Artificial Intelligence: Implications for Healthcare Practice, Research, and Education

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Overview

- Uses, successes, and limitations of AI in medicine
- AI in education
- AI impacts on how we find and apply information

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Artificial intelligence (AI)

- AI – information systems and algorithms capable of performing tasks associated with human intelligence (Stanford, 2024)
  - Origin of term attributed to summer workshop held at Dartmouth College in 1956 (McCarthy, 2007)
  - A large part of modern success due to machine learning (ML) – "computer programs that learn without being explicitly programmed" (McCarthy, 1990, attributed to Samuel, 1959)
    - Most success with deep learning, based on many-layered neural networks

Three "epochs" of AI (Howell, 2024), leading to current (21st century) classification of

- Predictive AI
- Generative AI

Next epoch may be agentic AI (Powell, 2026)?

Approximate beginning year	1950s **AI 1.0** Symbolic AI and probabilistic models	2011 **AI 2.0** Deep learning	2018-2022 **AI 3.0** Foundation models
Core functionality and key features	Follows directly encoded rules (if-then rules or decision trees)	Predicts and/or classifies information Task-specific (1 task at a time); requires new data and retraining to perform new tasks	Generates new content (text, sound, images) Performs different types of tasks without new data or retraining; prompt creates new model behaviors
Training method	Rules based on expert knowledge are hand-encoded in traditional programming	Learning patterns based on examples labeled as ground truth	Self-supervised learning from large datasets to predict the next word or sentence in a sequence
Performance capabilities	Follows decision path encoded in its rules. *Eg, ask a series of questions to determine whether a picture is a cat or a dog.*	Classifies information based on training: *"Is this a cat or a dog?"* *"How many dogs will be in the park at noon?"*	Interprets and responds to complex questions: *"Explain the difference between a cat and a dog."*
Examples of performance	IBM's Deep Blue beat the world champion in chess **Health care:** Rule-based clinical decision support tools	Photo searching without manual tagging, voice recognition, language translation **Health care:** diabetic retinopathy detection, breast cancer and lung cancer screening, skin condition classification, predictions based on electronic health records	Writing assistants in word processors, software coding assistants, chatbots **Health care:** Med-PaLM and Med-PaLM-2, medically tuned large language models, PubMedGPT, BioGPT
Examples of challenges and risks	Human logic errors and bias in encoded rules lead to limited capability with real-world situations	Out-of-distribution problems (real-time data differs from training data) Catastrophic forgetting (not remembering early parts of a long sequence of text) Bias related to underlying training data	Hallucinations (plausible but incorrect responses based solely on predictions) Grounding and attribution Bias related to underlying training data and semantics of language in datasets

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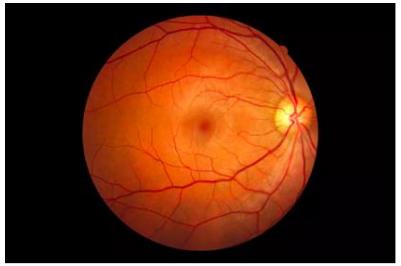
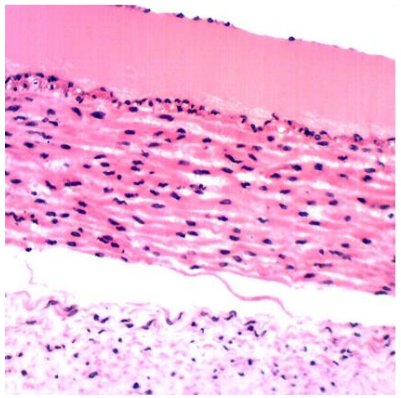
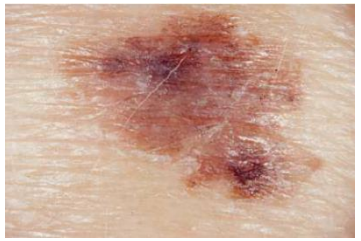
Predictive AI in medicine

- "Predictive AI" driven by advances in ML, increasing availability of data, and more powerful computers and networks (Topol, 2019; Rajpurkar, 2022)
  - Deep learning in imaging breakthroughs by Hinton (2006) – led to Nobel Prize for Physics 2024
- Most success in image interpretation (Rajpurkar, 2023); examples include
  - Radiology – chest x-rays for diagnosis of pneumonia and tuberculosis
  - Ophthalmology – retinal images for diagnosis of diabetic retinopathy
  - Dermatology – skin lesions for diagnosis of cancer
  - Pathology – breast cancer slides to predict metastasis







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Predictive AI not limited to imaging

- Many promising results, e.g.,
  - Protein folding from amino acid sequences (Jumper, 2021) – led to Nobel Prize for Chemistry 2024
  - Semantic reconstruction of continuous language from fMRI brain recordings (Tang, 2023)
  - Map chemicals to odors perceived by humans (Lee, 2023)
  - Predict Alzheimer's Disease from EHR data up to 7 years before diagnosis (Tang, 2024)
  - AI-supported mammography screening showed consistently favorable outcomes compared with standard double reading (Gommers, 2026)
- Mixed results in practice, e.g.,
  - Computer-aided detection (CAD) in colonoscopy did not improve detection of significant lesions (Hsu, 2026) – may lead to "de-skilling" (Budzyń, 2025)
  - Externally-validated CDS tools from Epic show mixed accuracy (Patel, 2026)

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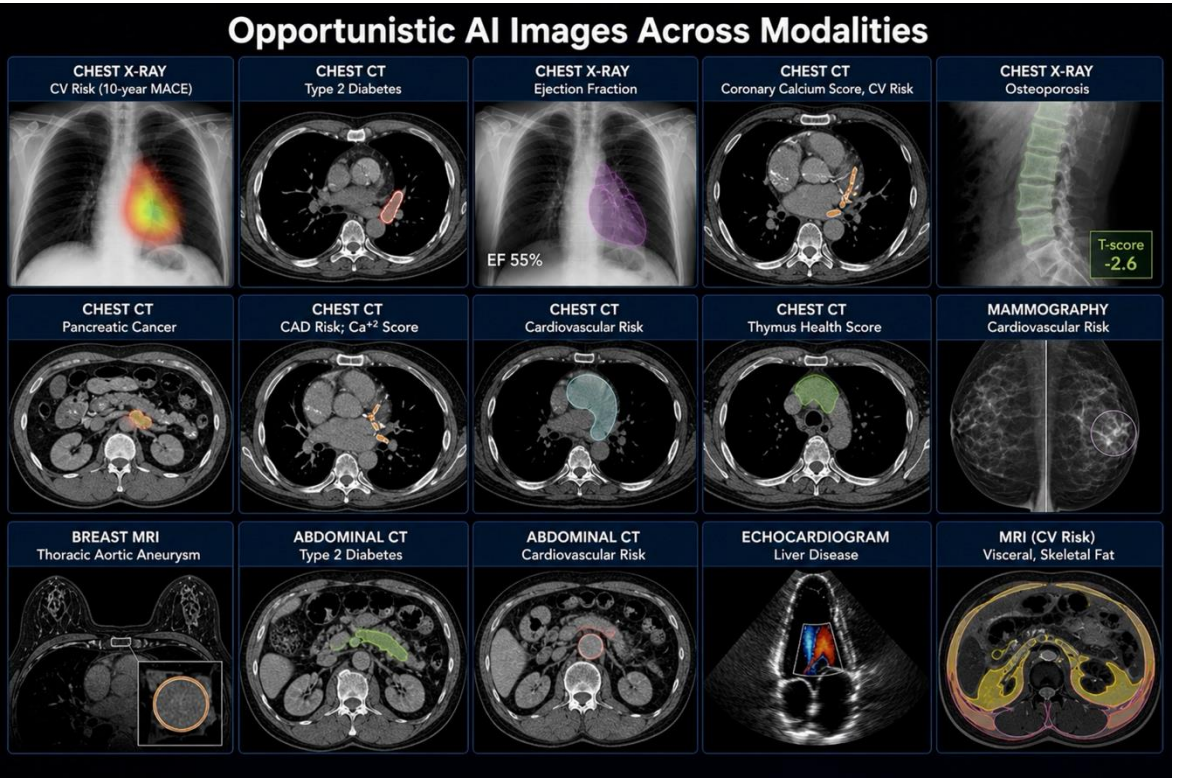
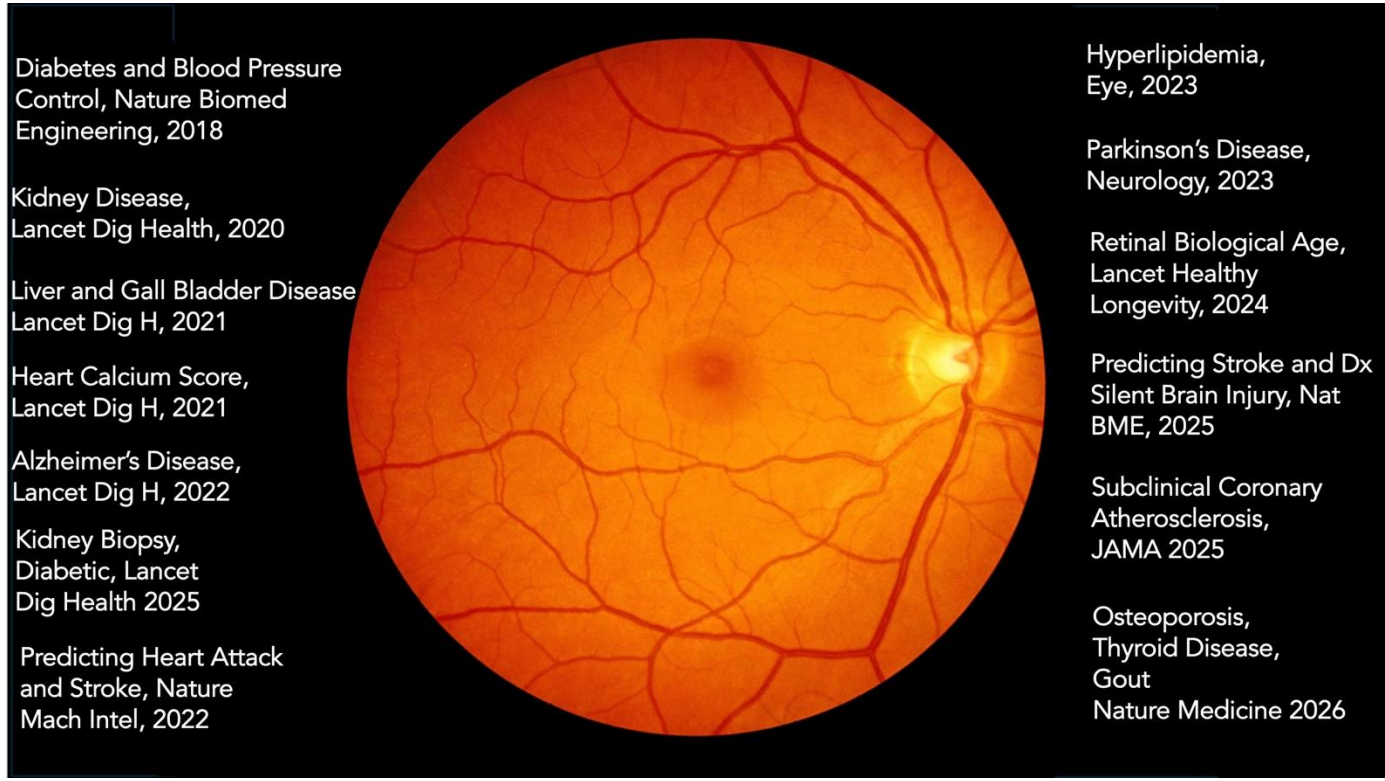
Can also “see” where humans cannot (Topol, 2022) – “opportunistic” AI (Topol, 2026)





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And now, generative AI

- Introduction of ChatGPT on November 30, 2022 brought new type of AI into focus: generative AI
- Based on large language models (LLMs) processed by deep neural networks using large amounts of training data and tuned for specific tasks (Teo, 2025; Wachter, 2026, Topol, 2026)
  - Trained on massive amounts of text and other content, e.g., large Web crawls, books, Wikipedia, and more for GPT (Roberts, 2022)
  - Use transformer models that predict words in sequence from billions/trillions of words and add measure of importance to “attention” words (Shao, 2024)
  - Fine-tuned with reinforcement learning from human feedback (RLHF) (Lambert, 2022)
  - Activated by (and importance of) prompting (Meskó, 2023; Liu, 2025)
  - Think “differently” from humans (Perc, 2025)

Recent developments in generative AI

- Growing use by
  - Patients
    - 32% of US adults for physical or mental health (Montero, 2026)
    - 20% of adolescents for mental health advice (McBain, 2026)
  - Consumers
    - 49% of US adults (Gottfried, 2026)
    - 55% of US adults over 50 (Brewer, 2025)
  - Clinicians – 81% of US physicians (AMA, 2026)
- From chatbots to agents – agentic AI (Zou, 2025; Powell, 2026)
  - From LLM responses to agents that sense, plan, act, and learn
  - Interaction with systems (e.g., EHRs), tools (e.g., knowledge access), and other agents to solve specific tasks, e.g., medical diagnoses, treatment recommendations, etc.

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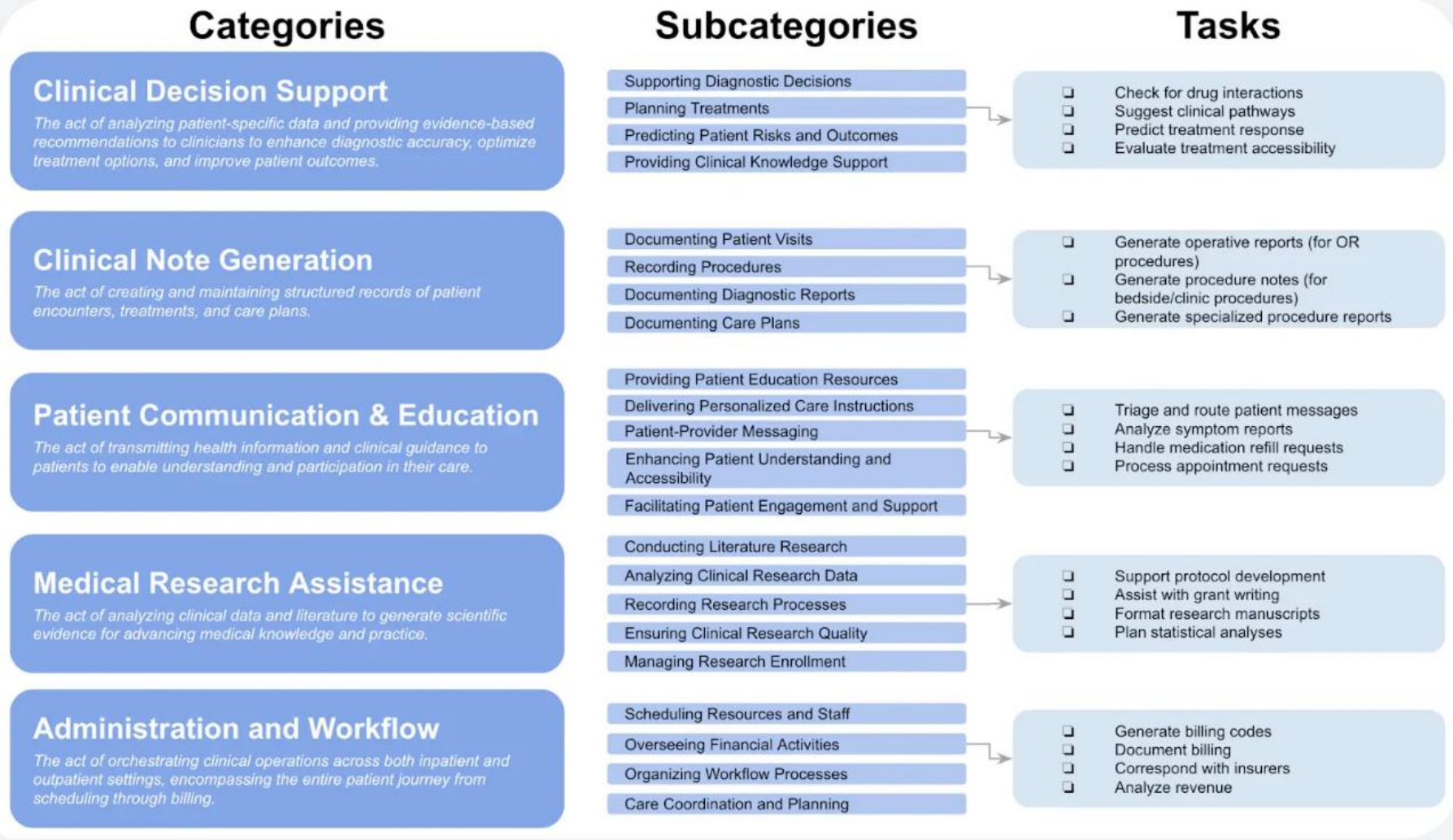
Uses of generative AI in healthcare (Shah, 2025)



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Successes and caveats from AI research

Successes and caveats

- Passing board exams
- Solving clinical cases
- Summarizing care
- Patient communication
- Conducting research
- Coordinating care

Concerns

- Tsunami of research papers
- Models are “black boxes,” proprietary and constantly changing
- Mostly models using datasets; little on real-world patient care and other tasks
- Predominantly text-based

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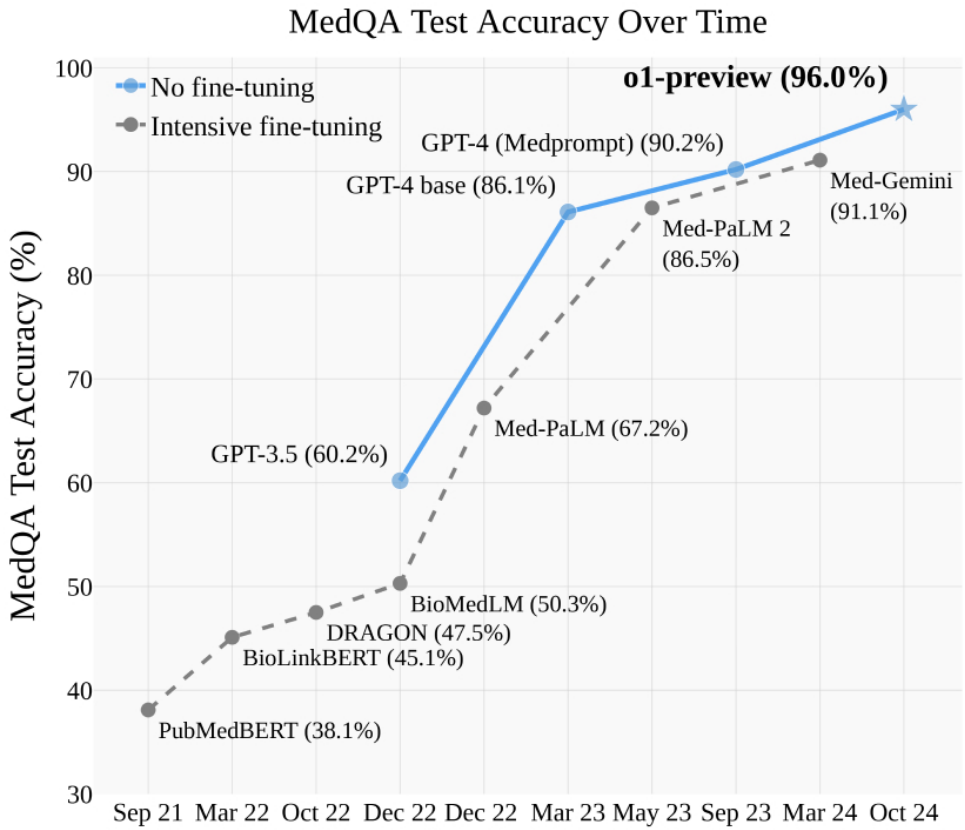
Early success – passing medical board exams

- MedQA dataset based on sample multiple-choice questions (12,273 in English, more in Chinese) from three-part medical exam required for licensing in US (Jin, 2021)
- USMLE "arms race" (Kung, 2023; Nori, 2023; Saab, 2024; Horvitz, 2024; Nori, 2024; OpenEvidence, 2025)
- Systematic review found 16 LLMs on 198 medical exams conducted in 28 countries across 15 languages (Zong, 2024)
  - Including post-residency board exams in Israel (Katz, 2024)
- Concerns for MedQA dataset
  - Time to bench USMLE benchmark? (Raji, 2025)
  - Changing correct answer to "none of the above" resulted in up to halving of scores (Bedi, 2025)



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Solving clinical cases – many studies, datasets, models, etc.

- Early LLMs comparable to expert humans (Kanjee, 2023; Rao, 2023; Chen, 2023; Cabral, 2024)
- Randomized vignette study of diagnostic reasoning (Goh, 2024)
  - Physicians scored comparably with or without GPT-4 (76.3% vs. 73.7%, NS)
  - GPT-4 alone did better (92.1%, SS)
- Outperformed physicians in emergency medicine at three diagnostic touchpoints (triage in ER, initial evaluation by physician, and admission to hospital or ICU) (Brodeur, 2026)
- Frontier models (GPT, Gemini, Claude) vs. specialized clinical models (Open Evidence, UpToDate AI)
  - Frontier models better in MedQA questions, HealthBench dataset items, and physician-generated queries (Vishwanath, 2026)
  - OE better in 620 real-world point-of-care queries (Real-POCQi) (Feng, 2026)

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Caveats for solving clinical cases – does AI "outperform" physicians?

- "Cases" entered in research studies typically highly curated and well-written – different from workflow of clinical practice (Pines, 2026)
- Frontier LLMs achieved high accuracy on final diagnoses but performed less well at generating differential diagnoses and navigating uncertainty at other reasoning stages (Rao, 2026)
- Performance declines with human use of LLMs
  - Physicians
    - For written cases, LLMs alone better (Goh, 2024)
    - Even with AI literacy training, still show automation bias (Qazi, 2026)
  - Patients – for 10 scenarios, LLMs alone identified conditions and dispositions better than use by general public (Bean, 2026)

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Summarizing care

- Widely adopted use is “ambient dictation”
  - Solution for increased clinician time spent in EHR
  - High physician satisfaction but small objective time savings (Shah, 2025; Ma, 2025; Duggan, 2025; Stults, 2025)
- Growing use for summarizing
  - Clinic notes (Van Veen, 2024)
  - Emergency department (You, 2026)
  - Discharge summaries (Grolleau, 2026)
  - In general, high satisfaction but small time savings

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Patient communication

- Early successes
  - Answering questions in public forums (Sarraju, 2023; Ayers, 2023)
  - Writing letters with comparable or better empathy (Ali, 2023, Ayers, 2023)
- Patient chatbots for health questions reviewed by physicians found 76% accuracy (Mingole, 2026)
  - Experience in health system patient portal showed high usability and satisfaction, especially among patients with greater comorbidities (Tai-Seale, 2026)
- Drafting replies to patient messages (Baxter, 2024; Small, 2024)
  - High clinician satisfaction; no time savings (Tai-Seale, 2024)

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Conducting research

- Growing ability to conduct aspects of research from hypothesis generation to experiments and data analysis – especially with use of agents (Li, 2026; Lu, 2026)
- Demonstrated success in identifying therapeutic agents for
  - Novel SARS-CoV-2 nanobodies (Swanson, 2025)
  - Dry age-related macular degeneration (dAMD) (Ghareeb, 2026)
- Concerns
  - Increasing volume of lower-quality publications, overwhelming peer-review system (Gartenberg, 2026)
  - Growing concern for “AI slop” in scientific papers (Thorp, 2026)
  - Detection of fabricated citations – increased from 4 per 10K papers through 2024 to 57 per 10K papers in 2026, 1 in 277 papers have 1+ (Topaz, 2026)

Coordinating care

- Growing application of agents for coordination of care (Jiang, 2025; Xu, 2026)
  - ChatEHR to navigate within Epic EHR (McElfresh, 2025)
  - Personal health agents (Heydari, 2025)
  - Deploying in clinical practice (Gallifant, 2025)
- Uptake by EHR vendors, e.g. Epic EHR agents for patients, clinicians, and healthcare operations

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Some downsides to generative AI

- Dictionary.com 2023 word of year: *hallucinate* (Norlen, 2023)
- Fabrication and errors in bibliographic citations (Walters, 2023; Wu, 2025)
  - Search still matters – authority of information as important as content (Hersh, 2024)
- Perpetuating bias
  - 8 clinical questions asked of 4 LLMs recapitulated “harmful, race-based medicine” (Omiye, 2023)
  - Give variable advice dependent upon race, socioeconomic status, and LGBT status not supported by clinical reasoning (Omar, 2025; Ji, 2025)

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Downsides to generative AI (cont.)

- Neither algorithms (Tang, 2024) nor humans (Cooke, 2025) can reliably detect
  - More likely to classify non-native English writing as AI-generated (Liang, 2023)
  - Clinicians unable to distinguish human-generated vs. ChatGPT-generated medical manuscripts (Helgeson, 2025)
- Deepfakes
  - Threaten clinician identity, data in record, and evidence (Bair, 2026)
  - Need to protect physician identity, patient safety, and trust (AMA, 2026)

Additional downsides to AI in general

- After clinical models deployed, performance may decline due to actual real-world use (Vaid, 2023; Palmer, 2023)
- Implementing diabetic retinopathy screening in rural Thailand and India found (Widner, 2023)
  - Challenges related to equipment operation, workflows, and image quality
  - Need for training and attention to human factors
- Environmental impact
  - Data center usage of US electricity was 4.4% in 2023, expected to rise to 6.7-12% by 2028 (Shehabi, 2024)
  - Context of energy use important (O'Donnell, 2025)
    - Many other human uses of energy and water are comparable (Masley, 2025)
    - Is AI prompt 10-fold better than Google search (de Vries, 2023)?
  - Data center needs can be met by renewable energy (Clemmer, 2026)

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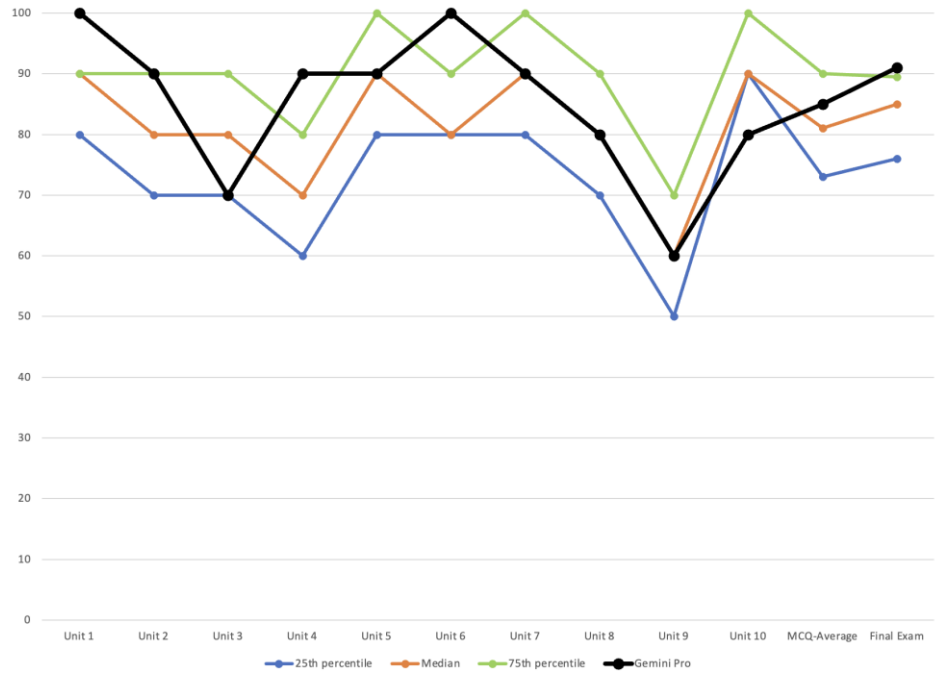
Challenges in education

- Early recognition of “homework apocalypse” (Mollick, 2023)
- Studies showing
  - Diminished skill for independent problem-solving (Lee, 2025)
  - Reduced cognitive connection and later recall (Kosmyna, 2025)
  - Use of LLMs resulted in ”shallower knowledge” than learned via Web search, even when links provided in LLM output (Melumad, 2025)
  - Diminished Long-term knowledge retention in undergraduates learning AI (Barcaui, 2025; Liu, 2026)
- Challenges for student assessment in an online introductory informatics course (Hersh, 2024)



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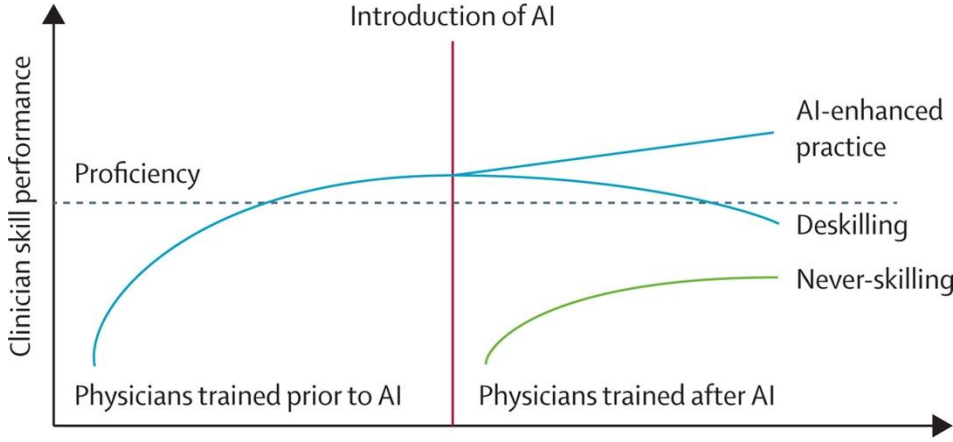
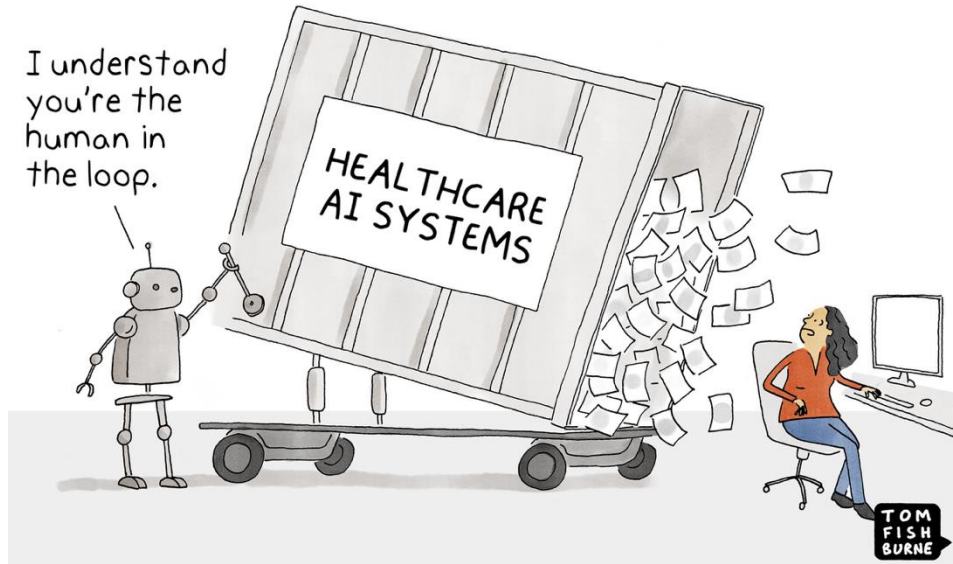
Challenges in medical education

- Concerns for de-skilling and never-skilling (Berzin, 2025)
- Scoping review found risk of deskilling and loss of expertise among multiple specialties (Heudel, 2026)
- Focus on “clinician in the loop” may shift responsibility for AI safety from developers to clinicians and not be failsafe for patients (Toro-Tobon, 2026)
- Concern about failure to acquire the cognitive foundations of clinical expertise because AI tools provided the answers before the struggle that produces mastery could occur (Keren, 2026)
- Students should be calibrated and supervised for optimal use in medical education and practice (Ke, 2026)





Conclusions

- AI profoundly impacting healthcare, but ultimate role unclear
  - Need real-world evidence base (Goldenberg, 2026)
  - 21st-century clinicians must be critical consumers (Hersh, 2025)
- "AI won't replace radiologists, but radiologists who use AI will replace radiologists who don't," (Langlotz, 2019)
  - (Plug in your health profession)

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Questions?

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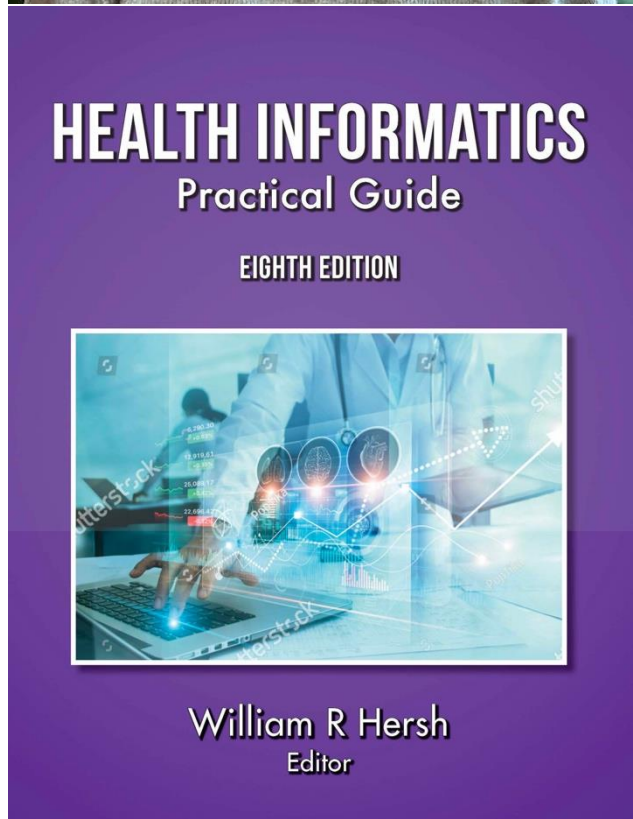

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