Lecture 01 - Contents

An overview of the main sections in this lecture.

This outline is for guidance. Navigate the slides with the left/right arrow keys.

Advanced Medical LLMs: Transforming Healthcare with AI

20-Lecture Comprehensive Course

Introduction to Biomedical Data Science

Instructor Name

Medical AI Research Center

Fall 2025

Course Overview and Prerequisites

Learning Objectives

- Understand medical LLM architectures
- Master clinical NLP techniques
- Deploy healthcare AI systems
- Ensure HIPAA compliance
- Evaluate model performance

Prerequisites

- Python programming
- Machine learning basics
- Medical terminology
- Neural networks fundamentals

PyTorch | Hugging Face | FHIR | Docker

Assessment Breakdown

40%	30%	30%
Project	Assignments	Exam

Course Structure

- 20 comprehensive lectures
- Hands-on coding sessions
- Real-world case studies
- Industry expert guest lectures

Part 1/3:

The Medical AI Revolution

1. Evolution from Rule-Based Systems to LLMs
2. GPT-4, Claude, and Gemini in Healthcare
3. Medical vs General-Purpose LLMs

Evolution From Rule-Based Systems to LLMs

Rule-Based

1970s - 1990s

Technology:

Expert systems
Decision trees
If-then rules

Limitation:

Cannot handle uncertainty

Statistical ML

2000s - 2010s

Technology:

SVM, Random Forest, Naive Bayes

Limitation:

Feature engineering required

Deep Learning

2010s - 2020

Technology:

CNN, RNN
LSTM, Attention mechanisms

Limitation:

Task-specific
Large labeled data

Large LLMs

2020s - Present

Technology:

Transformers
Self-attention
Pre-train + Fine-tune

Strength:

Few-shot learning
Broad knowledge

GPT-4, Claude, and Gemini in Healthcare

GPT-4

87%

Medical reasoning

1.7T+ parameters

Claude

85%

Safety & ethics

Constitutional AI

Gemini

90%

Multimodal capabilities

Text + Image integration

Medical vs General-Purpose LLMs

Medical LLMs

- ✓ Domain-specific knowledge
- ✓ Clinical safety protocols
- ✓ HIPAA/regulatory compliance
- ✓ Medical terminology precision
- ✓ Evidence-based responses
- ✓ Rare disease understanding

General-Purpose LLMs

- ✓ Broad knowledge coverage
- ✓ Creative problem-solving
- ✓ Multi-domain versatility
- ✓ General reasoning ability
- ✓ Larger training datasets
- ✓ Conversational flexibility

Common Ground

Language understanding • Contextual reasoning • Pattern recognition • Natural language generation

Key Medical AI Challenges

Data Privacy

HIPAA compliance, patient data protection, secure data handling and storage

Critical Risk

Medical Errors

Hallucinations, incorrect diagnoses, liability concerns, patient safety

High Risk

Regulatory Approval

FDA clearance process, clinical validation, compliance documentation

High Complexity

Explainability

Model interpretability, decision transparency, clinical reasoning clarity

Medium Risk

Bias & Fairness

Demographic bias, training data representation, equitable healthcare access

High Risk

Implementation Cost

Infrastructure investment, training costs, maintenance and updates

Medium Complexity

HIPAA Privacy and Data Security

18 PHI Identifiers

- Names
- SSN
- Addresses
- Medical Records
- Dates
- Phone Numbers
- Email
- IP Address
- Biometric IDs
- Photos

Security Requirements

- ✓ End-to-end encryption (AES-256)
- ✓ Access control & authentication
- ✓ Audit logging & monitoring
- ✓ Data de-identification
- ✓ Secure data transmission (TLS)
- ✓ Regular security assessments

Multi-layer Security Architecture

Compliance Checklist

- Privacy Notice
- Data Backup
- Incident Response

Staff Training

Business Associate Agreements

Risk Analysis

Clinical NLP Task Taxonomy

Named Entity Recognition

EXTRACTION

Identify diseases, medications, symptoms, procedures

Patient has diabetes and takes metformin

Relation Extraction

RELATION

Find relationships between medical entities

Drug X → causes → Side Effect Y

Temporal Expression

TEMPORAL

Normalize time expressions and event sequences

"2 weeks ago" → 2024-10-30

Negation Detection

LOGIC

Identify negated medical concepts

"No signs of infection" ≠ "Infection present"

Medical Code Mapping

MAPPING

Map clinical text to ICD-10, CPT, SNOMED codes

"Hypertension" → ICD-10: I10

Clinical Text Summarization

GENERATION

Generate concise summaries from clinical notes

Long note → Discharge summary

Diagnosis Generation Systems

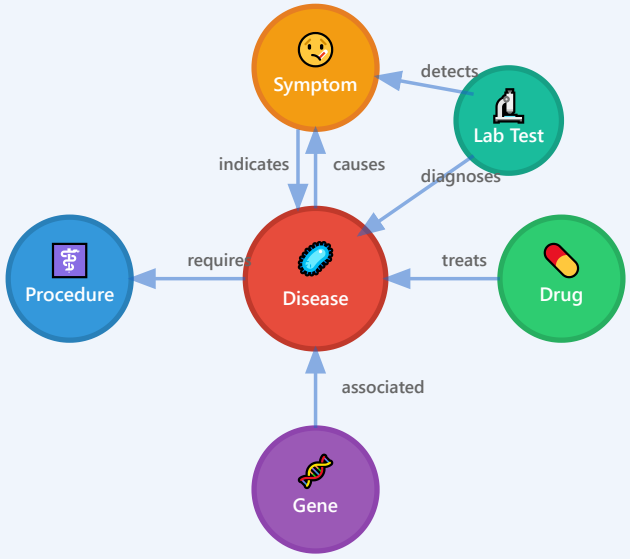
Example Output: Differential Diagnosis

1. **Community-Acquired Pneumonia**
   Probability: 78% | Evidence: Fever, cough, chest X-ray findings

2. **Acute Bronchitis**
   Probability: 15% | Evidence: Cough, no infiltrates on imaging

3. **Viral Upper Respiratory Infection**
   Probability: 7% | Evidence: Mild symptoms, no bacterial markers

Medical Knowledge Graph Integration



Triple Structure: Entity → Relation → Entity

2.8M
UMLS Concepts

15M+
Relationships

Graph Embedding

- → TransE, TransR for relations
- → Node2Vec for embeddings
- → Graph Attention Networks
- → Knowledge Graph Embeddings

LLM Integration Methods

Retrieval-Augmented Generation (RAG) • Knowledge-enhanced prompting • Graph-guided reasoning • Entity linking and normalization • Hybrid knowledge retrieval

Part 2/3:

State-of-the-Art Medical Models

- MedPaLM 2
- BioGPT
- RadBERT
- Multimodal Systems
- GatorTron
- PubMedGPT
- PathLLM

MedPaLM 2 Architecture

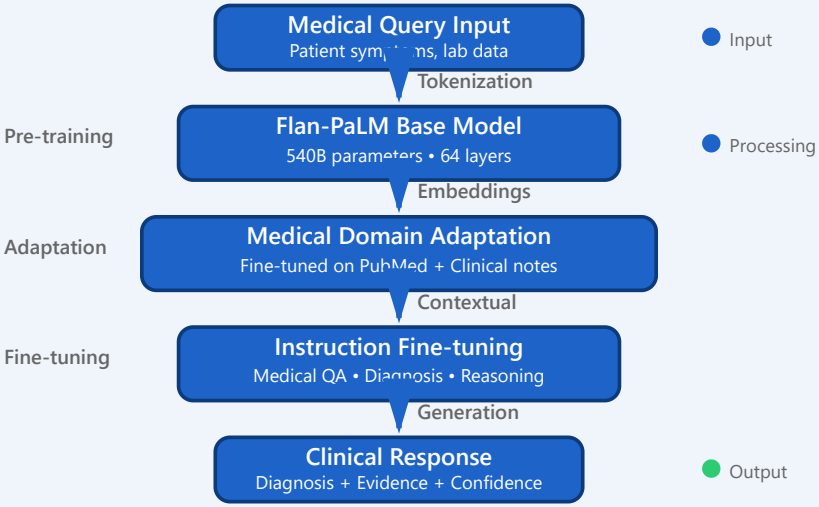
📊 540B parameters 🏗️ Flan-PaLM based ✅ 86.5% on MedQA

🎯 Instruction fine-tuning on medical tasks

Medical domain adaptation with specialized corpus

Few-shot clinical reasoning capabilities

Safety-focused design with alignment



GatorTron - Clinical BERT

8.9B Parameter Clinical Language Model

Trained on 90 billion words from UF Health clinical notes

NER Performance

96%

F1 Score

Relation Extract

94%

F1 Score

Parameters

8.9B

Largest clinical

BioGPT vs PubMedGPT Comparison

BioGPT

1.5B Parameters

Focus:	General biomedical text generation
Training:	PubMed abstracts (15M documents)
Strengths:	Question answering, summarization
Use Case:	Research assistance, literature review
Speed:	Faster inference time

PubMedGPT

2.7B Parameters

Focus:	Medical literature specialization
Training:	Full PubMed papers (3M+ full text)
Strengths:	Scientific writing, detailed analysis
Use Case:	Literature review, paper generation
Depth:	More comprehensive knowledge

📊 Performance Comparison

Reserved Slot (L01_16)

추후 내용이 추가될 자리입니다. 강의 흐름의 연속성을 위해 번호를 보존합니다.

Multimodal Medical Models

Text + Image

Radiology reports with X-rays, CT, MRI

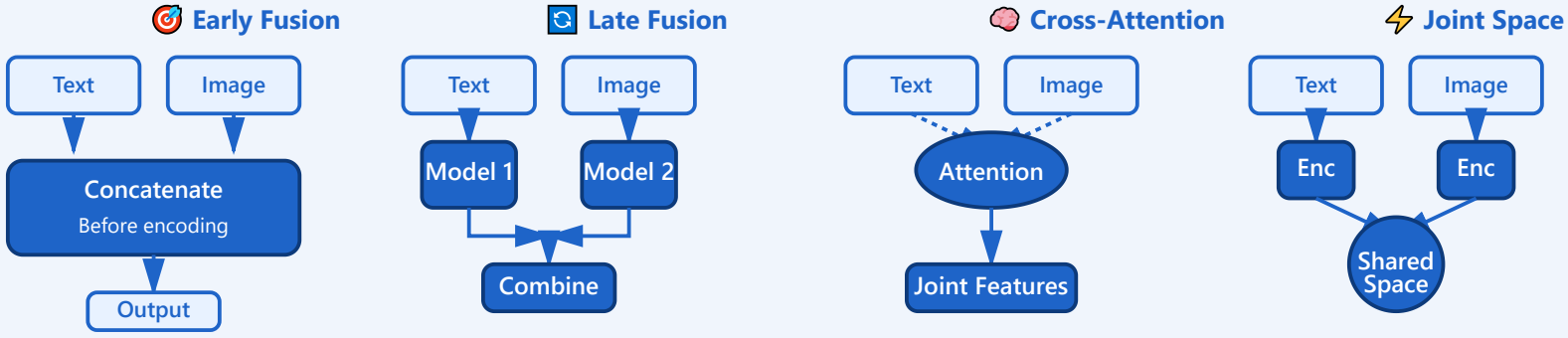
Text + Signal

ECG, EEG, waveform analysis

Text + Video

Surgical procedures, endoscopy

Fusion Strategies



RadBERT

Radiology Applications

📊 4.7M radiology reports

- ✓ Chest X-ray abnormality detection: 94% AUC
- ✓ Automated report generation
- ✓ Finding classification & localization
- ✓ Report quality assessment

PathLLM

Digital Pathology

📊 Whole Slide Image (WSI) processing

- ✓ Cancer grading & classification
- ✓ Cell counting & detection
- ✓ Tissue segmentation
- ✓ Histopathology report generation

Part 3/3:

Real-World Clinical Deployments

- Hospital Case Studies
- Emergency Department Applications
- Clinical Decision Support
- FDA Approved Systems
- ROI Analysis

Mayo Clinic Case Study

2021

Deployment Year

3M annually

Scale

15% diagnosis accuracy ↑

Key Result

Key Achievements

✓ 30% physician time saved

✓ 3-year payback period

✓ Enhanced clinical workflows and patient outcomes

Stanford Healthcare Case Study

2022

Deployment Year

Epic EHR integration

System

47% medication error reduction

Key Result

Key Achievements

✓ Real-time clinical decision support

✓ Improved patient safety

✓ Enhanced clinical workflows and patient outcomes

Emergency Department Triage

- 23 min average wait time reduction
- 92% priority accuracy
- ESI level prediction
- Real-time risk assessment

Clinical Decision Support Systems

- Drug interaction alerts
- Evidence-based guidelines
- Lab test optimization
- Risk score calculation

FDA Approved AI Systems

520+ FDA cleared devices

IDx-DR (diabetic retinopathy)

Caption Health (echocardiography)

Rapid regulatory growth

Performance Metrics & Benchmarks

MedQA: 87% accuracy

PubMedQA: 78% F1

MMLU-Medical: 91%

AUROC, Sensitivity, Specificity

Cost-Benefit Analysis

Initial: $2M investment

Operating: $500K/year

Savings: $3M/year (error reduction)

ROI: 250% over 3 years

Future Directions & Opportunities

Personalized Medicine

Genomic data integration, tailored treatment plans

Real-time Monitoring

Wearable integration, continuous health tracking

Drug Discovery

Accelerated compound identification, clinical trials

Precision Surgery

AI-assisted robotics, real-time guidance

Preventive Medicine

Early disease detection, risk prediction

Global Health Access

Telemedicine, underserved populations

⚙ Hands-On Environment Setup

📦 Required Software

- ✓ Python 3.9+
- ✓ PyTorch 2.0
- ✓ Transformers 4.30
- ✓ Docker Desktop
- ✓ CUDA 11.8+ (GPU)
- ✓ Jupyter Notebook

```
# Installation Commands pip install torch transformers datasets pip install huggingface_hub accelerate pip install pandas numpy scikit-learn pip install jupyter notebook # Verify Installation python -c "import torch; print(torch.cuda.is_available())"
```

📝 Assignment: Medical QA System

🎯 **Task:** Build a medical question-answering system

📊 **Dataset:** MedQA or PubMedQA (provided)

⏰ **Deadline:** 2 weeks

📋 **Evaluation:** Accuracy, code quality, documentation

Thank You! 

Questions? Contact your instructor

📧 instructor@university.edu

Next Lecture: Fine-tuning Medical LLMs