

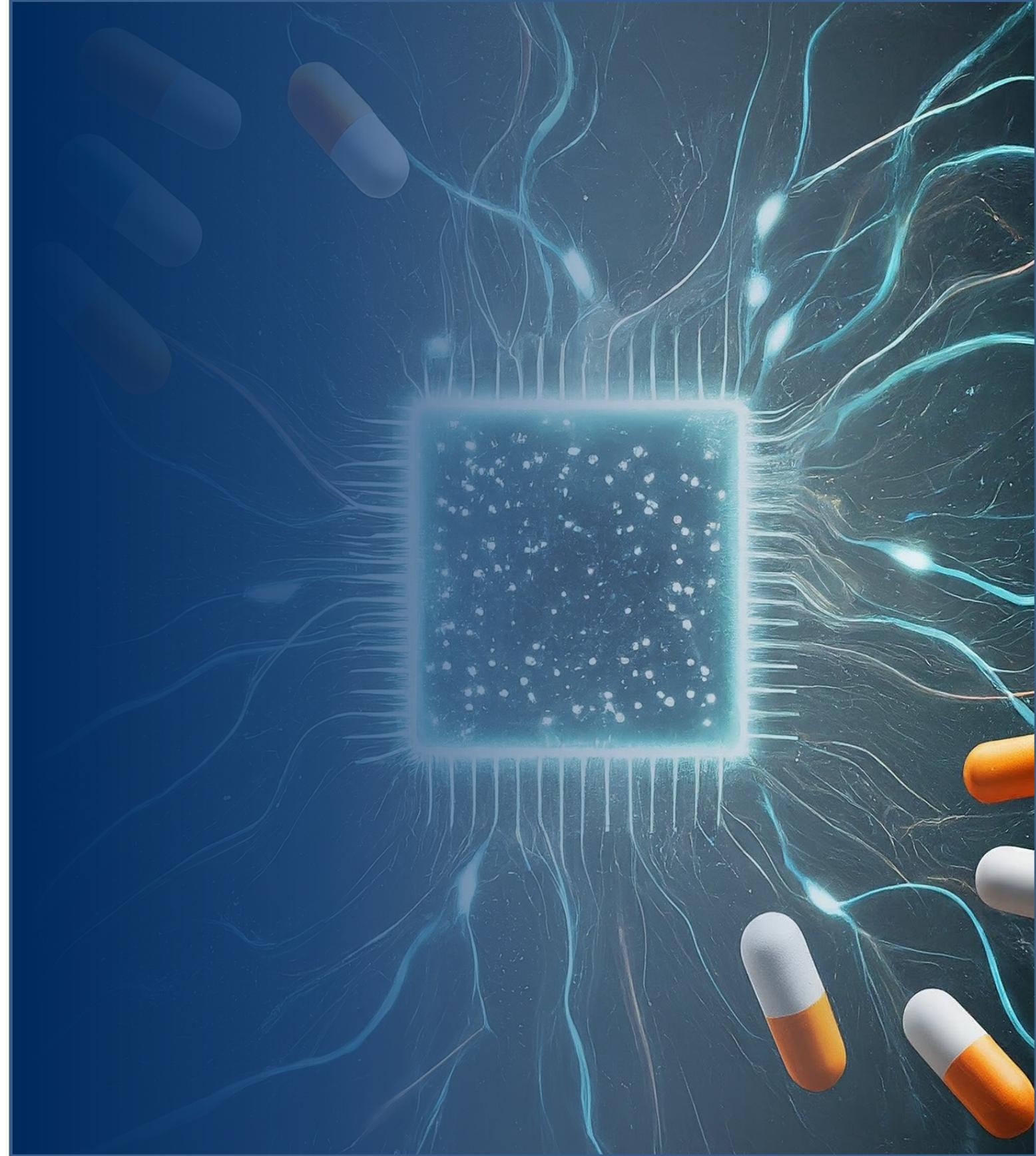
# Artificial Intelligence- Brave New World?

## Artificial Intelligence for Antimicrobial Stewardship

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University of Toronto

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# Disclosures

No relevant conflicts.

- I have received research funding (funds to organization) from the Canadian Institute for Health Research, World Health Organization, and University of Toronto

# A Pivotal Moment for Artificial Intelligence



March 2023 (Stable Diffusion)



February 2024 (Open AI, Sora)

# What is Artificial Intelligence?

“the discipline that creates computer systems capable of activities normally associated with cognitive effort”

# What is Artificial Intelligence?

## Artificial Intelligence

Computer systems capable of activities normally associated with cognitive effort

### Machine Learning

Training machines to recognize patterns. Using labelled (supervised) or unlabeled (unsupervised) data

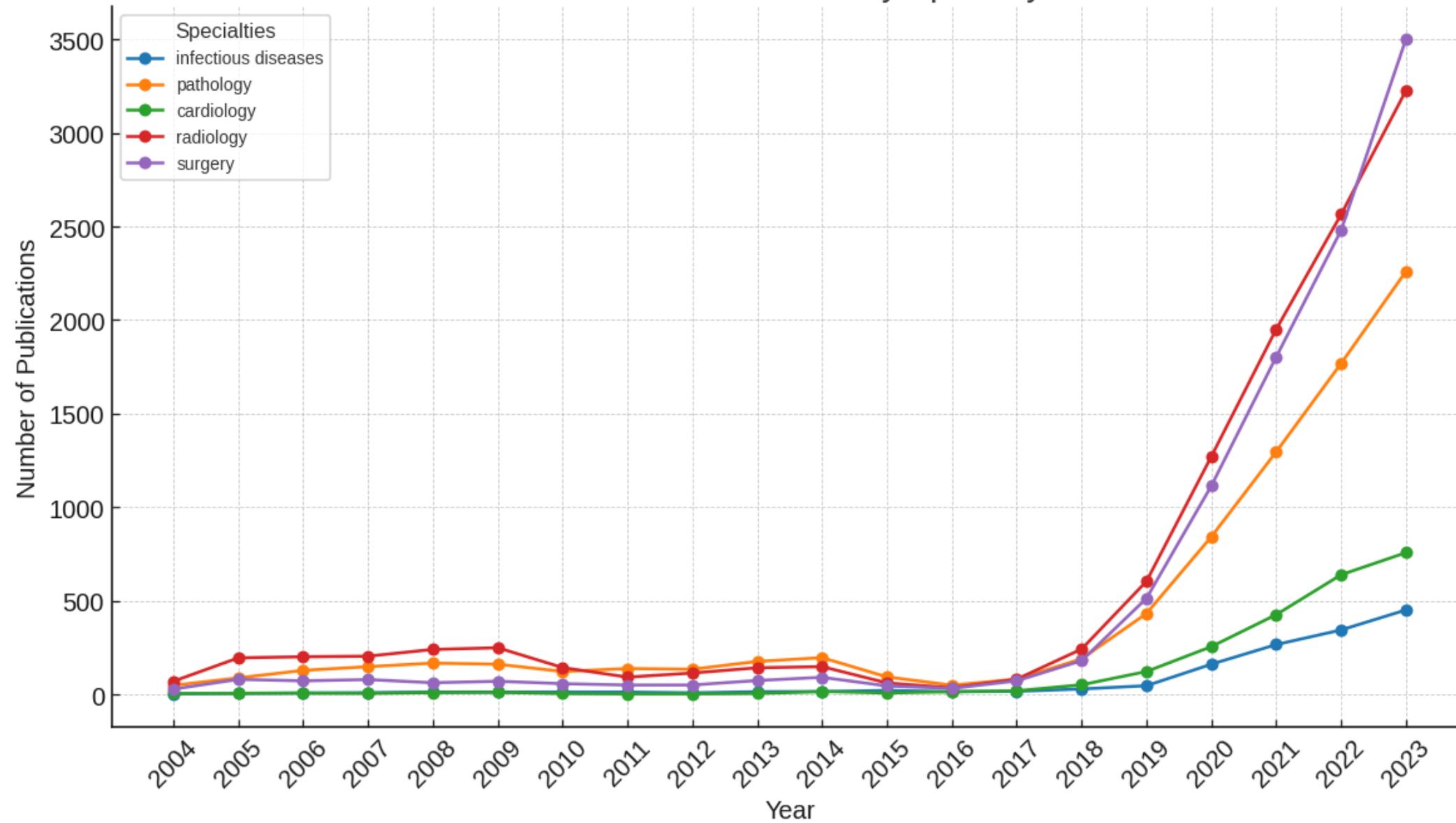
### Deep Learning

Subfield of machine learning using layered neural networks to learn from vast amounts of data

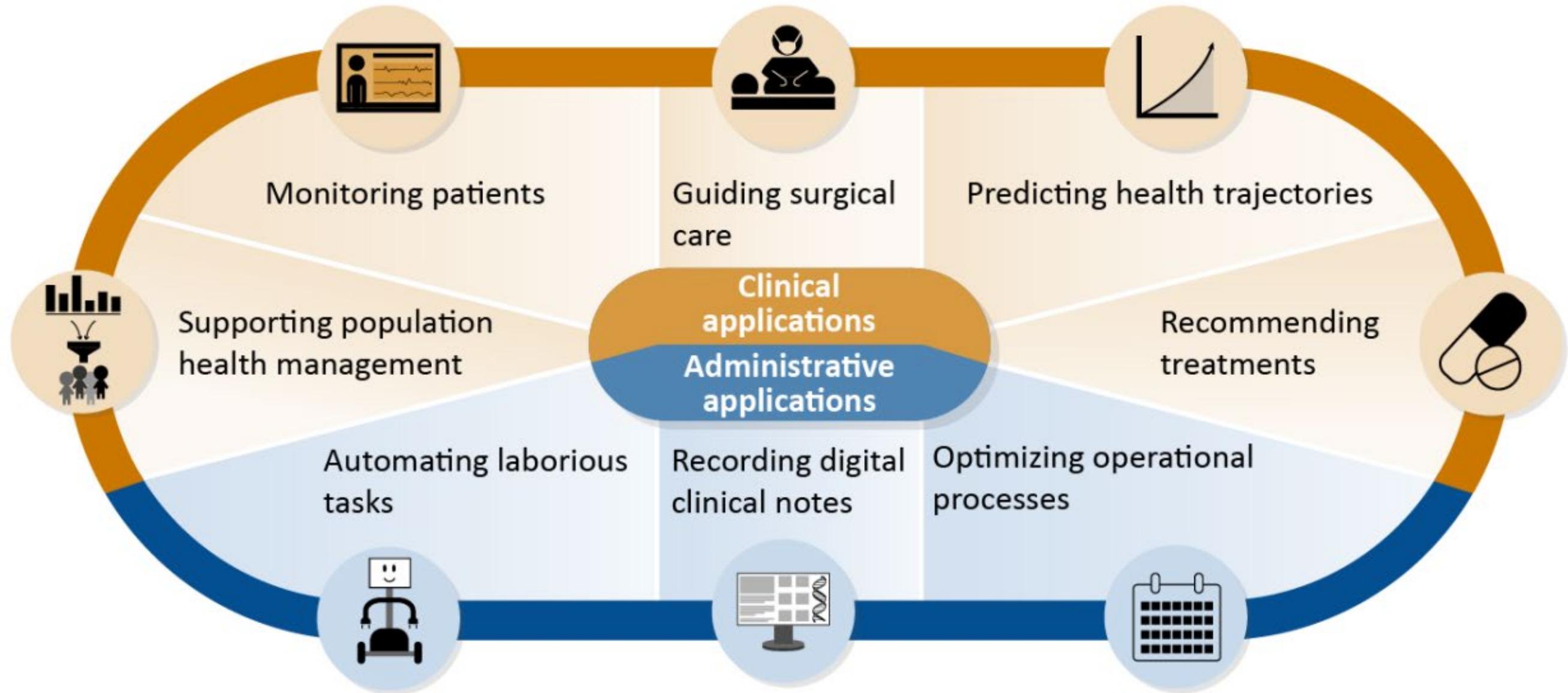
### Generative AI

Subfield of deep learning that relates to the generation of new data (text, audio, video, images)

# Artificial Intelligence Publications by Specialty



# Applications of AI in Healthcare



# Risks of Artificial Intelligence in Healthcare

Risk	Mitigation Strategy
<b>Model Bias</b> Underlying bias (e.g., race, gender) in dataset can be amplified via AI models.	Ensure high quality data input. Review and validate output. Incorporate equity lens to AI implementation
<b>Data Requirements</b> AI/ML model is limited by the quality and completeness.	Ensure sufficient volume and quality of data are available. Structured, and labelled data are ideal. Validation in new settings should be performed.
<b>Model Drift</b> Relationship between variables can change over time, leading to model instability.	Continuously evaluate model performance over time and adjust if needed.
<b>Automation (Human) Bias</b> Overreliance and excess trust in model output.	Training and education regarding AI literacy. Verification should be encouraged.
<b>Privacy Breaches</b> Risk of patient identification if data are shared beyond facility	Data protection regulations. Cryptographic models such as federated learning decentralizes AI models but allows for collaboration.
<b>Explainability</b> Sophisticated AI models are often 'black boxes' thereby reducing trust in their output.	"Explainable AI" approaches like SHAP (SHapley Additive exPlanations) can be used to measure the impact of each variable.

# Successful Implementation of AI in Healthcare



## Acceptance

- Perceived usefulness
- Perceived ease of use
- Organizational support



## Technical Integration

- Interface development (e.g., with EHR)
- Partnership with vendors
- Interdisciplinary teams



## Data and Resources

- Identified use cases
- Data cleaning and labeling
- Computational resources
- Expertise



## Governance

- Transparency and interpretability
- Mitigating inaccurate output
- Addressing ethical issues (e.g., privacy)
- Validation

# Three Epochs of AI in Healthcare

Approximate beginning year	1950s	2011	2018-2022
	AI 1.0 Symbolic AI and probabilistic models	AI 2.0 Deep learning	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. <i>Eg, ask a series of questions to determine whether a picture is a cat or a dog.</i>	Classifies information based on training: <i>"Is this a cat or a dog?"</i> <i>"How many dogs will be in the park at noon?"</i>	Interprets and responds to complex questions: <i>"Explain the difference between a cat and a dog."</i>
Examples of performance	IBM's Deep Blue beat the world champion in chess <b>Health care:</b> Rule-based clinical decision support tools	Photo searching without manual tagging, voice recognition, language translation <b>Health care:</b> 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 <b>Health care:</b> 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

Howell MD, Corrado GS, DeSalvo KB. Three Epochs of Artificial Intelligence in Health Care. JAMA. 2024;331(3):242-4.

# Epoch 1.0

## Symbolic AI and Probabilistic Models

# 1.0 Symbolic AI and Probabilistic Models

## Clinical decision support rules

- Allergy and drug-interaction check in electronic health records
- Dosing calculators
- Best practice advisory (BPA) alerts

### Diagnostic Stewardship Alerts

- Avoid order for *C. difficile* test in patients on laxatives
- Indwelling urinary catheter in place > 48 hours
- Prompt to indicate symptoms when ordering urine culture in hemodynamically stable patients

### Antimicrobial Stewardship Alerts

- Screening tool to predict risk of *C. difficile* based on history
- Positive *C difficile* assay without treatment
- Flag to re-assess duration of broad spectrum antibiotic therapy
- Re-assess vancomycin after >72 hours if no MRSA identified
- Bug-drug mismatch alert
- Highly bioavailable antibiotic receiving oral meds/diet
- Sepsis alert based on lab criteria/vitals



### AI in Antibiotic Stewardship Opportunities

- Identify, synthesize, and evaluate antimicrobial stewardship alerts and algorithms
- Prioritize and provide recommendations for ASP implementation of alerts

1. Van Dort BA, et al. JAC. 2022;77(7):1828-37.

2. Heil EL, et al. OFID 2023

# Epoch 2.0

## The Era of Machine and Deep Learning

# 2.0 Machine/Deep Learning

## Streamlining Antimicrobial Stewardship Workflow

- Acute teaching hospital in S. Korea, prospective audit and feedback data
- Machine learning was used to identify predictors for a PAF intervention amongst >160 variables

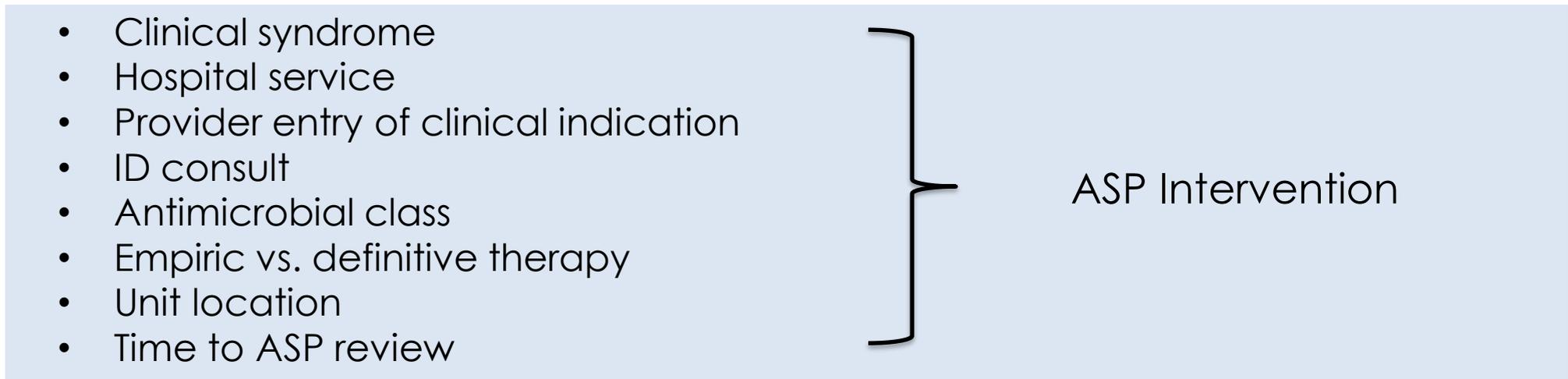
Predictors of PAF Intervention		
Discontinue	Intravenous to Oral	De-Escalation
<ul style="list-style-type: none"><li>• Infection recovery</li><li>• Illness severity score, body temp, CRP, absence of SIRS, % mature neutrophils, absence of blood cx in past 3 days</li></ul>	<ul style="list-style-type: none"><li>• Infection recovery</li><li>• Taking oral medications in past 3 days</li></ul>	<ul style="list-style-type: none"><li>• Targeted antibiotic use</li><li>• Susceptibility to narrower agents</li><li>• Negative predictors: mechanical ventilation, supplemental O2</li></ul>

- **Compared to PAF based on length of therapy, models identified a higher number of patients for intervention ↑17-41%**

# 2.0 Machine/Deep Learning

## Streamlining Antimicrobial Stewardship Workflow

- Prospective audit/feedback data from University of Maryland Medical Center
- Machine learning using random forest captured several variables



- **Compared to standard methods, algorithm reduced reviews by 49%, with 78% sensitivity**



### AI in Antibiotic Stewardship Opportunities

- Consider ML approaches to identify prospective audit and feedback “hotspots”

# 2.0 Machine/Deep Learning

## Predicting Antimicrobial Resistance using Laboratory and Health Records Data

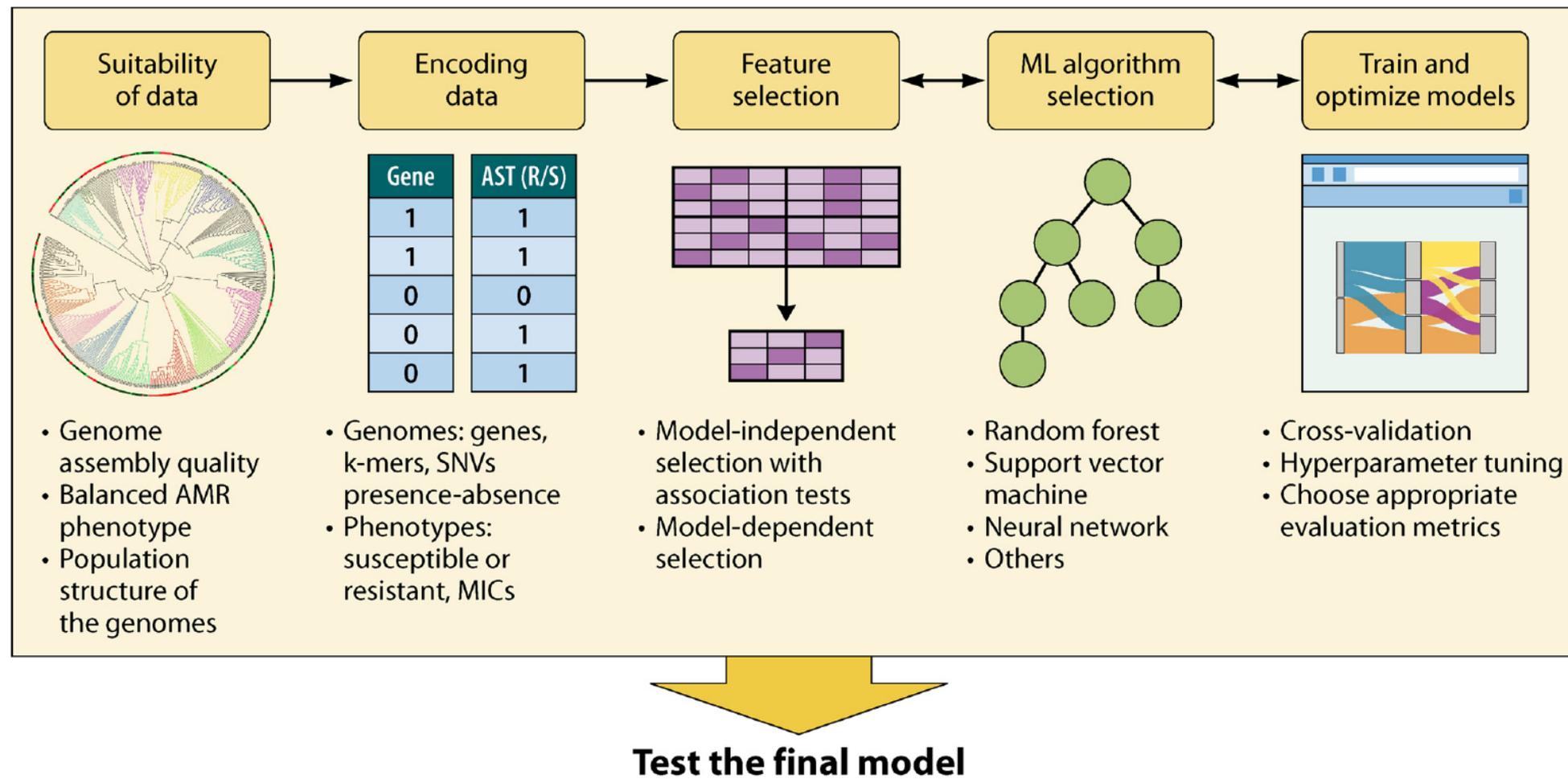
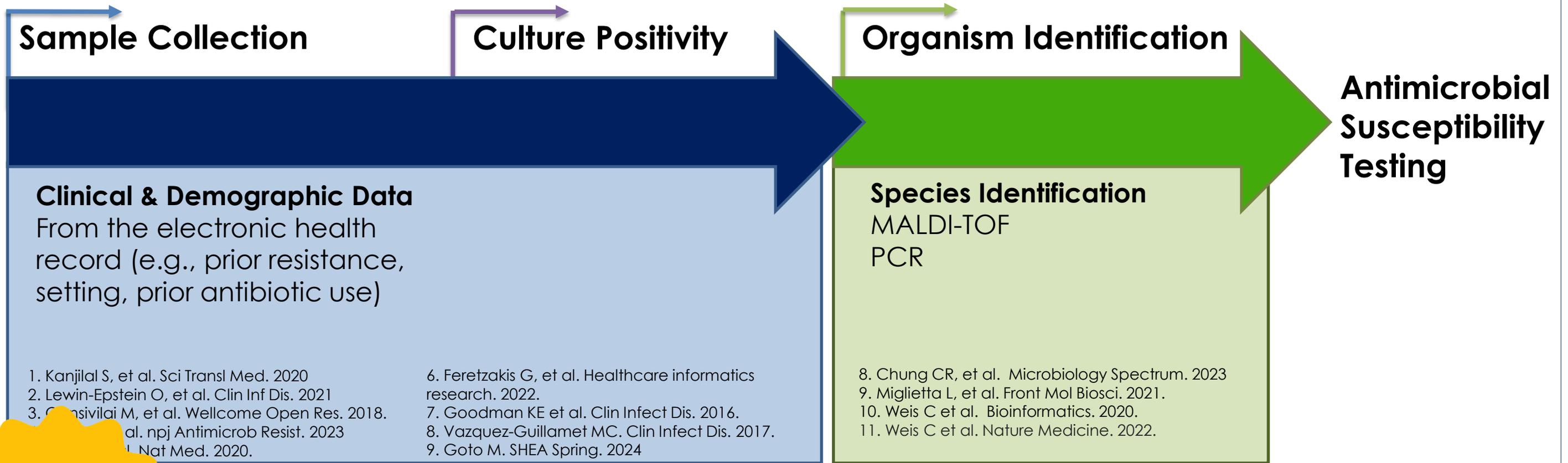


FIG 1 Workflow for ML prediction of AMR.

Kim JI, Maguire F, Tsang KK, Gouliouris T, Peacock SJ, McAllister TA, McArthur AG, Beiko RG. Machine learning for antimicrobial resistance prediction: current practice, limitations, and clinical perspective. *Clinical microbiology reviews*. 2022 Sep 21;35(3):e00179-21.

# 2.0 Machine Learning

## Predicting Antimicrobial Resistance



Cluster RCT using real-time EHR prompts providing patient-specific risk estimates for MDROs - reduction in empiric broad spectrum antibiotic prescribing in hospitalized patients with pneumonia.

**Gohil SK et al. INSPIRE Trial. JAMA. 2024.**

# 2.0 Machine Learning

## Precision Infectious Diseases: Improving Antibiotic Appropriateness

	Population	Input	Model	Output
	<b>Recurrent UTI</b> Cai T, et al. Antibiotics. 2023.	Current C&S, Prior C&S Prior antibiotics, Treatment success	Artificial Neural Network (ANN)	Clinical efficacy of empiric antibiotics
	<b>Intravenous to oral switch</b> Bolton WJ, Nat commun. 2024.	Clinical data (vital signs), IV to PO guidelines	Artificial Neural Network (ANN)	Suggestion for IV to PO switch
	<b>Suspected pneumonia</b> Tang S, et al. IDWeek 2023.	Electronic health record clinical, radiographic data	Gradient boosting algorithm	Suggestion for antibiotic initiation for lower respiratory tract infection
	<b>Pharyngitis</b> Jin Z, et al. Sci Rep. 2023	Hematological parameters (i.e., CBC)	Various	Likelihood of viral vs. bacterial infection



### AI in Antibiotic Stewardship Opportunities

- Ensure availability of high quality data; collaborate with experts in AI to build and test models

# 2.0 Machine/Deep Learning

## Population-Level Surveillance and Benchmarking



### Healthcare Facilities

Patient encounter level variables predict facility-wide antimicrobial usage<sup>1,2</sup>



### Community

Provider and patient-level variables predict populations high risk for inappropriate antibiotic use for respiratory tract infections<sup>3</sup>



### AI in Antibiotic Stewardship Opportunities

- Implement and evaluate patient-level risk-adjustment to assist in inter-facility benchmarking
- Use AI-assisted methods to identify targets for antimicrobial stewardship intervention

# Epoch 3.0

## Foundation Models and Generative AI

# 3.0 Generative AI

## Foundational Model Examples (Large Language Models)

Corporation	Model	Formal Medical Application
	<b>GPT-4</b> Generative Pre-trained Transformer	Integration into EHRs (e.g., writing notes, report generation, ambient listening)
	<b>LLaMA-2</b> Large Language Model Meta AI	<b>Me LLaMA</b> open source medical large language model
		<b>Med-PaLM</b> multi-modal medical large language model
<b>ANTHROPIC</b>	<b>Claude-3</b>	None at this time

# GENERATIVE AI AND ANTIMICROBIAL STEWARDSHIP

## Practical Use Cases



### DEVELOP GUIDANCE

- ✦ Create custom antibiotic stewardship GPTs
- ✦ Develop new guidance documents using prior examples



### EDUCATE

- ✦ Generate quizzes from existing content
- ✦ Create analogies to explain concepts
- ✦ Develop infographics and presentations



### SUMMARIZE

- ✦ Shorten long documents and articles
- ✦ Identify key messages from podcasts and videos
- ✦ Act as a personal meeting note-taker



### RESEARCH

- ✦ Perform a literature search
- ✦ Critique your scientific writing
- ✦ Write statistical analysis code



### TRANSLATE & SIMPLIFY

- ✦ Translate to/ from English
- ✦ Simplify language to a specific reading level or audience



### MANIPULATE DATA

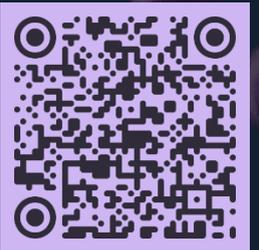
- ✦ Visualize quantitative data
- ✦ Summarize and categorize qualitative data



### Caution

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For example prompts



# Use Case #1

## Education

**PROMPT:** Please write 5 multiple choice questions to assist trainees to learn about evidence based strategies for antimicrobial stewardship implementation. Base the questions on the attached guideline.

**Example Response:** What is the recommended strategy to improve antibiotic utilization and patient outcomes?

- A) Preauthorization only
- B) Prospective audit and feedback only
- C) Both preauthorization and/or prospective audit and feedback
- D) Neither preauthorization nor prospective audit and feedback

Answer: C) Both preauthorization and/or prospective audit and feedback

Source: ChatGPT 4 Plus. 2024



*Clinical Infectious Diseases*

**IDSA GUIDELINE**

**Implementing an Antibiotic Stewardship Program:  
Guidelines by the Infectious Diseases Society of America  
and the Society for Healthcare Epidemiology of America**

Tamar F. Barlam,<sup>1,2</sup> Sara E. Cosgrove,<sup>2,3</sup> Lillian M. Abbo,<sup>3</sup> Conan MacDougall,<sup>4</sup> Audrey N. Schuetz,<sup>5</sup> Edward J. Septimus,<sup>6</sup> Arjun Srinivasan,<sup>7</sup> Timothy H. Dellit,<sup>8</sup> Yngve T. Falck-Ytter,<sup>9</sup> Neil O. Fishman,<sup>10</sup> Cindy W. Hamilton,<sup>11</sup> Timothy C. Jenkins,<sup>12</sup> Pamela A. Lipsett,<sup>13</sup> Preeti N. Malani,<sup>14</sup> Larissa S. May,<sup>15</sup> Gregory J. Moran,<sup>16</sup> Melinda M. Neuhauser,<sup>17</sup> Jason G. Newland,<sup>18</sup> Christopher A. Ohl,<sup>19</sup> Matthew H. Samore,<sup>20</sup> Susan K. Seo,<sup>21</sup> and Kavita K. Trivedi<sup>22</sup>

# Use Case #2

## Education

**PROMPT:** Based on the attached article create a common clinical case scenario in which antibiotics are overused. Include age, sex, past medical history, history of presenting illness, any relevant laboratory information and interdisciplinary communication.



*Antimicrobial Stewardship & Healthcare Epidemiology* (2023), **3**, e4, 1-4  
doi:10.1017/ash.2022.343



### Commentary

#### Bacteriuria in older adults triggers confusion in healthcare providers: A mindful pause to treat the worry

Eva M. Amenta MD<sup>1,2</sup> , Robin L.P. Jump MD, PhD<sup>3,4</sup>  and Barbara W. Trautner MD, PhD<sup>1,5</sup> 

<sup>1</sup>Center for Innovations in Quality, Effectiveness, and Safety (IQUES), Michael E. DeBakey Veterans' Affairs Medical Center, Houston, Texas, <sup>2</sup>Section of Infectious Diseases, Department of Medicine, Baylor College of Medicine, Houston, Texas, <sup>3</sup>Geriatric Research Education and Clinical Center (GRECC) at the VA Pittsburgh Healthcare System, Pittsburgh, Pennsylvania, <sup>4</sup>Division of Geriatric Medicine, Department of Medicine, School of Medicine, University of Pittsburgh, Pittsburgh, Pennsylvania and <sup>5</sup>Section of Health Services Research, Department of Medicine, Baylor College of Medicine, Houston, Texas

Amenta EM, Jump RL, Trautner BW. Bacteriuria in older adults triggers confusion in healthcare providers: A mindful pause to treat the worry. *Antimicrobial Stewardship & Healthcare Epidemiology*. 2023 Jan;3(1):e4.

Source: ChatGPT 4 Plus. 2024

# Case Scenario Output

## Patient Profile:

- Age: 79 years old
- Sex: Female
- Past Medical History:
  - Type 2 Diabetes Mellitus
  - Hypertension
  - Chronic Kidney Disease (Stage 3)
  - History of urinary tract infections (UTIs)
- Current Medications:
  - Metformin
  - Lisinopril
  - Calcium supplements

## History of Presenting Illness:

- The patient is a resident in a long-term care facility. She was noted by the nursing staff to be slightly more confused than usual this morning, without other new specific symptoms. Her confusion did not have an apparent trigger and resolved within a few hours.
- A well-meaning nurse, concerned about a potential UTI given the patient's past history, ordered a routine urinalysis and urine culture without the presence of urinary symptoms like dysuria, frequency, or urgency.

## Relevant Laboratory Information:

- Urinalysis:
  - Cloudy urine
  - Negative for nitrite
  - Positive for leukocyte esterase
  - Moderate bacteria
- Urine Culture:
  - Escherichia coli >100,000 CFU/mL
- Blood Tests:
  - Normal white blood cell count
  - Slightly elevated C-reactive protein

## Interdisciplinary Communication:

- **\*\*Nursing Notes:\*\*** Documented the patient's temporary confusion and the lack of urinary symptoms, initiated urine tests based on past medical history.
- **\*\*Physician Review:\*\*** A physician reviewed the results the next day, noted the absence of urinary symptoms, but decided to prescribe antibiotics fearing potential repercussions of an untreated UTI, especially given the patient's history and the high bacterial count in the culture.
- **\*\*Pharmacy Consult:\*\*** The pharmacist questioned the necessity of antibiotic treatment given the asymptomatic presentation and suggested reviewing the case. However, the physician decided to proceed with antibiotics due to concern over the patient's age and comorbidities.

Source: ChatGPT 4 Plus. 2024

# Use Case #3

## Literature Search

**PROMPT:** Provide a list of diagnostic stewardship intervention studies that aim to reduce unnecessary urine culturing for asymptomatic bacteriuria.

### Example Response (CSV Output):

Title	Takeaway	Authors	Year	Citations	Abstract	Study Type	Journal	DOI
Applying Diagnostic Stewardship to Proactively	Diagnostic	Faiza Mor	2022	8	A urinary	systematic	Antibiotics	10.3390/a
Effectiveness of an Antimicrobial Stewardship	An antimic	B. Trautne	2015	163	IMPORTA		JAMA inte	10.1001/ja
The Use of Clinical Decision Support in Reducing	Clinical de	S. Keller, L	2017	31	Clinical de	non-rct ex	Journal of	10.12788/
Asymptomatic bacteriuria: Impact of an antimic	An antimic	Matthew I	2021	1	PURPOSE	non-rct ex	American	10.1093/a
Impact of a Stewardship Initiative to Decrease	A multi-fa	J. Smith, J.	2017	1	Abstract B	non-rct ex	Open Foru	10.1093/C
1853. Impact of Antimicrobial Stewardship Inte	Interdiscip	P. Shah, C.	2018	0	Abstract B	non-rct ex	Open Foru	10.1093/o
1592. SHEA Featured Oral Abstract: Reducing U	Diagnostic	Valerie M.	2022	0	Abstract Background		Open Foru	10.1093/o
219. Characteristics Associated with Inappropri	Inappropr	M. Bixby, I	2020	0		non-rct ok	Open Foru	10.1093/o
Reducing antimicrobial therapy for asymptoma	No longer	J. Leis, Gal	2014	134	This proof-of-concep		Clinical inf	10.1093/ci
Impact of Antimicrobial Stewardship Interventi	Interdiscip	P. Shah, C.	2019	2	Backgrour	non-rct ex	Hospital P	10.1177/0

- AI Literature Search Tools
- <https://consensus.app/>
  - <https://scholarai.io/>
  - <https://elicit.com>
  - <https://www.perplexity.ai/>

Source: Consensus.app. 2024

# Use Case #3

## Literature Search

**PROMPT:** Provide a list of diagnostic stewardship intervention studies that aim to reduce unnecessary urine culturing for asymptomatic bacteriuria. Create a summary table with headings of citation, year, country, strategy, and outcomes. Include up to ten articles. Think step by step about articles to include based on relevance, and think step by step about the appropriate information to include under each heading.

### Example Response (Google Sheets Output):

Citation	Year	Country	Strategy	Outcomes					
A Statewide Qua	2003	USA	Compared reduc	Decreased ASB-related antibiotic use associated with decline in unnecessary cultures					
Applying Diagno	2019	Not specified (R	Analyzed studies	Reduced urine cultures through clinician education & EMR prompts for appropriate ordering					
Implementing an	2016	USA	Guidelines for im	Indirectly promotes diagnostic stewardship by focusing on appropriate testing					
Controlled Quas	2015	Multi-national	Educational outr	Reduced rates of inappropriate antibiotic use for ASB, potentially impacting culture requests					
Downstream Imp	2014	USA	Analyzed impact	Demonstrated high rates of negative cultures, highlighting unnecessary resource use					
Reflex Urine Cul	2012	USA	Implementation	Reduced costs associated with unnecessary cultures for ASB					
Electronic Memc	2011	USA	Electronic alerts	Reduced rates of inappropriate antibiotic use and potentially unnecessary cultures					

Source: Gemini. 2024

# Use Case #4

## Chat with Guidelines

**PROMPT:** What is the recommended antibiotic treatment for bronchitis?

*Many foundational model platforms allow users to customize responses with domain-specific information.*

A custom GPT "Virtual Antibiotic Steward" was built using GPT builder in ChatGPT with instructions to only respond with information from the WHO AWaRe handbook

ChatGPT 4 Plus. 2024  
WHO AWaRe Handbook. 2022

### RESPONSES:

#### AI in Antibiotic Stewardship Opportunities



- Consider creating fine-tuned infectious diseases/antimicrobial stewardship GPTs
- GPTs can be tailored for different audiences (e.g., clinician vs. patient)
- Compare fine-tuned ASP/ID models with those for general use
- Explore options for integration into existing resources (website, EHR)

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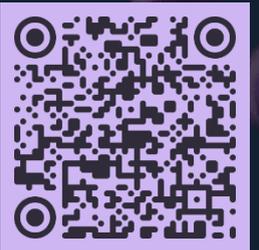
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# Artificial Intelligence Disruption of the Infectious Disease Workforce



## AI Disruption



### Prediction

Early identification of patients at risk for infection; prediction of optimal empiric therapy; detection and evaluation of outbreak scenarios



### Synthesizing Data

Summarizing data in textual and graphical format; writing notes, reports, and preparing presentations



### Development of Novel Tools

With increasing data points and model sophistication, functionality of AI will increase; use cases will continue to emerge



### Uncertain Future

The full impact of AI on infectious disease, infection control, antimicrobial stewardship and public health is not yet known



## ID Adaptation

### Decision Making

Focus on leadership and change management. ID expertise needed for nuanced clinical judgement and empathetic patient interaction

### Increased Efficiency

More efficient development of reports, consult notes, and presentations; Free up time for tasks requiring human interaction; mitigating burnout

### Planning and Evaluation

Subject matter expertise is needed for needs assessment, development, validation, and evaluation of patient-centered AI tools

### Advocacy and Training

ID experts should advocate for their involvement in AI development, workforce protection, and training to adapt to new automation

# Take-Home Messages and Future Steps

- **Artificial intelligence includes many subfields**, most of which are applicable to antimicrobial stewardship
- High quality models require access to **high quality data**
- Take a **cautiously optimistic** approach to AI in stewardship understanding both the benefits and limitations
- **Generative AI holds promise** but technology is nascent
- To keep up with rapid advancement in AI, antimicrobial stewards and hospital epidemiologists can **participate in training and advocate for ID specialist involvement** in model development and testing

“Once a new technology rolls over you, if you're not part of the steamroller, you're part of the road.” -Stewart Brand

Non LR. Antimicrobial Stewardship & Healthcare Epidemiology. 2023.

**Dalla Lana**  
School of Public Health

**Thank you!**

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**@BRxAD**