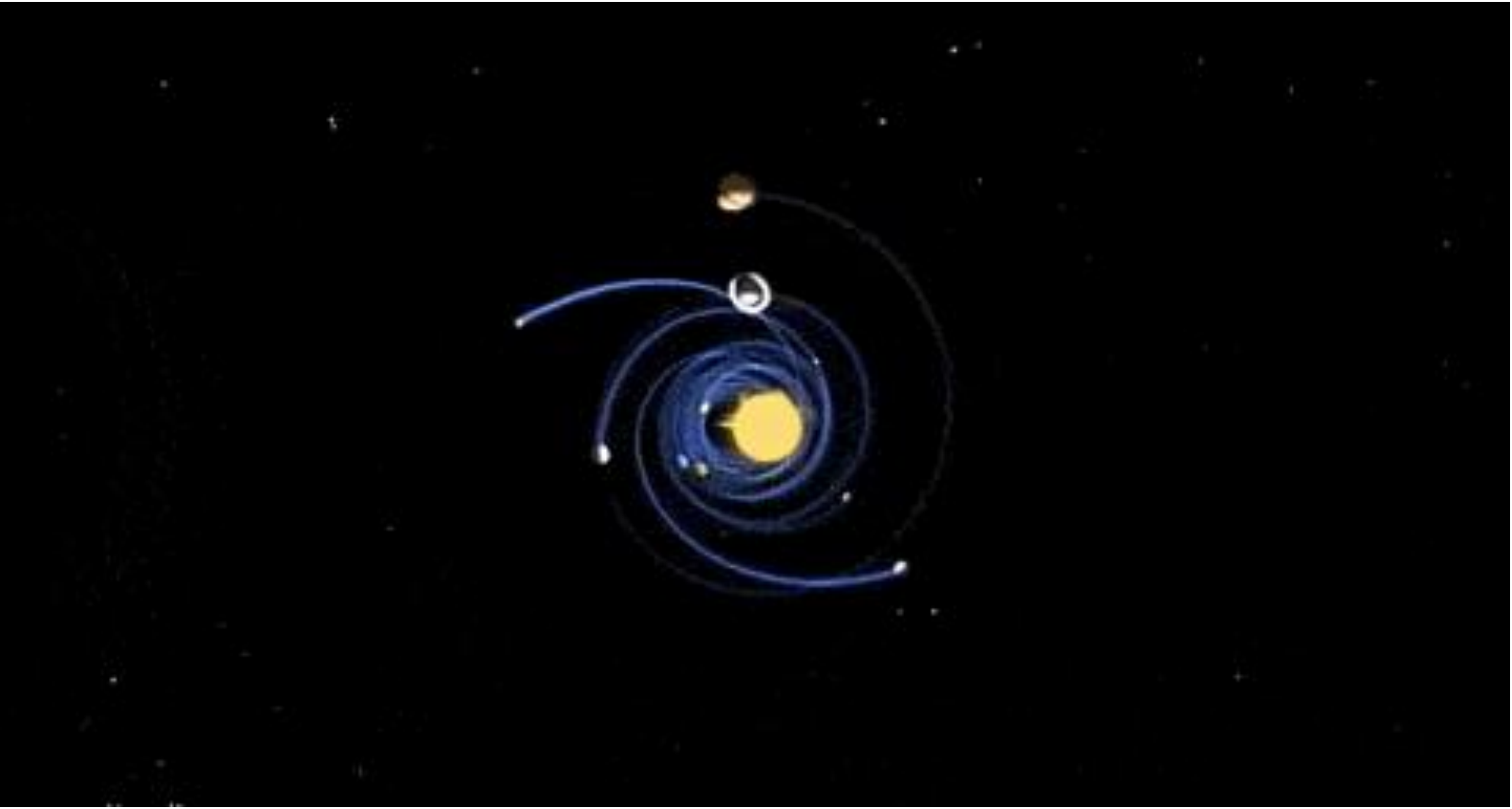


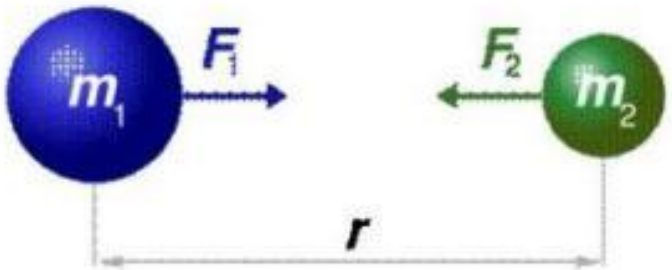
Figure 1: The Transformer - model architecture.



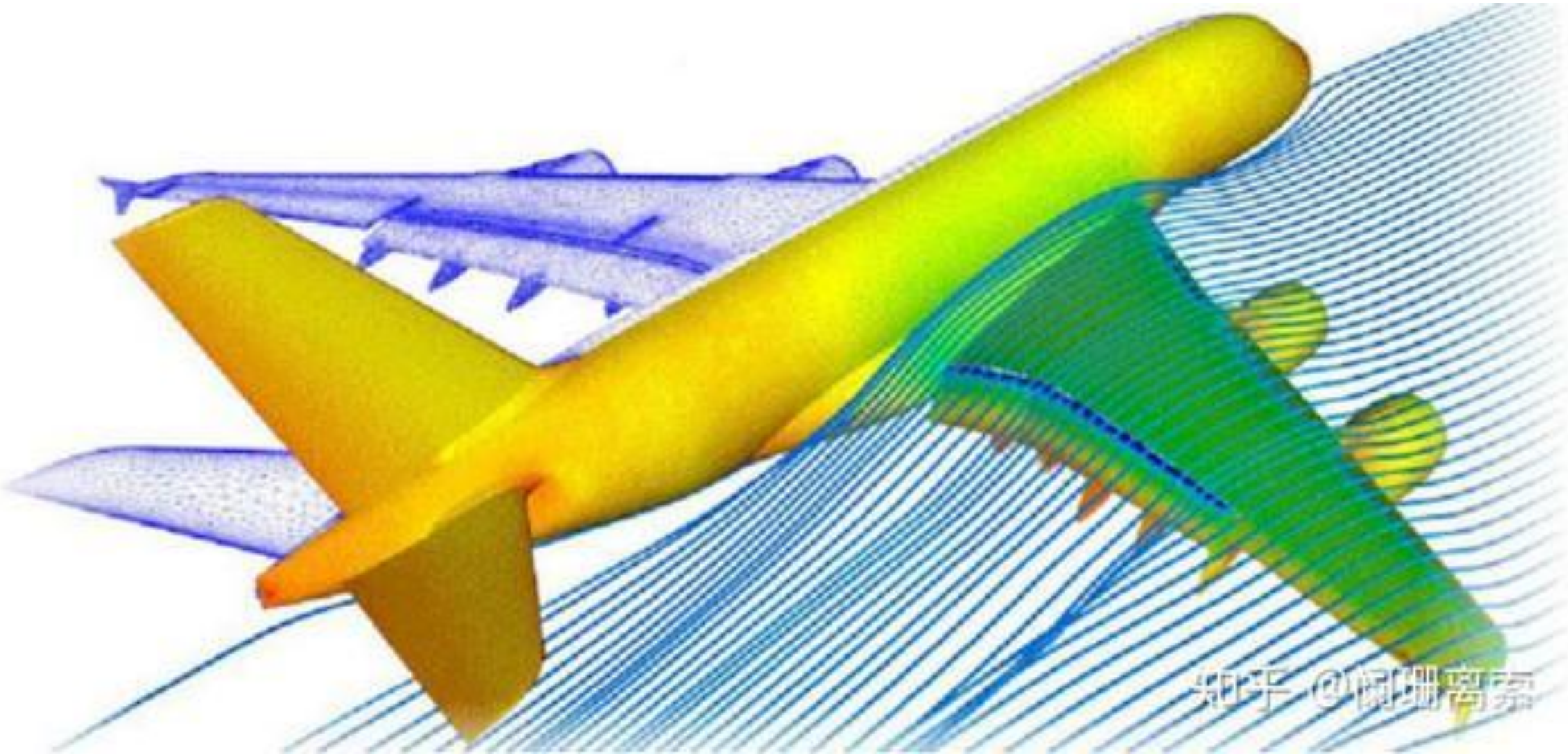
Is intelligence complex or simple?



The law of gravity



$$F_1 = F_2 = G\frac{m_1 \times m_2}{r^2}$$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Bernoulli's principle

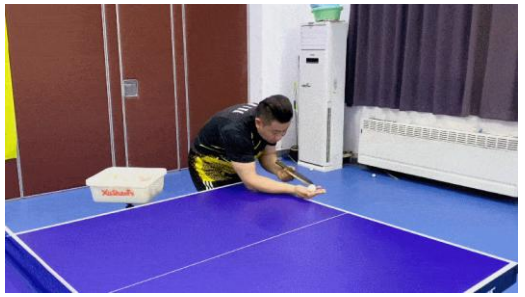
$$\frac{v^2}{2} + gz + \frac{p}{\rho} = \text{constant}$$

where:

- v is the fluid flow speed at a point,
- g is the acceleration due to gravity,
- z is the elevation of the point above a reference plane, with the positive z-direction pointing upward—so in the direction opposite to the gravitational acceleration,
- p is the static pressure at the chosen point, and
- ρ is the density of the fluid at all points in the fluid.

Model: the simplicity behind complicity

- **An informative representation of an object, person or system**
  - Variables and their mathematical relations
- Is it from the objective natural law, humans discover it from common features of different complex systems?
- Is it from the subjective feature of cognition, humans summarize the simple useful patterns from various complex systems?
  - Embodied cognition (psychology): observation → intervention (interaction) → for same environment, diff. interaction forms diff. cognition (intelligence model)
  - “All models are wrong, but some are useful”
  - No ultimate truth, just improving cognitive iterations（Geocentric model地心说→Heliocentrism日心说→Modern cosmology宇宙说）
  - Hume: causality is illusion of human perception
  - Farmer and turkey



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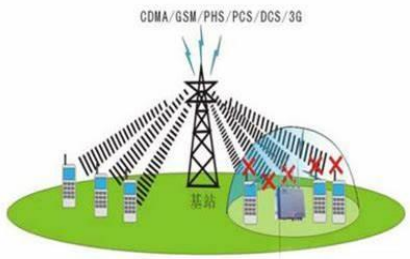
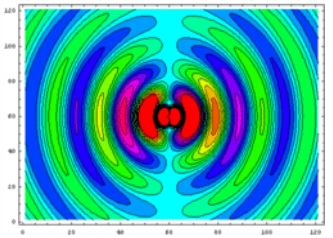
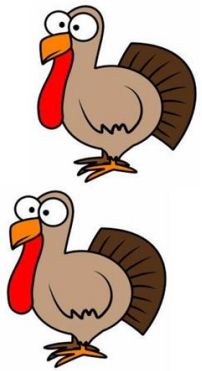
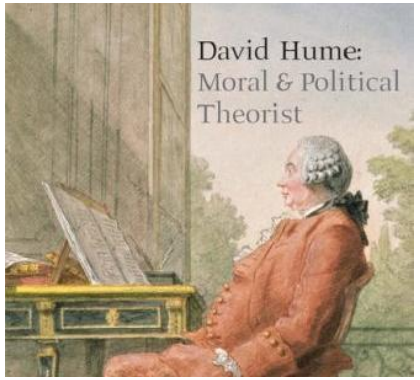
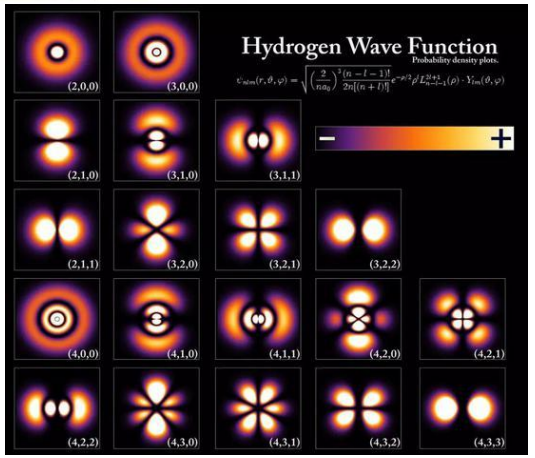




$$\nabla \cdot \boldsymbol{E} = \frac{\rho}{\varepsilon_0}$$
$$\nabla \cdot \boldsymbol{B} = 0$$
$$\nabla \times \boldsymbol{E} = -\frac{\partial \boldsymbol{B}}{\partial t}$$
$$\nabla \times \boldsymbol{B} = \mu_0\left(\boldsymbol{J} + \varepsilon_0 \frac{\partial \boldsymbol{E}}{\partial t}\right)$$







$$i\hbar\frac{\partial}{\partial t}\Psi = \hat{H}\Psi$$

Is there a simple and elegant principle (model) behind the phenomenon of intelligence?

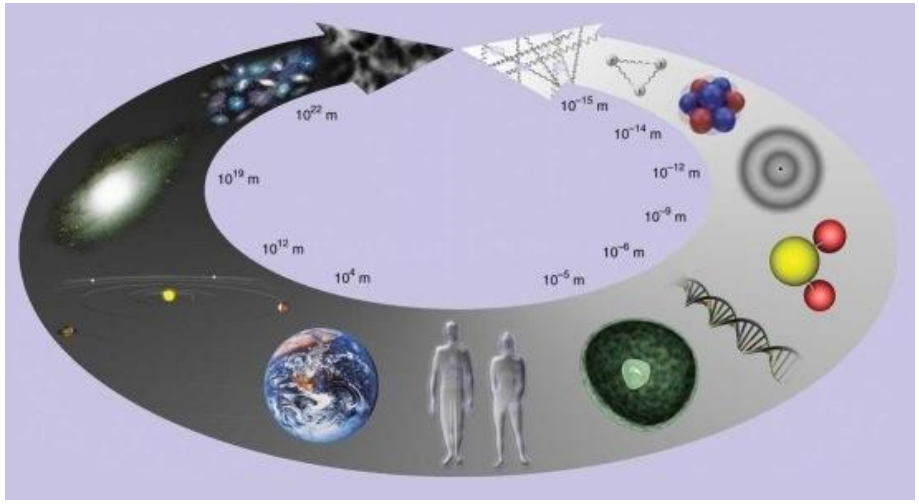
An open question, 7 answers (opinions)

- ①No, intelligence is a collection of (unlimited) abilities
- ②Yes, intelligence is an emergence of (large-scale) complex systems
- ③Yes, intelligence is a meta-ability
  - Learning ability
  - Adaptation to new task or new environment
  - The ability to acquire all other abilities
  - The principle that once is organized in such a way, it will automatically discover and utilize all other principles of the world
- ④Yes, intelligence is world model
- ⑤Yes, intelligence follows free energy principle (FEP)
- ⑥Yes, intelligence comes from parsimony and consistency
- ⑦Yes, intelligence comes from compression, simulation, adaptation

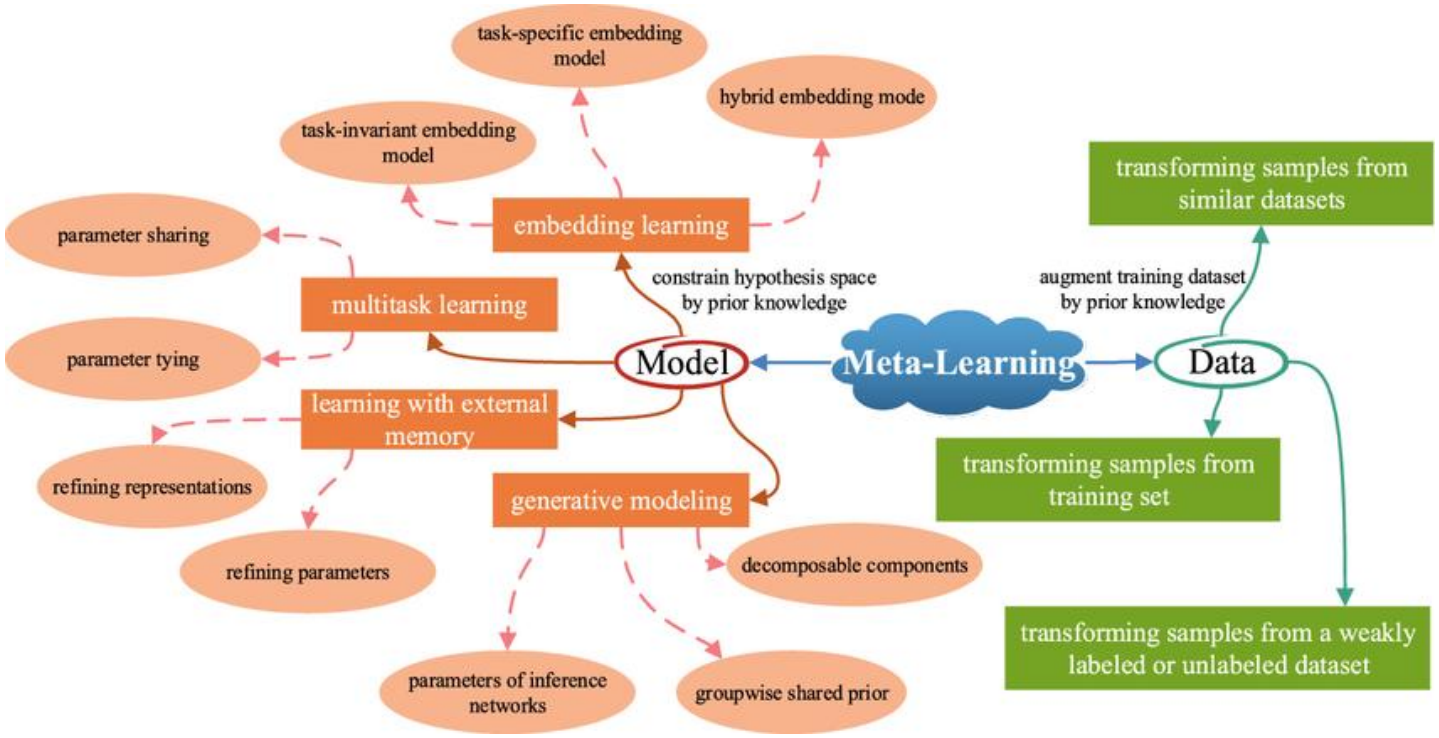
①No, intelligence is a collection of (unlimited) abilities

②Yes, intelligence is an emergence of (large-scale) complex systems

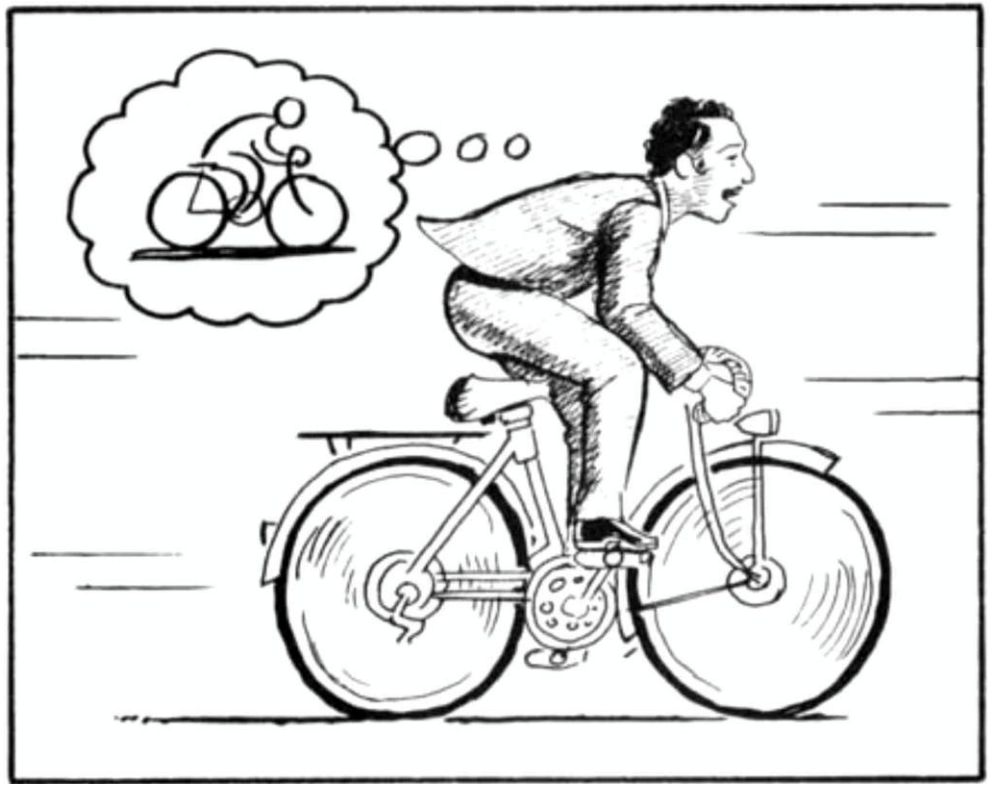
- Ant → Ant ball

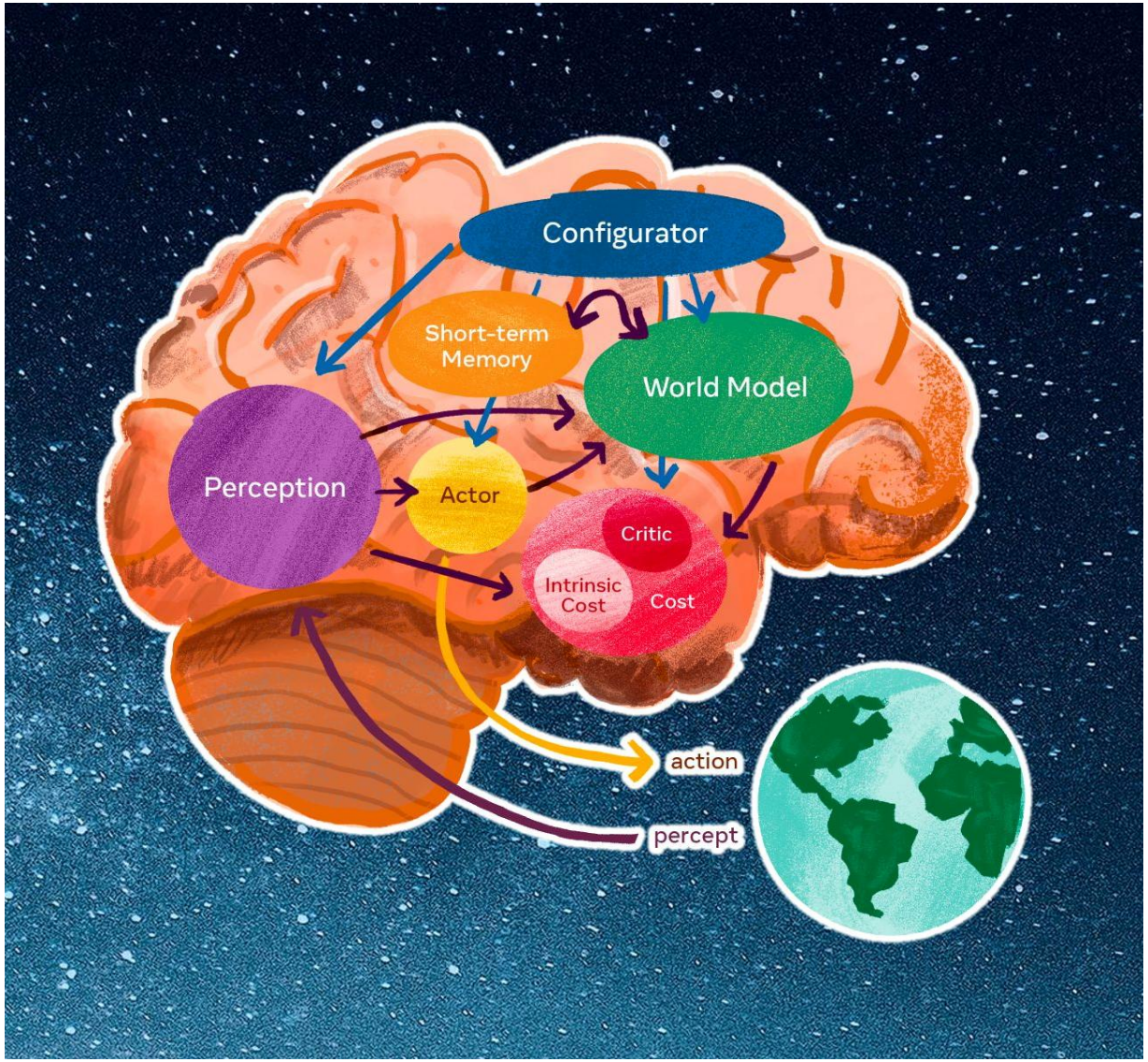


③Yes, intelligence is a meta-ability



④Yes, intelligence is world model





⑤Yes, intelligence follows free energy principle (FEP)

- **Intelligence is prediction (Bayesian inference machine)**

- **Object Recognition in a Dimly Lit Room**
- **Scenario:**

You enter a dimly lit room and see a vague shape. Based on prior experience, you predict that it is a chair.

- **Process Explanation:**
  1. **Internal Model Prediction:**

     Your brain predicts that the **object s** is a chair, so the **internal model Q(s)** assigns a high probability to s=chairs.
  2. **Sensory Input:**

     The **visual input o** is unclear due to poor lighting, leading to a discrepancy between prediction and actual input.
  3. **Minimizing Free Energy:**
     1. **Perceptual Inference:**

        You might **adjust your internal model** to consider other possibilities, such as the **object being a suitcase**.
     2. **Active Inference:**

        You **move closer** to the object or **turn on a light** to obtain clearer sensory input.
  4. **Outcome:**

     By acting or updating your beliefs, you reduce the prediction error, lower free energy, and accurately identify the object as a chair.

$$F = D_{\mathrm{KL}}(Q(s)\|P(s|o)) - \ln P(o)$$

Where:

- F is the free energy.
- $D_{\mathrm{KL}}(Q(s)\|P(s|o))$ is the Kullback-Leibler (KL) divergence between the approximate posterior distribution $Q(s)$ and the true posterior distribution $P(s|o)$, measuring the difference between the two distributions.
- $Q(s)$ is the organism's approximate posterior distribution over the environmental states s (the internal model).
- $P(s|o)$ is the true posterior distribution of the states given the observations o.
- $P(o)$ is the marginal likelihood or prior probability of the observations.

Since organisms cannot directly compute the true posterior $P(s|o)$, they minimize free energy F to make their internal model $Q(s)$ as close as possible to $P(s|o)$.

⑥Yes, intelligence comes from parsimony and consistency

- 提出两个原则:
  - **Parsimony简约**
  - **Self-consistency自洽**
  - govern the function and design of any intelligent system, artificial or natural
- 对应回答两个问题
  - 1. What to learn: what is the objective of learning from data, and how can it be measured?
    - Information/Coding Theory信息论、编码理论： how to accurately quantify and measure the information in the data and then seek the most compact representations of the information
  - 2. How to learn: how can we achieve such an objective via efficient and effective computation?
    - Control/Game Theory控制论、博弈论： a universally effective computational framework, i.e., a closed-loop feedback system, for achieving any measurable objective consistently

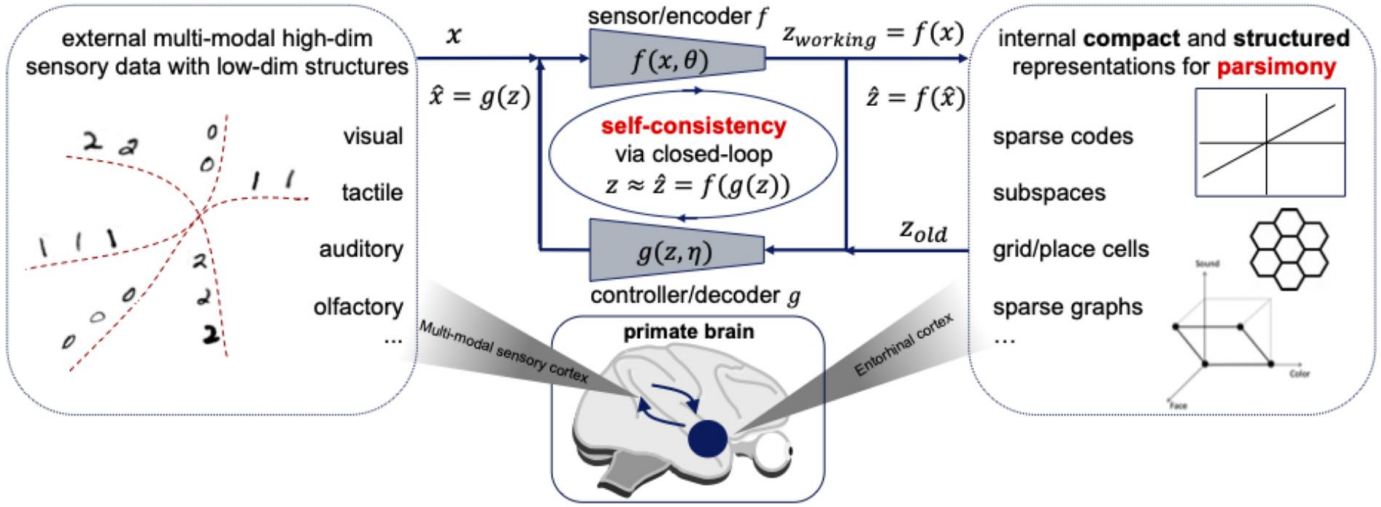
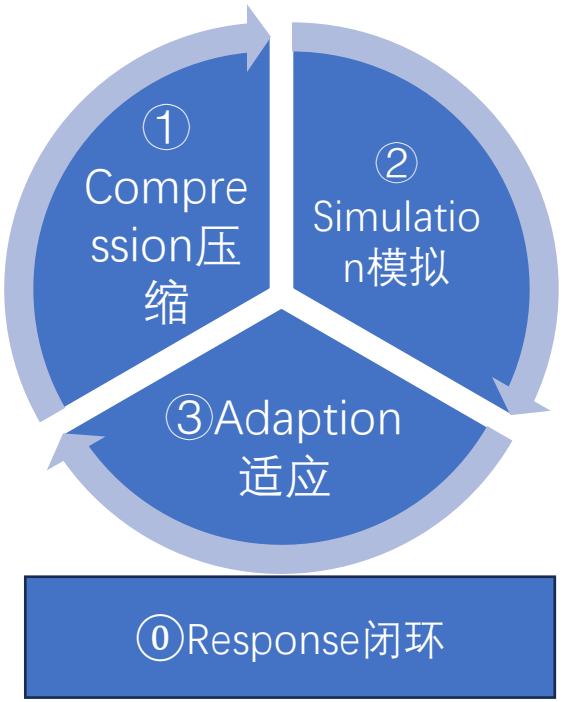


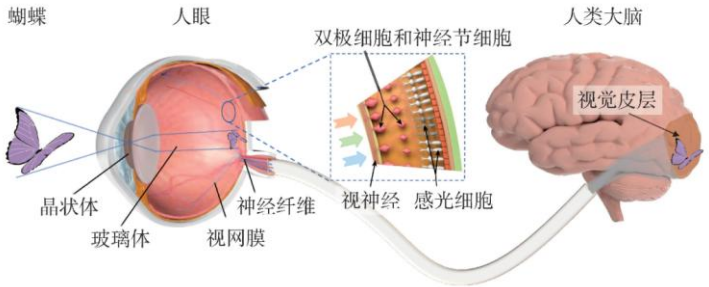
Fig. 1 Overall framework for a universal learning engine: seeking a compact and structured model for sensory data via a compressive closed-loop transcription: a (nonlinear) mapping $f(\cdot, \theta) : x \mapsto z$ that maps high-dimensional sensory data with complicated low-dimensional structures to a compact structured representation. The model needs to be self-consistent, i.e., it can regenerate the original data via a map $g(\cdot, \eta) : z \mapsto \hat{x}$ such that f cannot distinguish despite its best effort. (Often, for simplicity, we omit the dependency of the mappings f and g on their parameters θ and η, respectively.)

⑦Yes, intelligence comes from response, compression, simulation, adaptation

- **1 basic aspects**
  - **①Response**
    - ①Form the closed loop of perception-decision-action
      - Input-calculate-output
      - Robot vacuum
      - Autonomous vehicle
      - Chatbot
- **3 advanced aspects**
  - **②Information representation**
    - ②Collect, transform, and often compress information, to form an internal representation of task-related information
      - Convolution, feature extraction (in CV)
      - State representation "world model" (in RL)
      - Word embedding (in NLP)
      - Attention-based encoder (in ChatGPT)
      - SLAM (in robotics)
      - Human vision
    - …
  - **③Dynamics simulation**
    - ③Based on the internal information representation, simulate the dynamics of the task-related subsystem of the world-self system, evaluate action reward towards goal, and output action decision
      - Classifier inference (in CV)
      - Rule-based Factoring
      - Causal inference (in ML)
      - Q-value calculation (in RL)
      - Route planning (in robotics)
      - Trajectory prediction (with GNN)
      - Human thinking
  - **④Learning**
    - ④Interact with external world, update the self to better serve the goal
      - Supervised training of a classifier
      - NTP training of a LLM foundation model
      - RLHF
      - Policy update of an agent (in RL)
      - Non-BP-based parameter update
      - Human training (adaption to a new task or new environment)
- Proposed "Levels of Intelligence"
  - L0: Non-intelligence
  - IS-L1: ①
  - IS-L2: ①+②+③
  - IS-L3: ①+②+③+④



Relook at a few examples



- Face Recognition access control system 人脸识别门禁系统
  - ① Response
    - Input picture – calculation – output door control action
  - ② Compression (information representation):
    - Camera
    - light → electric signal → image → features
  - ③ Simulation (dynamics simulation):
    - Recognition as a certain person (e.g., softmax), judge in the granted database or not
      - Pre-installed knowledge
    - output action (open the door or not)
  - ④ Adaptation:
    - Training process (parameter update)
    - Re-train with bigger/better data
- ChatGpt
  - ① Response
    - Input text query – calculation – output response
  - ② Compression (information representation):
    - Natural language and artificial symbol (scientific, programming, etc) as baseline representation
    - Embedding
    - Transformer encoder → new (numerical) representations
  - ③ Simulation (dynamics simulation):
    - Activation of single or multiple neurons on a certain task
      - Some internal structure of knowledge about the world
    - Logical Factoring
  - ④ Adaptation:
    - Training process (parameter update)
    - Re-training and version update
      - ChatGPT May 24 Version
- Human
  - ① Response
    - Input sensory info – “calculation” – output actions
  - ② Compression (information representation):
    - Example: vision and brain
  - ③ Simulation (dynamics simulation):
    - Sys1
    - Sys2
  - ④ Adaptation:
    - Education
    - New environment adaption

Natural Flight and Artificial Flight 自然飞行与人工飞行

- Same 相同
  - Wings 翅膀
  - Feet 脚
  - The interaction between wings and air generates upward force 翅膀与空气的相互作用产生向上的力
- Different 不同
  - Flapping wings vs fixed wings 扇动翅膀vs固定翼
  - Energy source: insects vs gasoline 能量来源：虫子vs汽油
  - Control signals: nerves vs wires and optical fibers 控制信号：神经vs导线与光纤
- Artificial performance is better 人工表现更优
  - Flight speed, altitude, range 飞行速度、高度、航程
  - Flight load capacity 飞行载重
- Natural performance is better 自然表现更优
  - Flight maneuverability 飞行机动
  - Flexibility of takeoff and landing conditions 起降条件灵活性

Natural Intelligence and Artificial Intelligence 自然智能与人工智能

智能能力分类	人类能力特点	大模型AI能力特点	能力对比（AI相对人类水平）
1. 感知处理	多模态整合能力强，但带宽有限（如视觉仅400-700nm）	单模态处理卓越，多模态融合待提升（如CLIP的跨模态对齐误差）	**2005**: 30% **2015**: 60% **2025**: 120% **2035**: 300% **2045**: 500% （特定传感器下）
2. 程序性记忆	容量有限（工作记忆4±1组块），但具身记忆深刻	存储容量无限，但缺乏情境关联（如ChatGPT的"记忆失联"现象）	**2005**: 10% **2015**: 200% **2025**: 1e4% **2035**: 1e6% **2045**: 理论无限 （提取效率受限）
3. 逻辑推理	慢速但稳健（每小时处理约5个复杂推论）	快速但无法确保正确（GPT-4数学证明错误率18%）	**2005**: 5% **2015**: 30% **2025**: 90% **2035**: 200% **2045**: 500% （受限哥德尔不完备定理）
4. 模式识别	强小样本学习（儿童单样本识物），弱于海量数据	大数据下卓越（ImageNet 99%），小样本弱（Few-shot learning 80%）	**2005**: 40% **2015**: 150% **2025**: 300% **2035**: 1000% **2045**: 超越生物感知极限
5. 知识整合	跨领域联想能力强（如达芬奇式思维），但知识广度受限	领域内整合强（如AlphaFold2），跨领域组合强	**2005**: 8% **2015**: 50% **2025**: 120% **2035**: 300% **2045**: 800% （更底层的创新）
6. 动作控制	精细操作卓越（人手7自由度），能量效率高（20W）	机械精度高（工业机器人0.02mm），但适应性差（新任务需重新编程）	**2005**: 20% **2015**: 80% **2025**: 150% **2035**: 400% **2045**: 1000% （结构化环境）
7. 情感理解	深度共情（镜像神经元系统），文化敏感性	可做情绪识别（FER准确率92%），情感现象的机制不同	**2005**: 5% **2015**: 40% **2025**: 80% **2035**: 120% **2045**: 200% （无生物化学体验）
8. 创造性思维	突破性创新（量子力学诞生），但产出效率低	组合式创新（DALL-E 3），缺乏范式颠覆能力	**2005**: 2% **2015**: 15% **2025**: 60% **2035**: 150% **2045**: 300% （已有范式内）
9. 战略决策	模糊环境下的风险预估（前额叶皮层），长期视野	明确规则下优化（AlphaGo），复杂环境易失焦	**2005**: 1% **2015**: 20% **2025**: 70% **2035**: 150% **2045**: 250% （需人类设值）
10. 元认知	自我反思与认知调控（默认模式网络），终身学习	有限的自监控（如AI安全护栏）	**2005**: 0.1% **2015**: 5% **2025**: 30% **2035**: 80% **2045**: 120% （不同的意识特征基础）
11. 伦理判断	文化适应性道德推理（科尔伯格阶段理论）	规则化伦理（Asimov三定律），对伦理规则的机械性理解	**2005**: 0% **2015**: 10% **2025**: 50% **2035**: 90% **2045**: 150% （预设框架内）
12. 具身认知	多感官统合的环境交互（本体感觉+前庭系统）	传感器数据融合困难（机器人的地形适应延迟）	**2005**: 1% **2015**: 15% **2025**: 60% **2035**: 200% **2045**: 500% （结构化环境）
13. 社会智能	复杂人际关系导航（邓巴数150），非言语交流	表面社交模式（Replika聊天机器人），缺乏深层理解	**2005**: 2% **2015**: 25% **2025**: 80% **2035**: 150% **2045**: 300% （标准化场景）
14. 跨域迁移	知识类比迁移（蒸汽机→热力学）	需要显式提示（GPT-4的思维链引导），自发迁移弱	**2005**: 0.5% **2015**: 10% **2025**: 50% **2035**: 120% **2045**: 250% （相似领域间）
15. 意识体验	主观感受（感质），自我意识	无真正意识（中文房间论证），行为模拟	**2005**: 0% **2015**: 10% **2025**: 30% **2035**: 90% **2045**: 120% （哲学不可逾越）

Thank you!

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Pillars.Creation 创世之柱（Left左: C8HD, Right右: Hubble.Space.Telescope哈勃） | Target: d~5700Ly/D~5Ly(pillar)/VM=+6.4 | Telescope: D=203mm/F=1439mm/T~336min | Time.Loc.: 20230528/CN-SZ-KJY@Bortle9 | Photo by: 馒头星系Matt

OOB Fun Time