Unit 5: Machine Learning in Biomedical Engineering

I. Pre-reading

A. New Vocabulary

Word	Form	Definition / Synonym	Persian Translation
dataset	n	a collection of related data	مجموعه‌داده
classification	n	process of categorizing data	طبقه‌بندی
regression	n	predicting continuous values	رگرسیون
segmentation	n	dividing an image into meaningful parts	قطعه‌بندی / بخش‌بندی
neural network	n	a system of algorithms modeled after the human brain	شبکهٔ عصبی
feature	n	a measurable property or characteristic of data	ویژگی
supervised	adj	involving labeled training data	نظارت‌شده
unsupervised	adj	not involving labeled data	بدون‌نظارت
training	n	the process of teaching a model from data	آموزش
validation	n	checking how well a model performs	اعتبارسنجی
interpretation	n	explaining the meaning of results	تفسیر
explainable	adj	able to be understood or interpreted	قابل‌توضیح / قابل‌فهم

B. Pre-reading Questions

1. What is machine learning and how is it used in medicine?
2. How can machine learning help doctors make better decisions?
3. What are some types of biomedical data used in ML models?
4. Why is accuracy important in diagnostic algorithms?

II. Reading

Machine Learning in Biomedical Engineering

Machine learning (ML) is one of the most powerful tools transforming biomedical engineering today. It enables computers to learn from data, identify patterns, and make predictions without being explicitly programmed. In biomedical contexts, ML helps improve diagnostic systems, design intelligent medical devices, and support clinical decision-making.

A typical ML system is trained using large datasets that include medical images, genetic information, or patient records. Engineers use **supervised learning** when the data includes known labels (such as "healthy" or "diseased") and **unsupervised learning** when exploring unknown patterns. These models can detect subtle changes in medical images that are sometimes invisible to the human eye.

Neural networks—especially deep learning architectures—have greatly improved **image analysis** and **signal processing** in healthcare. For instance, convolutional neural networks (CNNs) are widely used for **tumor detection** in MRI scans or **cell segmentation** in microscopic images. Recurrent neural networks (RNNs) can analyze biomedical signals like ECG or EEG to detect abnormalities in heart or brain activity.

In clinical environments, ML-based systems assist doctors by providing **decision support**. Algorithms can analyze patient history and lab data to **predict diseases** such as diabetes or heart failure. They can also suggest optimized treatment plans based on past outcomes. These systems increase diagnostic accuracy and reduce human error.

Biomedical data analysis presents challenges like privacy protection, data imbalance, and interpretability. Biomedical engineers work to make ML systems not only accurate but also **explainable**, so that clinicians can understand why a model makes a particular decision. This is crucial for trust and patient safety.

Machine learning also accelerates **drug discovery**, **personalized medicine**, and **robot-assisted surgery**. In personalized medicine, ML identifies which treatments are most effective for individual patients based on genetic and clinical profiles. In robotic surgery, ML helps robots learn from thousands of surgical videos to improve precision and safety.

In conclusion, the fusion of **machine learning** and **biomedical engineering** opens vast opportunities for improving diagnosis, treatment, and healthcare efficiency. Biomedical engineers play a vital role in designing, implementing, and maintaining intelligent systems that shape the future of medicine.

III. Post-reading

A. True (T), False (F), or Not Given (NG)

1. CNNs are commonly used for biomedical image processing.
2. ML helps doctors make faster and more accurate diagnoses.
3. Biomedical data never contains privacy concerns.
4. ML systems in biomedical engineering can be trained using genetic data.
5. RNNs are used to analyze biomedical signals like ECG.
6. ML replaces doctors completely in modern hospitals.
7. Explainable ML helps improve clinical trust and safety.
8. ML algorithms are already capable of performing fully autonomous surgeries.

B. Multiple Choice

1. What is supervised learning?
   a) Training without labeled data b) Using human supervision during surgery
   c) Training with labeled data d) Detecting patterns in images
2. Which algorithm is used for image segmentation?
   a) CNN b) RNN
   c) Regression d) Classifier
3. What is one major challenge of ML in healthcare?
   a) Too much labeled data b) Privacy and interpretability
   c) Lack of computational power d) Too few engineers
4. What does “fusion” in this context refer to?
   a) Combination of biology and physics b) Combination of ML and biomedical engineering
   c) Merging two datasets d) Integrating robotic arms
5. Which field benefits from ML-based prediction systems?
   a) Automotive engineering b) Civil engineering
   c) Clinical decision-making d) Marine biology

C. Fill in the blanks

1. The _____ model can identify cancer cells in images.
2. Data scientists collect and clean large _____ before training models.
3. Early disease _____ can save many lives.
4. Doctors must be able to _____ AI-based predictions.
5. _____ learning is useful when labels are not available.
6. _____ improves machine efficiency by minimizing human work.
7. Engineers try to _____ algorithms to get better accuracy.
8. _____ networks mimic the human brain’s processing structure.
