Università di Pisa

Regolamento didattico

Corso di Studio	WBER-LM - BIONICS ENGINEERING
Tipo di Corso di Studio	Laurea Magistrale
Classe	Ingegneria biomedica (LM-21 R)
Anno Ordinamento	2025/2026
Anno Regolamento (coorte)	2025/2026

Presentazione

Struttura didattica di riferimento	DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE
Docenti di Riferimento	- NICOLA CARBONARO - VINCENZO CATRAMBONE - MATTEO CIANCHETTI - CHRISTIAN CIPRIANI - FULVIO GINI - CHIARA MAGLIARO - ARIANNA MENCIASSI - LEONARDO RICOTTI - ENZO PASQUALE SCILINGO
Tutor	- ARTI DEVI AHLUWALIA - NICOLA CARBONARO - Cristian CIPRIANI - SIMONA CREA - Arianna MENCIASSI - Emiliano RICCIARDI - Leonardo RICOTTI - ENZO PASQUALE SCILINGO - GAETANO VALENZA

	- GIOVANNI VOZZI
Durata	2 Anni
CFU	120
Titolo Rilasciato	Laurea Magistrale in BIONICS ENGINEERING
Titolo Congiunto	Sì
Atenei Convenzionati	Scuola Superiore Sant'Anna - di Studi Universitari e Perfezionamento Data: 28/01/2015
Doppio Titolo	No
Modalità Didattica	Convenzionale
Lingua/e in cui si tiene il Corso	Inglese
Indirizzo internet del Corso di Studio	http://www.bionicsengineering.it/
Il corso è	Corso di nuova istituzione
Massimo numero di crediti riconoscibili	24
Corsi della medesima classe	WIBR-LM - INGEGNERIA BIOMEDICA
Programmazione accessi	Programmazione locale
Posti Programmazione Locale	30
Obbligo di tirocinio	No
Percorsi di studio	NEURAL ENGINEERING (1) BIOROBOTICS (2)
Sedi del Corso	Università di Pisa (Responsabilità Didattica)

Obiettivi della Formazione

Consultazione con le organizzazioni rappresentative - a livello nazionale e internazionale - della produzione di beni e servizi, delle professioni (Istituzione del corso)

L'Università di Pisa è attualmente interessata da una profonda evoluzione, innescata dalla pubblicazione del D.M. 270/04, e incentrata su innovativi processi di autonomia, di responsabilità e di qualità. L'attuazione di tali processi, però, dipende anche dalla possibilità di realizzare una più efficace integrazione tra università e apparato produttivo. L'autonomia didattica si sta indirizzando verso alcuni obiettivi di sistema, come il ridurre e razionalizzare il numero dei corsi di laurea e delle prove d'esame, il migliorare la qualità e la trasparenza dell'offerta, nonché il rapportarsi di progettazione e analisi della domanda di conoscenze e competenze espressa dai principali attori del mercato del lavoro, elemento questo fondamentale per la qualità e l'efficacia delle attività che l'università è chiamata a svolgere.
Sulla base delle precedenti considerazioni, è stato organizzato in data 26/01/2015 un evento di presentazione della proposta di Laurea Magistrale in BIONICS ENGINEERING alle parti sociali e agli stakeholder industriali, che ha riscosso un notevole successo. L'evento si è svolto nell'Aula Magna storica della Scuola Sant'Anna, previo invito di numerosi rappresentanti delle principali realtà accademiche e industriali Toscane, nell'ambito del biomedicale.
La partecipazione all'evento è stata numerosa: oltre a circa venti docenti dell'Università di Pisa e della Scuola Sant'Anna e circa trentacinque studenti della Laurea Triennale in Ingegneria Biomedica dell'Università di Pisa, hanno preso parte all'incontro rappresentanti di realtà industriali e cliniche Toscane (Ekymed, Endotics Technodeal, ITH, Adatech, Magna Closures, Menarini, Ericcson Italia, Dedalo Solutions, Scienzia Machinale, Kayser Italia ,Auxilium).
Inoltre, hanno preso parte all'incontro anche Matteo Caleo, rappresentante del Consiglio Nazionale delle Ricerche (CNR), Lorenzo Zolfanelli, rappresentante dell'Università di Firenze e Barbara Mazzolai, Direttore del Centro di MicroBioRobotica dell'Istituto Italiano di Tecnologia (IIT).
Complessivamente, i partecipanti all'evento sono stati circa 70. La presentazione del corso di Laurea Magistrale in BIONICS ENGINEERING ha avuto inoltre una copertura mediatica notevole, con la presenza di emittenti televisive locali e giornalisti di testate sia locali che nazionali. Il lancio dell'evento è stato ovviamente anche disseminato attraverso i canali a disposizione dell'Università di Pisa e della Scuola Superiore Sant'Anna (siti Web di Ateneo, pagine facebook, ecc.
Il fatto che l'Università di Pisa abbia privilegiato nel triennio la formazione di base spostando al secondo livello delle lauree magistrali numerosi indirizzi specialistici, che potranno coprire alcune esigenze di conseguimento di professionalità specifiche, è stato giudicato positivamente. E' stato sottolineato che, oltre all'attenzione posta alla formazione di base, positivi sono sia la flessibilità curricolare che l'autonomia e la specificità degli atenei coinvolti, che mostrano in questo contesto tutte le eccellenze di cui sono depositarie.
E' stato dimostrato come, a fronte della crisi economica e della disoccupazione giovanile, la domanda di laureati con competenze avanzate in settori biomedicali innovativi e non tradizionali sia largamente in crescita.
Il corso di studio, in previsione del riesame annuale, promuoverà nuove consultazioni con le organizzazioni maggiormente rappresentative nel settore di interesse, nell'intento di verificare e valutare gli interventi mirati al miglioramento del corso stesso
Di seguito è riportato un breve riassunto delle fasi fondamentali e degli interventi che si sono succeduti nel corso dell'incontro. 11.00: Paolo Dario (Direttore dell'Istituto di BioRobotica della Scuola Sant'Anna) e Fabio Mancarella (Prorettore alla didattica dell'Università di Pisa) iniziano con una breve introduzione all'incontro ed evidenziano come questa proposta di Laurea Magistrale sia in controtendenza con la razionalizzazione dell'offerta didattica; questo costituisce sicuramente un tentativo ambizioso di creare nuovi profili ingegneristici che possano essere utili sia all'accademia che all'industria del domani.
11.15: Giovanni Corsini (Direttore del Dipartimento di Ingegneria dell'Informazione dell'Università di Pisa) descrive il Dipartimento di Ingegneria dell'Informazione e descrive le premesse al corso di Laurea

Magistrale in BIONICS ENGINEERING.
11.35: Paolo Dario prosegue con una breve descrizione dell'Istituto di BioRobotica della Scuola Superiore Sant'Anna; evidenzia poi il contributo che i docenti della Scuola Sant'Anna hanno dato nel corso degli ultimi anni al corso esistente in Ingegneria Biomedica dell'Università di Pisa, al fine di dimostrare che la collaborazione, già attiva da anni, tra la Scuola Sant'Anna e l'Università di Pisa ha già portato a notevoli successi nei corsi di Laurea tradizionali. Prosegue poi con una descrizione dei concetti principali alla base della proposta di Laurea Magistrale in BIONICS ENGINEERING e con una descrizione delle modalità di accesso e dei corsi della nuova Laurea.
11.55: Danilo De Rossi (Direttore del Centro di Ricerca "E. Piaggio" dell'Università di Pisa) effettua una breve descrizione del Centro di Ricerca E. Piaggio ed evidenzia come la multidisciplinarietà dell'Ingegneria Biomedica in generale e della proposta di Laurea Magistrale in BIONICS ENGINEERING in particolare, sia un requisito fondamentale per la formazione di nuovi ingegneri in grado di risolvere problemi complessi.
12.00: Danilo De Rossi prosegue descrivendo la struttura e dei contenuti della Laurea Triennale e della Laurea Magistrale tradizionale in Ingegneria Biomedica dell'Università di Pisa, al fine di evidenziare le profonde differenze che ci sono con la nuova proposta di Laurea Magistrale in BIONICS ENGINEERING.
12.15: Inizia la discussione e il confronto con i partecipanti. Di seguito sono riportati tutti gli interventi effettuati
13:00: Paolo Dario conclude con delle considerazioni finali sull'utilità del coinvolgimento degli stakeholder industriali, che hanno fornito utili spunti di riflessione e che verranno sempre più coinvolti per l'ottimizzazione dell'offerta formativa del nuovo corso di Laurea Magistrale, qualora questo fosse approvato in via definitiva dal Ministero.
13.15: Ringraziamenti e chiusura dell'evento.

Consultazione con le organizzazioni rappresentative – a livello nazionale e internazionale – della produzione di beni e servizi, delle professioni (Consultazioni successive)

Il corso di laurea magistrale in Bionics Engineering è un corso che ha sempre cercato di mantenere attiva la consultazione di ditte, organizzazioni ed enti di ricerca nazionali ed internazionali per l'acquisizione di informazioni in modo da mantenere alta la qualità della formazione degli studenti e tenere l'organizzazione del piano di studi del suddetto corso sempre rispondente ai requisiti degli enti consultati. Gli studenti che conseguono la laurea Magistrale in Bionics Engineering trovano sbocco lavorativo principalmente in dottorati di ricerca di ambito ingegneristico e/o biomedicale nazionali ed internazionali o in ditte del settore della ingegneria biomedica avanzata. Alcuni laureati di questo corso sono stati ammessi a corsi di dottorato nazionali, Dottorato in Biorobotica della Scuola Superiore S. Anna, ed esteri. Il corso di laurea magistrale prevede inoltre nella sua programmazione didattica che un suo corso sia tenuto da docenti appartenenti alla Scuola IMT Alti Studi Lucca, ente convenzionato per l'attivazione di questo corso di laurea. Sono stati inoltre organizzati diversi seminari nell'ambito dei corsi con esperti del mondo della ricerca. Questi seminari permettono agli studenti sia di conoscere aspetti nuovi e specifici della ricerca e del mondo del lavoro nell'ambito dell'Ingegneria Bionica, ed al docente di tale attività didattica di fornire un feed back al corso di laurea sulla preparazione degli studenti e dare eventuali consigli su aspetti didattici da implementare. Il Corso di Laurea Magistrale in Bionics Engineering inoltre ha già attivato convenzioni con ditte, come la IUVO S.r.l, azienda che opera nell'ambito della biorobotica. In base al questionario compilato dalle ditte e gli enti di ricerca presso cui gli studenti del corso di laurea Magistrale in Bionics Engineering hanno svolto attività di tirocinio, tesi o sono assunti per avere un feed-back sulla preparazione degli studenti del suddetto corso di Laurea, emerge un giudizio positivo sulla preparazione di tali studenti. Il consiglio aggregato in Ingegneria Biomedica e Bionics Engineering ha deciso di istituire una giornata di incontro tra studenti ed esponenti del mondo del lavoro, per presentare da un lato l'offerta formativa del corso di laurea triennale in ingegneria biomedica e dall'altro avere input dalle aziende e dagli enti invitati su eventuali migliorie da apportare. Quest'anno l'evento si terrà il 16 Maggio 2025 presso l'aula magna del polo Fibonacci e

parteciperanno alcune ditte del settore quali General Electric Healthcare, Esaote, Dieng Corp, Fondazione Monasterio, Elcam Medical, Rimos e Enki. L'evento, organizzato con cadenza annuale, favorisce l'incontro tra aziende e studenti, offrendo soprattutto un'opportunità per raccogliere feedback sulle competenze richieste dal mondo del lavoro e valutare quanto la didattica del Corso di Laurea le soddisfi o necessiti di aggiornamenti.

Profilo professionale e sbocchi occupazionali e professionali previsti per i laureati

Ingegnere e ricercatore dei sistemi neurali

Funzioni in un contesto di lavoro:

Funzioni di elevata responsabilità nella progettazione, sviluppo e gestione di nuove neuroprotesi e di sistemi innovativi sensoriali, nello sviluppo di nuove metodiche per lacquisizione e il trattamento dei segnali neurali, nello sviluppo e nella gestione di sistemi robotici capaci di interagire e comunicare con gli esseri umani seguendo comportamenti sociali e regole legate al proprio ruolo specifico, nonché nello sviluppo di nuove linee di ricerca in tali ambiti.

Competenze associate alla funzione:

Competenze sul design e lo sviluppo di strumentazione per ingegneria neurale e neuroscienze e di neuroprotesi, sull’acquisizione e il trattamento di segnali neurali, sullo sviluppo di architetture software per la modellizzazione delle reti neurali, sulla progettazione e realizzazione di sistemi bionici per il recupero e la sostituzione di funzioni motorie e sensoriali, sulla progettazione di sistemi robotici capaci di interagire e comunicare con gli esseri umani seguendo comportamenti sociali e regole legate al proprio ruolo specifico, sull’affective computing.

Sbocchi occupazionali:

Il laureato magistrale in Bionics Engineering è in grado si svolgere attività professionale altamente qualificata e specializzata:
1) nell’industria per la progettazione, realizzazione e gestione di strumentazione per ingegneria neurale e neuroscienze, di neuroprotesi, di robot, di sistemi sensoriali bionici nonché per lo sviluppo di piattaforme informatiche per una migliore acquisizione e trattamento dei segnali neurali, e di architetture software per la modellizzazione delle reti neurali;
2) nelle aziende sanitarie pubbliche e private;
3) nell’ambito della ricerca per lo sviluppo di nuove tematiche di frontiera in Ingegneria Neurale.

Ingegnere e ricercatore dei sistemi biorobotici

Funzioni in un contesto di lavoro:

Funzioni di elevata responsabilità nella progettazione, sviluppo e gestione di nuovi sistemi biorobotici per la salute e/o biomimetici, di sistemi telerobotici, di dispositivi protesici e ortesici avanzati per l'assistenza al movimento e alla riabilitazione delle persone con disabilità, di robot chirurgici e di micro/nano sistemi terapeutici e per la medicina rigenerativa, nonché nello sviluppo di nuove linee di ricerca in tali ambiti.

Competenze associate alla funzione:

Competenze sullo sviluppo di modelli robotici umani ed animali, sullo sviluppo di piattaforme e dispositivi robotici per la chirurgia e le terapie mirate, per la riabilitazione robotica, per la

sostituzione o l’assistenza funzionale di arti superiori e inferiori, e sulla biomeccanica computazionale.

Sbocchi occupazionali:

Il laureato magistrale in Bionics Engineering è in grado si svolgere attività professionale altamente qualificata e specializzata: 1) nell’industria per la progettazione, sviluppo e gestione di piattaforme e dispositivi neuroprotesici, biorobotici e/o biomimetici, per la riabilitazione, per la terapia mini-invasiva, per la sostituzione e l’assistenza funzionale di arti, per la telerobotica;
2) nelle aziende sanitarie pubbliche e private;
3) nell’ambito della ricerca, per lo sviluppo di nuove tematiche di frontiera in Biorobotica.

Il corso prepara alla professione di (Codifiche ISTAT):

- Ingegneri biomedici e bioingegneri (2.2.1.8.0)
- Ricercatori e tecnici laureati nelle scienze ingegneristiche industriali e dell’informazione (2.6.2.3.2)

Conoscenze richieste per l'accesso

Per l'accesso al corso è richiesto il possesso dei requisiti curriculari sotto indicati, e una personale preparazione che garantisca la conoscenza fondamenti della Bioingegneria Industriale e della Bioingegneria Elettronica e dell'Informazione,
Requisito generale è infine il possesso di una buona conoscenza della lingua Inglese, di livello non inferiore a B2, secondo il Quadro Comune Europeo di riferimento per le Lingue.
Requisiti curriculari
Requisito curriculare è il possesso di almeno 90 CFU così distribuiti:
i) Almeno 42 CFU appartenenti ai SSD: MAT/02, MAT/03, MAT/05, MAT/06, MAT/07, MAT/08, MAT/09, FIS/01, FIS/02, FIS/03, FIS/07, CHIM/07, CHIM/03.
ii) Almeno 12 CFU appartenenti ai SSD: ING-INF/06, ING-IND/34.
iii) Almeno 12 CFU appartenenti ai SSD: ING-INF/01, ING-INF/05, ING-INF/04, ING-IND/ 13, ING-ING/14, ING-IND/15.
iv) Oltre ai CFU nei punti (i-iii), almeno 24 CFU appartenenti ai SSD caratterizzanti per la Classe L-8 o L-9.
REQUISITI PER CANDIDATI CON TITOLO ESTERO
In caso di candidati con titolo acquisito all'estero, la Commissione Interna di Valutazione valuterà i requisiti curriculari sulla base della durata temporale dei singoli insegnamenti e dei programmi dei relativi esami sostenuti.
PER TUTTI I CANDIDATI è inoltre richiesta una adeguata conoscenza della lingua Inglese di livello non inferiore a B2, secondo il Quadro Comune Europeo di riferimento per le Lingue.
Inoltre sarà effettuata la verifica della personale preparazione con le modalità specificate nel Regolamento Didattico del corso di studio.

Modalità di ammissione

Per essere ammessi al concorso i candidati, entro il termine di scadenza per la presentazione delle domande devono aver acquisito almeno 90 CFU così distribuiti:
i) Almeno 42 CFU appartenenti ai SSD: MAT/02, MAT/03, MAT/05, MAT/06, MAT/07, MAT/08, MAT/09, FIS/01, FIS/02, FIS/03, FIS/07, CHIM/07, CHIM/03.
ii) Almeno 12 CFU appartenenti ai SSD: ING-INF/06, ING-IND/34.
iii) Almeno 12 CFU appartenenti ai SSD: ING-INF/01, ING-INF/05, ING-INF/04, ING-IND/ 13, ING-ING/14, ING-IND/15.
iv) Oltre ai CFU nei punti (i-iii), almeno 24 CFU appartenenti ai SSD caratterizzanti per la Classe L-8 o

L-9.
Gli SSD per la classe L-8 sono: ING-INF/01, ING-INF/02, ING-INF/03, ING-INF/04, ING-INF/05, ING-INF/06, ING-INF/07. Gli SSD per la classe L-9 degree sono: ING-IND/01, ING-IND/02, ING-IND/03, ING-IND/04, ING-IND/05, ING-IND/06, ING-IND/07, ING-IND/08, ING-IND/09, ING-IND/10, ING-IND/11, ING-IND/12, ING-IND/13, ING-IND/14, ING-IND/15, ING-IND/16, ING-IND/17, ING-IND/17, ING-IND/18, ING-IND/19, ING-IND/20, ING-IND/21, ING-IND/22, ING-IND/23, ING-IND/24, ING-IND/25, ING-IND/26, ING-IND/27, ING-IND/28, ING-IND/29, ING-IND/30, ING-IND/31, ING-IND/32, ING-IND/33, ING-IND/34, ING-IND/35.

Se lo studente soddisfa a pieno questo requisito può partecipare alla selezione e, se selezionato, non avrà debiti formativi. Se lo studente soddisfa solo in parte questo requisito risulterà avere dei debiti formativi e, se selezionato, dovrà colmarli sostenendo esami aggiuntivi e raggiungendo i CFU sopra citati. Se tali debiti risultano pari o superiori a 40 CFU, lo studente non soddisfa il requisito minimo e non può partecipare alla selezione.

Gli studenti stranieri devono essere in possesso di un titolo di studio rilasciato da un'Università straniera, dopo il completamento di almeno tre anni di corso di studio. La Commissione, in fase di valutazione, deciderà sull'equivalenza o meno del titolo straniero, ai soli fini del presente concorso, se selezionato. L'ammissione di candidati con titolo estero conseguito in un Paese non-UE avviene in ogni caso sotto condizione della verifica della legittimità del titolo posseduto, dichiarata ufficialmente dalle competenti Rappresentanze diplomatiche italiane.
Per la sezione di concorso riservata ai candidati non-UE ed UE, la partecipazione è consentita anche ai candidati non ancora in possesso del titolo di Laurea. In questo caso, l'ammissione del candidato è disposta con riserva, ed è condizionata al successivo conseguimento del titolo di studio e alla presentazione della relativa documentazione entro e non oltre i termini previsti dal bando di ammissione.
Oltre al titolo di studio di cui ai commi precedenti, i candidati devono mostrare una buona conoscenza della lingua inglese, corrispondente ad almeno un livello intermedio (Livello B2 secondo il Quadro comune europeo di riferimento per la conoscenza delle lingue). Il livello di conoscenza della lingua inglese sarà accertato dalla Commissione, durante il colloquio di valutazione.

Obiettivi formativi specifici del Corso e descrizione del percorso formativo

La Bionics Engineering è una nuova frontiera dell'ingegneria biomedica. Infatti, il termine "bionica" è sempre più utilizzato a livello internazionale per indicare l'area di ricerca che integra gli aspetti più innovativi della robotica e delle tecnologie bioingegneristiche con le scienze della vita, come la medicina e le neuroscienze, con l'obiettivo finale di sviluppare una nuova generazione di dispositivi biorobotici e biomimetici, nonchè nuove tecnologie sanitarie maggiormente incentrate sul singolo paziente e che svolgono una migliore attività di supporto ed assistenza.
Uno degli obiettivi principali di questo corso di laurea magistrale è quello di formare degli studenti altamente qualificati che, oltre ad acquisire competenze professionali di alto livello, potranno far progredire la ricerca nel campo della Bionica.

Uno degli obiettivi non secondari sarà quello di formare studenti capaci di trasferire le conoscenze scientifiche acquisite durante il corso di laurea nello sviluppo di applicazioni pratiche e fruibili che possano aprire nuove opportunità di mercato.
I contenuti formativi della laurea magistrale in Bionics Engineering saranno basati sui principi fondamentali dell'ingegneria biomedica, della biorobotica e dell'ingegneria neurale. Agli studenti della suddetta laurea magistrale saranno forniti strumenti didattici utili ad affrontare tematiche di ricerca multidisciplinare tramite un dialogo proficuo con scienziati provenienti da diversi campi della ricerca, quali la medicina, la biologia, le neuroscienze, la riabilitazione medica e la chirurgia. Gli studenti del corso in Bionics Engineering arricchiranno il loro background con specifiche competenze nei seguenti settori: ingegneria meccatronica, robotica, robotica biomedica, telerobotica, design di piattaforme robotiche bioispirate, neuroprotesi, tecnologie indossabili e impiantabili, e ambienti di simulazione

avanzati.
Il corso di laurea magistrale in Bionics Engineering è organizzato in modo da prevedere una combinazione equilibrata di corsi teorici tradizionali e di attività sperimentali e di ricerca.
Di seguito si riportano, a titolo di esempio, alcune attività principali :
- Progettazione, sviluppo e sperimentazione di robot sociali e ambienti intelligenti per l'assisted living, per l'active ageing e per il benessere;
- Progettazione, sviluppo e test di protesi neurali;
- Sviluppo di sistemi in grado di imitare i sensi naturali;
- Analisi delle funzioni cerebrali e sviluppo di nuove metodologie per l'elaborazione di segnali e immagini del cervello;
- Progettazione, sviluppo e sperimentazione di robot bio-ispirati e / o biomimetici in grado di riprodurre funzionalità umane e/o animali ;
- Progettazione, sviluppo e sperimentazione di dispositivi protesici e ortesi avanzate per l'assistenza al movimento e la riabilitazione delle persone con disabilità;
- Progettazione, sviluppo e sperimentazione di sistemi miniaturizzati per la terapia minimamente invasiva e per la medicina rigenerativa ;
- Progettazione, sviluppo e sperimentazione di biomateriali avanzati per nuove interfacce uomo- robot impiantabili;
- Progettazione, sviluppo e sperimentazione di metodologie avanzate per l'acquisizione ed il trattamento dei biosegnali.

Il Corso di studio presenta due curricula uno denominato Neural Engineering legato all'Ingegneria dell'Informazione e l'altro Biorobotics legato all'area dell'Ingegneria Industriale.

Nel curriculum Neural Engineering lo studente ha modo di acquisire conoscenze nella progettazione, sviluppo e gestione di nuove neuroprotesi e di sistemi innovativi sensoriali, nello sviluppo di nuove metodiche per l'acquisizione e il trattamento dei segnali neurali, nello sviluppo e nella gestione di sistemi robotici capaci di interagire e comunicare con gli esseri umani seguendo comportamenti sociali e regole legate al proprio ruolo specifico.
Nel curriculum Biorobotics lo studente ha modo di acquisire conoscenze sullo sviluppo di modelli robotici umani ed animali, sullo sviluppo di piattaforme e dispositivi robotici per la chirurgia e le terapie mirate, per la riabilitazione robotica, per la sostituzione o l'assistenza funzionale di arti superiori e inferiori, e sulla biomeccanica computazionale.

Infine il Corso di studi permette allo studente di acquisire crediti formativi a scelta scegliendoli tra:
1) insegnamenti dell'altro curriculum rispetto a quello di elezione;
2) insegnamenti appositi inseriti nella programmazione del corso di studi e che ricoprono aspetti innovativi e focalizzati che non riescono ad essere trattati nei corsi caratterizzanti;
3) tramite attività di tirocinio presso enti e aziende;
4) insegnamenti attivi nei corsi di laurea dell'Università di Pisa inerenti le tematiche tipiche della Bionics Engineering e di interesse per lo studente.

Tale struttura permette allo studente di crearsi una background multidisciplinare tale da permettergli di capire, analizzare ed affrontare le problematiche complesse del settore della Bionics Engineering.

Capacità di applicare conoscenza e comprensione:

La Laurea Magistrale in Bionics Engineering viene essere conferita a studenti che siano capaci di applicare le loro conoscenze e capacità di comprensione in maniera da dimostrare un approccio professionale al loro lavoro, e possiedano competenze adeguate sia per ideare e sostenere argomentazioni che per risolvere problemi nel proprio campo di studi.
La sua formazione ingegneristica sarà conseguita non solo tramite insegnamenti tipici dell'Ingegneria Biomedica e delle Discipline Biomediche, ma vista la natura complessa e multidisciplinare delle problematiche dell'Ingegneria Bionica, tramite insegnamenti tipici dell'Ingegneria dell'Informazione e

dell'Informatica. Lo studente alla fine del suo percorso grazie alle competenze da lui apprese durante le lezioni sarà in grado di progettare e realizzare sia dispositivi robotici bioinspirati per applicazioni dalla chirurgia, all'assistenza o sistemi biomedicali dedicati allo sviluppo di terapie mediche personalizzate se ha scelto il curriculum Biorobotics, o di progettare e realizzare sistemi ingegnerizzati per il recupero delle funzionalità nervose, di sistemi biomedicali in grado di mimare i sensi, di robot per l'interazione sociale e di dispositivi o software per l'analisi delle funzioni cerebrali in condizioni fisiologiche e/o patologiche se ha scelto il curriculum Neural Engineering.
La parte di approfondimento ed elaborazione delle conoscenze acquisite in aula tramite le lezioni teoriche e le esercitazioni svolte in aula o in laboratorio è demandata allo studio, col quale lo studente misura concretamente quale sia il livello di padronanza delle conoscenze. Le attività che permettono l'acquisizione di queste competenze sono principalmente le attività laboratoriali.

Conoscenza e comprensione e Capacità di applicare conoscenza e comprensione: Dettaglio

1. AREA DEI SETTORI AFFINI

Conoscenza e capacità di comprensione:

In questa area lo studente assumerà conoscenze e competenze di argomenti di livello universitario elevato tipici dei settori bioingegneristici affini all'Ingegneria Biomedica, quali l'Ingegneria delle Telecomunicazioni (ING-INF/03), l'Ingegneria Elettronica (ING-INF/01), dell'Ingegneria Informatica (ING-INF/05), della Psicobiologia e Psicologia Fisiologica (MPSI/02) E dell'Informatica (INF/01). Infatti le tematiche avanzate affrontate nel corso di Laurea Magistrale in Bionics Engineering per poter essere meglio affrontate e comprese dallo studente necessitano di un approccio multidisciplinare, per tale motivo lo studente acquisirà` conoscenza e competenze che comprendono lo studio e l'analisi di metodiche di progettazione elettroniche avanzate per lo sviluppo di dispositivi biomedicali innovativi, la conoscenza e l'analisi di sistemi innovativi per l'elaborazione dei segnali, la conoscenza e la comprensione di nuove tecniche di programmazione avanzata per l'analisi delle interazioni uomo-macchina e la modellizzazione delle reti neurali, E la conoscenza e la comprensione delle interazioni fisiologiche in ambito cerebrale.
La capacità di comprensione di argomenti di livello universitario elevato viene anche raggiunta attraverso l'elaborazione di progetti e l'utilizzo esteso di laboratori e tecniche di simulazione. Inoltre, grazie all'opportunità di svolgere la tesi di laurea magistrale all'interno delle imprese o di rinomati centri di ricerca nazionali e internazionali, o anche come lavori che si collocano in progetti di ricerca già avviati, il laureando consegue conoscenze inerenti agli aspetti applicativi dei suoi studi, già introdotti mediante le sessioni di esercitazione e laboratorio.

Capacità di applicare conoscenza e comprensione:

Le capacità applicative sono assunte dal laureato attraverso un marcato coinvolgimento diretto nelle attività di esercitazione e laboratorio, nonché attraverso lo sviluppo di progetti con crescente grado di autonomia. Il lavoro di tesi per la Laurea Magistrale, in cui il grado di autonomia e la capacità di proporre soluzioni originali e innovative costituiscono i principali criteri di giudizio, rappresenta il momento di sintesi e verifica di questo processo di apprendimento. Infine, ulteriori capacità di comprensione applicata vengono acquisite attraverso le opportunità scaturite da visite presso le imprese, lo sviluppo di progetti in collaborazione con i dottorandi di ricerca, lo svolgimento di tirocini ed esperienze internazionali collegate ai progetti di scambio e mobilità studentesca, il dialogo produttivo con scienziati provenienti da diversi campi della ricerca, come la medicina, la biologia, le neuroscienze, la riabilitazione medica e la chirurgia.

Le conoscenze e capacità sono conseguite e verificate nelle seguenti attività formative:
846II ELECTRONICS FOR BIONICS ENGINEERING 6
765II STATISTICAL SIGNAL PROCESSING 6

705II BIOINSPIRED COMPUTATIONAL METHODS 12
001MA COMPUTATIONAL NEUROSCIENCE (modulo di APPLIED BRAIN SCIENCE) 6
1229I HUMAN-COMPUTER INTERACTION. TOOLS AND STRATEGIES (modulo di HUMAN-COMPUTER INTERACTION AND AFFECTIVE COMPUTING) 6

2. AREA DELL'INGEGNERIA BIOMEDICA AVANZATA E DELLE DISCIPLINE BIOMEDICHE

Conoscenza e capacità di comprensione:

In questa area lo studente assumerà conoscenze e competenze tipiche di settori giovani ed innovativi dell'Ingegneria Biomedica e delle discipline biomediche. Il Corso di studio presenta due curricula uno denominato Neural Engineering prettamente legato all'area dell'Ingegneria dell'Informazione e l'altro Biorobotics prettamente legato all'area dell'Ingegneria Industriale. Nel curriculum Neural Engineering lo studente acquisirà conoscenze nella progettazione, sviluppo e gestione di nuove neuroprotesi e di sistemi innovativi sensoriali, nello sviluppo di nuove metodiche per l'acquisizione e il trattamento dei segnali neurali, nello sviluppo e nella gestione di sistemi robotici capaci di interagire e comunicare con gli esseri umani seguendo comportamenti sociali e regole legate al proprio ruolo specifico.
Nel curriculum Biorobotics lo studente acquisirà conoscenze sullo sviluppo di modelli robotici umani ed animali, sullo sviluppo di piattaforme e dispositivi robotici per la chirurgia e le terapie mirate, per la riabilitazione robotica, per la sostituzione o l'assistenza funzionale di arti superiori e inferiori, sulla biomeccanica computazionale e sulla rigenerazione di organi artificiali bionici.
La capacità di comprensione di argomenti di livello universitario elevato viene anche raggiunta attraverso l'elaborazione di progetti e l'utilizzo esteso di laboratori e tecniche di simulazione. Inoltre, grazie all'opportunità di svolgere la tesi di laurea magistrale all'interno delle imprese o di rinomati centri di ricerca nazionali e internazionali, o anche come lavori che si collocano in progetti di ricerca già avviati, il laureando consegue conoscenze inerenti agli aspetti applicativi dei suoi studi, già introdotti mediante le sessioni di esercitazione e laboratorio.

Capacità di applicare conoscenza e comprensione:

Le capacità applicative sono assunte dal laureato attraverso un marcato coinvolgimento diretto nelle attività di esercitazione e laboratorio, nonché attraverso lo sviluppo di progetti con crescente grado di autonomia. Il lavoro di tesi per la Laurea Magistrale, in cui il grado di autonomia e la capacità di proporre soluzioni originali e innovative costituiscono i principali criteri di giudizio, rappresenta il momento di sintesi e verifica di questo processo di apprendimento. Infine, ulteriori capacità di comprensione applicata vengono acquisite attraverso le opportunità scaturite da visite presso le imprese, lo sviluppo di progetti in collaborazione con i dottorandi di ricerca, lo svolgimento di tirocini ed esperienze internazionali collegate ai progetti di scambio e mobilità studentesca, il dialogo produttivo con scienziati provenienti da diversi campi della ricerca, come la medicina, la biologia, le neuroscienze, la riabilitazione medica e la chirurgia.

Le conoscenze e capacità sono conseguite e verificate nelle seguenti attività formative:
1081I ADVANCED MATERIALS FOR BIONICS 6
1128I ANALYSIS OF BIONIC AND ROBOTIC SYSTEM 12
1092I ARTIFICIAL INTELLIGENT SYSTEM FOR HUMAN IDENTIFICATION 6
1078I BIOINSPIRED AND SOFT ROBOTICS 12
710II BIONIC SENSES 6
700II NEURAL PROSTHESES 12
706II NEUROMORPHIC ENGINEERING 6
1079I ROBOT PROGRAMMING FRAMEWORKS AND IOT PLATFORMS 6
1033I WEARABLE ROBOTICS 12
1229I AFFECTIVE COMPUTING (modulo di HUMAN-COMPUTER INTERACTION AND AFFECTIVE COMPUTING) 6
1226I NEURAL SIGNAL PROCESSING AND MEASUREMENT TECHNIQUES 12
1104I DESIGN PRINCIPLES FOR BIONIC TISSUE ENGINEERING 6

1105I REHABILITATION AND ASSISTIVE TECHNOLOGIES 12
1103I ADVANCED INTERVENTIONAL AND THERAPEUTIC TECHNOLOGIES 12
1127I PROBABILITY AND BIOSTATISTICS 6
0080M NEUROANATOMY AND COGNITIVE NEUROSCIENCE 6
001MA INTEGRATIVE CELEBRAL FUNTION (modulo di APPLIED BRAIN SCIENCE) 6

Autonomia di giudizio, Abilità comunicative, Capacità di Apprendimento

Autonomia di giudizio (making judgements):

La Laurea Magistrale in Bionics Engineering può essere conferita a studenti che abbiano acquisito la capacità di integrare le conoscenze e gestire la complessità, nonché di formulare giudizi sulla base di informazioni limitate o incomplete, includendo la riflessione sulle responsabilità sociali ed etiche collegate all'applicazione delle loro conoscenze e giudizi nel settore della Biorobotica e della Ingegneria Neurale. Tali obiettivi sono ottenuti attraverso l'elaborazione, con crescente grado di autonomia, di progetti, esercizi, ed applicazioni. Le capacità di giudizio vengono inoltre ampliate attraverso incontri e colloqui con esponenti del mondo del lavoro e della ricerca promossi con l'organizzazione di seminari, conferenze, visite aziendali. L'accertamento dell'autonomia di giudizio è effettuato mediante le prove ed esami di profitto relativi ai diversi insegnamenti e tramite la valutazione degli eventuali elaborati e alla tesi finale. La tesi di laurea magistrale, infatti, rappresenta il momento più alto in cui lo studente, confrontandosi con un contesto caratteristico della Bionics Engineering, elabora idee originali e innovative, assumendosi il compito, durante la discussione, di illustrarle e sostenerne la validità.

Capacità di apprendimento (learning skills):

La Laurea Magistrale in Bionics Engineering può essere conferita a studenti che abbiano sviluppato capacità di apprendimento tali da consentire loro di impostare in modo autonomo lo studio di discipline ingegneristiche avanzate, come la biorobotica, la meccatronica e l'ingegneria neurale, e di discipline di base anche non contemplate nel proprio curriculum. Gli studi in ingegneria da sempre hanno avuto l'obiettivo di fornire metodi e capacità per affrontare problemi di natura tecnico-ingegneristica non necessariamente uguali o simili a quelli affrontati durante gli studi. Pertanto, la capacità di affrontare ulteriori studi dopo la laurea magistrale, sia autonomi che mediante percorsi formativi post-laurea magistrale, è nella tradizione del laureato magistrale in ingegneria. Nel Corso, tale capacità viene stimolata mediante attività di sintesi e attività progettuali, presenti in molti insegnamenti, in cui occorre raccogliere in modo autonomo informazioni, elaborarle e acquisire ulteriori conoscenze, al fine di sviluppare elaborati di progetto o di laboratorio. La verifica della capacità di apprendimento è effettuata mediante le prove ed esami di profitto relativi ai diversi insegnamenti e tramite la valutazione degli eventuali elaborati e alla tesi finale. Inoltre, nel lavoro per la preparazione della tesi, viene sviluppata la capacità del singolo di costruire le nuove competenze necessarie, non incluse nei programmi di studio, attraverso ricerche, studi e applicazioni autonomamente condotti.

Caratteristiche della prova finale

La prova finale (Tesi) consiste nella preparazione di una relazione scritta elaborata in modo originale sotto la guida di un relatore su una tematica caratterizzante il Corso di Studio e nella illustrazione dei risultati conseguiti durante lo svolgimento dell'attività di tesi davanti alla Commissione di Laurea.
La prova mira a valutare la capacità del candidato di svolgere in completa autonomia: l'approfondimento di un'attività di progettazione o di ricerca, documentata in una dissertazione scritta; l'illustrazione in forma di presentazione scritta ed orale del lavoro svolto.

Modalità di svolgimento della prova finale

La Commissione di Laurea, composta da 5 docenti afferenti al Consiglio di Corso di Laurea Magistrale, accerta il livello di autonomia e di padronanza di specifiche metodologie raggiunto dal candidato, tramite l'esposizione in forma orale del lavoro di tesi del candidato e formulando domande al candidato sul lavoro da lui svolto, e provvede a determinare il voto di laurea. A questo scopo, anche per dare continuità alla valutazione, la Commissione adotta regole di calcolo che mettono in relazione la media degli esami con il voto di laurea, espresso in 110-esimi. Il voto di laurea è da considerarsi formalmente una prerogativa della Commissione di Laurea la quale, per dare continuità nel tempo alle valutazioni, adotta regole di calcolo che mettono in relazione media degli esami e voto di laurea. Per la determinazione del voto di laurea, espresso in 110esimi, sono accolti da tutti i Corsi di Studio del Dipartimento di afferenza del Corso di Studio i seguenti criteri comuni: la media è calcolata pesando le votazioni riportate nei singoli corsi sulla base dei relativi crediti formativi universitari (media pesata sui CFU). La media viene tradotta in 110 decimi e poi la Commissione aggiunge dei punti, che variano tra 0 e 4, a questo punteggio base, in base a come il candidato ha sviluppato il suo lavoro di tesi, come ha risposto alle domande fatte dalla Commissione durante l'esposizione del lavoro di tesi, ed in base al giudizio del docente che lo ha seguito durante la tesi e del contro relatore che ha revisionato il lavoro di tesi. Le votazioni con lode ottenute nei corsi sono contate come 33/30; l'attribuzione della votazione 110/110 richiede una media non inferiore a 27/30; l'attribuzione della votazione 110/110 e lode richiede una media non inferiore a 28/30.
La Commissione di Laurea è nominata dal Direttore del Dipartimento (art.24 dello Statuto), su proposta del Corso di Studio. Sono previste almeno 6 sessioni di laurea in un anno accademico (art.25 del Regolamento Didattico di Ateneo).

Esperienza dello Studente

Aule

https://su.unipi.it/OccupazioneAule

Laboratori e Aule informatiche

Vedi allegato

Sale Studio

https://www.unipi.it/campus-e-servizi/servizi/biblioteche-e-sale-studio/

Biblioteche

http://www.sba.unipi.it/it/biblioteche/polo-5/ingegneria

Orientamento in ingresso

https://www.unipi.it/didattica/iscrizioni/orientamento/

Orientamento e tutorato in itinere

https://www.unipi.it/campus-e-servizi/servizi/servizio-di-tutorato-alla-pari-gli-studenti-esperti-tutor/

Assistenza per lo svolgimento di periodi di formazione all’estero (Tirocini e stage)

https://www.unipi.it/campus-e-servizi/verso-il-lavoro/

Assistenza e accordi per la mobilità internazionale degli studenti

https://www.unipi.it/didattica/studi-e-tirocini-allestero/studiare-allestero/

Accompagnamento al lavoro

https://www.unipi.it/campus-e-servizi/verso-il-lavoro/career-service/

Eventuali altre iniziative

Il consiglio aggregato in Ingegneria Biomedica e Bionics Engineering ha deciso di istituire una giornata di incontro tra studenti ed esponenti del mondo del lavoro, per presentare da un lato l'offerta formativa del corso di laurea triennale in ingegneria biomedica e dall'altro avere input dalle aziende e dagli enti invitati su eventuali migliorie da apportare.

Quest'anno l'evento si terrà il 16 Maggio 2025 presso l'aula magna del polo Fibonacci e parteciperanno alcune ditte del settore quali General Electric Healthcare, Esaote, Dieng Corp, Fondazione Monasterio, Elcam Medical, Rimos e Enki. L'evento, organizzato con cadenza annuale, favorisce l'incontro tra aziende e studenti, offrendo soprattutto un'opportunità per raccogliere feedback sulle competenze

richieste dal mondo del lavoro e valutare quanto la didattica del Corso di Laurea le soddisfi o necessiti di aggiornamenti.

Opinioni studenti

Vedi allegato

Opinioni laureati

Vedi allegato

Risultati della Formazione

Dati di ingresso, di percorso e di uscita

Vedi allegato

Organizzazione e Gestione della Qualità

Struttura organizzativa e responsabilità a livello di Ateneo

https://www.unipi.it/ateneo/qualita-e-valutazione/

Organizzazione e responsabilità della AQ a livello del Corso di Studio

https://www.unipi.it/ateneo/qualita-e-valutazione/

Programmazione dei lavori e scadenze di attuazione delle iniziative

https://www.unipi.it/ateneo/qualita-e-valutazione/

Riesame annuale

https://www.unipi.it/ateneo/qualita-e-valutazione/

Progettazione del Corso di Studio

Vedi allegato

Classe/Percorso

Classe	Ingegneria biomedica (LM-21 R)
Percorso di Studio	BIOROBOTICS

Quadro delle attività formative

Caratterizzante				
Ambito disciplinare	**CFU**	**Intervallo di CFU da RAD**	**SSD**	**Attività Formative**
Bioingegneria	66	48 - 72	ING-IND/34	1 - ROBOTIC FOR MINIMAL INVASIVE AND TARGETED THERAPY, 6 CFU, OBB (Modulo dell'Attività formativa integrata ADVANCED INTERVENTIONAL AND THERAPEUTIC TECHNOLOGIES (1103I))
				1 - PROSTHESES, 6 CFU, OBB (Modulo dell'Attività formativa integrata WEARABLE ROBOTICS (1033I))
				1 - MECHANICS OF SMART MATERIALS AND STRUCTURES, 6 CFU, OBB (Modulo dell'Attività formativa integrata BIOINSPIRED AND SOFT ROBOTICS (1078I))
				1 - ROBOTIC AND DATA-DRIVEN REHABILITATION, 6 CFU, OBB (Modulo dell'Attività formativa integrata REHABILITATION AND ASSISTIVE TECHNOLOGIES (1105I))
				2 - BIONIC ORGANS AND TISSUES, 6 CFU, OBB (Modulo dell'Attività formativa integrata ADVANCED INTERVENTIONAL AND THERAPEUTIC TECHNOLOGIES (1103I))
				2 - EXOSKELETONS, 6 CFU, OBB (Modulo dell'Attività

				formativa integrata WEARABLE ROBOTICS (1033I))
				2 - SOFT ROBOTICS TECHNOLOGIES, 6 CFU, OBB (Modulo dell'Attività formativa integrata BIOINSPIRED AND SOFT ROBOTICS (1078I))
				2 - BIOMECHANICS OF HUMAN MOTION, 6 CFU, OBB (Modulo dell'Attività formativa integrata REHABILITATION AND ASSISTIVE TECHNOLOGIES (1105I))
				1 - PRINCIPLES OF BIONICS AND BIOROBOTICS ENGINEERING, 6 CFU, OBB (Modulo dell'Attività formativa integrata ANALYSIS OF BIONIC AND ROBOTIC SYSTEMS (1128I))
		48 - 72	ING-INF/06	1 - DESIGN PRINCIPLES FOR BIONIC TISSUE ENGINEERING, 6 CFU, OBB
				2 - MODELING OF MULTI-PHYSICS PHENOMENA, 6 CFU, OBB (Modulo dell'Attività formativa integrata ANALYSIS OF BIONIC AND ROBOTIC SYSTEMS (1128I))
Discipline biomediche	6	6 - 12	M-PSI/02	0080M - BEHAVIOURAL AND COGNITIVE NEUROSCIENCE, 6 CFU, OBB
Totale Caratterizzante	72	54 - 84		

Affine/Integrativa				
Ambito disciplinare	**CFU**	**Intervallo di CFU da RAD**	**SSD**	**Attività Formative**
Attività formative affini o integrative	18	18 - 30	ING-INF/03	1 - STATISTICAL SIGNAL PROCESSING, 6 CFU, OBB
		18 - 30	ING-INF/05	1 - BIOLOGICAL DATA MINING, 6 CFU, OBB (Modulo dell'Attività formativa integrata BIOINSPIRED COMPUTATIONAL METHODS (705II))
				2 - NEURAL AND FUZZY COMPUTATION, 6 CFU, OBB (Modulo dell'Attività formativa integrata BIOINSPIRED

				COMPUTATIONAL METHODS (705II))
Totale Affine/Integrativa	18	18 - 30		

A scelta dello studente				
Ambito disciplinare	**CFU**	**Intervallo di CFU da RAD**	**SSD**	**Attività Formative**
A scelta dello studente	12	12 - 12	ING-IND/34	1 - ADVANCED MATERIALS FOR BIONICS, 6 CFU, OPZ 1 - ROBOT PROGRAMMING FRAMEWORKS AND IOT PLATFORMS, 6 CFU, OPZ 1 - NEUROMORPHIC ENGINEERING, 6 CFU, OPZ
		12 - 12	ING-INF/01	1 - ELECTRONICS FOR BIONICS ENGINEERING, 6 CFU, OPZ
		12 - 12	ING-INF/06	1 - ARTIFICIAL INTELLIGENT SYSTEM FOR HUMAN IDENTIFICATION, 6 CFU, OPZ 1 - PROBABILITY AND BIOSTATISTICS, 6 CFU, OPZ
Totale A scelta dello studente	12	12 - 12		

Lingua/Prova Finale				
Ambito disciplinare	**CFU**	**Intervallo di CFU da RAD**	**SSD**	**Attività Formative**
Per la prova finale	15	15 - 15	PROFIN_S	1 - FINAL EXAMINATION, 15 CFU, OBB
Totale Lingua/Prova Finale	15	15 - 15		

Altro				
Ambito disciplinare	**CFU**	**Intervallo di CFU da RAD**	**SSD**	**Attività Formative**
Tirocini formativi e di orientamento	3	1 - 3	NN	1 - LAB TRAINING, 3 CFU, OBB
Totale Altro	3	1 - 3		

Totale	120	100 - 144		

Classe/Percorso

Classe	Ingegneria biomedica (LM-21 R)
Percorso di Studio	NEURAL ENGINEERING

Quadro delle attività formative

Caratterizzante				
Ambito disciplinare	**CFU**	**Intervallo di CFU da RAD**	**SSD**	**Attività Formative**
Bioingegneria	48	48 - 72	ING-IND/34	1 - PRINCIPLES OF BIONICS AND BIOROBOTICS ENGINEERING, 6 CFU, OBB (Modulo dell'Attività formativa integrata ANALYSIS OF BIONIC AND ROBOTIC SYSTEMS (1128I))
		48 - 72	ING-INF/06	1 - BIONIC SENSES, 6 CFU, OBB
				1 - NEURAL INTERFACES AND BIOELECTRONIC MEDICINE, 6 CFU, OBB (Modulo dell'Attività formativa integrata NEURAL PROSTHESES (700II))
				1226I - METHODS AND TECHNIQUES OF MEASUREMENT AND SIGNAL PROCESSING, 6 CFU, OBB (Modulo dell'Attività formativa integrata NEURAL SIGNAL PROCESSING AND MEASUREMENT TECHNIQUES (1226I))
				1226I-A - ADVANCED NEURAL SIGNAL PROCESSING, 6 CFU, OBB (Modulo dell'Attività formativa integrata NEURAL SIGNAL PROCESSING AND MEASUREMENT TECHNIQUES (1226I))
				1229I - AFFECTIVE COMPUTING, 6 CFU, OBB (Modulo dell'Attività formativa integrata HUMAN-COMPUTER INTERACTION AND AFFECTIVE COMPUTING

				(1229I)) 2 - NEURAL TISSUE ENGINEERING, 6 CFU, OBB (Modulo dell'Attività formativa integrata NEURAL PROSTHESES (700II)) 2 - MODELING OF MULTI-PHYSICS PHENOMENA, 6 CFU, OBB (Modulo dell'Attività formativa integrata ANALYSIS OF BIONIC AND ROBOTIC SYSTEMS (1128I))
Discipline biomediche	12	6 - 12	M-PSI/02	001MA-A - INTEGRATIVE CEREBRAL FUNCTION, 6 CFU, OBB (Modulo dell'Attività formativa integrata APPLIED BRAIN SCIENCE (001MA)) 0080M - BEHAVIOURAL AND COGNITIVE NEUROSCIENCE, 6 CFU, OBB
Totale Caratterizzante	60	54 - 84		

Affine/Integrativa				
Ambito disciplinare	**CFU**	**Intervallo di CFU da RAD**	**SSD**	**Attività Formative**
Attività formative affini o integrative	30	18 - 30	INF/01	1229I-A - HUMAN-COMPUTER INTERACTION. TOOLS AND STRATEGIES, 6 CFU, OBB (Modulo dell'Attività formativa integrata HUMAN-COMPUTER INTERACTION AND AFFECTIVE COMPUTING (1229I)) 2 - COMPUTATIONAL NEUROSCIENCE, 6 CFU, OBB (Modulo dell'Attività formativa integrata APPLIED BRAIN SCIENCE (001MA))
		18 - 30	ING-INF/03	1 - STATISTICAL SIGNAL PROCESSING, 6 CFU, OBB
		18 - 30	ING-INF/05	1 - BIOLOGICAL DATA MINING, 6 CFU, OBB (Modulo dell'Attività formativa integrata BIOINSPIRED COMPUTATIONAL METHODS (705II)) 2 - NEURAL AND FUZZY COMPUTATION, 6 CFU, OBB (Modulo dell'Attività formativa

				integrata BIOINSPIRED COMPUTATIONAL METHODS (705II))
Totale Affine/Integrativa	30	18 - 30		

A scelta dello studente				
Ambito disciplinare	**CFU**	**Intervallo di CFU da RAD**	**SSD**	**Attività Formative**
A scelta dello studente	12	12 - 12	ING-IND/34	1 - ADVANCED MATERIALS FOR BIONICS, 6 CFU, OPZ 1 - ROBOT PROGRAMMING FRAMEWORKS AND IOT PLATFORMS, 6 CFU, OPZ 1 - NEUROMORPHIC ENGINEERING, 6 CFU, OPZ
		12 - 12	ING-INF/01	1 - ELECTRONICS FOR BIONICS ENGINEERING, 6 CFU, OPZ
		12 - 12	ING-INF/06	1 - ARTIFICIAL INTELLIGENT SYSTEM FOR HUMAN IDENTIFICATION, 6 CFU, OPZ 1 - PROBABILITY AND BIOSTATISTICS, 6 CFU, OPZ
Totale A scelta dello studente	12	12 - 12		

Lingua/Prova Finale				
Ambito disciplinare	**CFU**	**Intervallo di CFU da RAD**	**SSD**	**Attività Formative**
Per la prova finale	15	15 - 15	PROFIN_S	1 - FINAL EXAMINATION, 15 CFU, OBB
Totale Lingua/Prova Finale	15	15 - 15		

Altro				
Ambito disciplinare	**CFU**	**Intervallo di CFU da RAD**	**SSD**	**Attività Formative**
Tirocini formativi e di orientamento	3	1 - 3	NN	1 - LAB TRAINING, 3 CFU, OBB
Totale Altro	3	1 - 3		

Totale	120	100 - 144		

Percorso di Studio: comune (PDS0)

CFU totali: 90, di cui 54 derivanti da AF obbligatorie e 36 da AF a scelta

1° Anno (anno accademico 2025/2026)

Attività Formativa	CFU	Classe	TAF	Ambito	SSD	Obblig.
ADVANCED MATERIALS FOR BIONICS (1081I) **Obiettivi** The aim of the course is to provide a solid background in Materials Science and Engineering as relevant for Bionics Engineering. Together with basic understanding of the various classes of materials, their structure, composition, structural and functional properties, the students will learn about more advanced concepts and recent developments of modern Materials Science, lying at the interface between chemistry, physics, engineering and biology. The course is structured in three sections. In the first section (1-Basic Materials Science & Engineering) basic and traditional topics of Materials Science will be covered/refreshed to provide a common basis among students with different background knowledge. Topics include: nomenclature and classification of materials, basic physical and chemical knowledge of solid matter, structure/properties correlation in materials, hierarchical structuring, phase transitions, fundamentals of mechanical behaviour, viscoelasticity, basic characterization tools. Various classes of engineering relevant materials will be reviewed: metals, ceramics, polymers, composites. In the second section (2 – Advanced Materials Concepts) more advanced concepts will be introduced, regarding: biocompatibility of Materials, complex behaviour of soft matter, nanotechnology and nanostructures, biological materials, bioinspired materials, stimuli-responsive materials, electro-active polymers, advanced investigation and fabrication techniques for micro- and nano-structures. In the third section (3 Technology & Bionics Applications) relevant examples of applications of materials in Bionics will be reviewed, including: advanced functional surfaces and interfaces, structural materials for bionics, materials for bioelectronics, materials for sensors & actuators in robotics.	6	LM-21 R	D	A scelta dello studente	ING-IND/34	No
ANALYSIS OF BIONIC AND ROBOTIC SYSTEMS (1128I) **Obiettivi** In particular, the “Principles of Bionics and Biorobotics Engineering” module will introduce the wide and interdisciplinary field of bionics and related scientific areas, such as biorobotics, neuroengineering and bioengineering. Bionics aims at gathering specific knowledge through the analysis/modeling of living	12	LM-21 R	B	Bioingegneria	ING-INF/06, ING-IND/34	Si

organisms/ecosystems and applies it to the development of newly inspired advanced devices. Bionics also focuses on artificial systems deeply connected to body tissues, and/or interacting with organisms. The application of bionics principles is nowadays widespread in many engineering sub-fields. During this course, the pillars of bionics and robotics are presented to allow the proper understanding of the whole loop from scientific insights to engineering innovation. In particular, the course focuses on the key principles of biological locomotion, swarm robotics, artificial organs, neurorobotics, neuroprostheses, neural interfaces with the nervous system, morphological computation, energy issues, principles of structural bionic design and main manufacturing techniques, as well as the fundamentals of robot mechanics. At the end of the module “Principles of Bionics and Biorobotics Engineering”, the student: ● Will possess the main knowledge about bionic and robotics engineering principles; ● Will be able to orient him/herself in the scientific literature; ● Will be able to formulate innovative hypotheses and to devise new solutions on bionic design and bioinspired robotic paradigms. To profitably attend this module, no specialistic knowledge is required. However, consolidated competences of physics and mathematics are needed. In addition, even if not strictly needed, competences concern mechanics, signal processing, and electronics are desirable. The “Principles of Bionics and Biorobotics Engineering” module topics are the following: ● Historical evolution of bionics, related to robotics and bioengineering; ● Model organisms and biological locomotion principles in different media, and applications in robotics; ● Bionic energy management: comparison between organisms and robots; ● Fabrication technologies at different scales; ● Bioinspired structural design and advanced materials; ● Fundamentals of robot mechanics (schematic of the joints, homogeneous transformations, Jacobian, methods for kinematic and dynamic studies); ● Swarm robotics; ● Principles to design effective neural interfaces and neuroprostheses ● Ethical issues and legal considerations. The “Modeling of multi-physics phenomena” module provides a basic, practical knowledge of computational mechanics of solids (linear/non-linear elasticity) and fluids (incompressible flows of Newtonian fluids). and computational electromagnetism at low frequencies, mainly associated to bioelectric phenomena and neural models. The first part of the course deals with the theory of the Finite Element Method and introduces numerical algorithms and practices for the solution of non-linear and time-dependent problems, which are common to all the aforementioned computational disciplines. Then, the numerical implementations of several physical models in a commercial FE software will be shown during hands-on sessions, along with applications to design problems involving sensors and bioinspired devices.

Moduli PRINCIPLES OF BIONICS AND BIOROBOTICS ENGINEERING (1) MODELING OF MULTI-PHYSICS PHENOMENA (2)	 6 6					
ARTIFICIAL INTELLIGENT SYSTEMS FOR HUMAN IDENTIFICATION (1092I) **Obiettivi** This course provides fundamentals about techniques to verify or recognize the identity of a living person based on the analysis of biological/physiological traits and/or behavioural features. The topics of the course will be: - Biometrics overview (history of biometrics, applications); - Recognition, identification and verification; - Privacy, security and ethics; - Overview of image processing; - Physiological biometric systems: fingerprint recognition, face recognition, iris recognition, retina recognition, hand recognition, vein patterns; - Behavioral biometric systems: keystroke dynamics, signature recognition, voice recognition, gait recognition; - Multi-modal biometric systems; - Biometric applications.	6	LM-21 R	D	A scelta dello studente	ING-INF/06	No
BIOINSPIRED COMPUTATIONAL METHODS (705II) **Obiettivi** The course aims to introduce the main concepts and techniques used in bioinspired computational methods. The course is divided in two modules “Neural and fuzzy computation” and “Biological data mining”. The first module intends to offer students the opportunity to learn the basic concepts and models of computational intelligence, to have a thorough understanding of the associated computational techniques, such as artificial neural networks, fuzzy systems and genetic algorithms, and to know how to apply them to a wide variety of application areas. The second module will focus on the basic aspects of biological data mining: data pre-processing, frequent pattern mining, classification, prediction, clustering and outlier detection. **Moduli** NEURAL AND FUZZY COMPUTATION (2) BIOLOGICAL DATA MINING (1)	12 6 6	LM-21 R	C	Attività formative affini o integrative	ING-INF/05	Si
ELECTRONICS FOR BIONICS ENGINEERING (846II) **Obiettivi** The student who successfully completes the course will be able to demonstrate a solid knowledge of the main issues related to the design of sensor based electronic systems for bionics engineering. He or she will acquire the ability to analyse and design the building blocks of an analogue front-end for the acquisition, conditioning and conversion of biological sensor data, and will master the design methodologies adopted for instrumentation amplifiers, passive and active filters, analogue-to-digital and digital-to-analogue converters. He or she will then familiarise with standard digital interfaces utilised to transfer digitalised sensor data to an embedded microcontroller or microprocessor. The student will	6	LM-21 R	D	A scelta dello studente	ING-INF/01	No

deepen his or her learning on the conditioning and digitalization chain of biological sensor data by familiarising with standard digital interfaces utilised to transfer digitalised sensor data to an embedded microcontroller or microprocessor. Finally, he or she will be exposed to state-of-the-art design methodologies adopted for tightly energy-/power-constrained electronic systems in wearable and implantable devices, and will have the opportunity to consolidate his or her learning by working with advanced EDA tools.						
NEUROANATOMY AND COGNITIVE NEUROSCIENCE (0080M)	6	LM-21 R	B	Discipline biomediche	M-PSI/02	Si
NEUROMORPHIC ENGINEERING (706II) **Obiettivi** The course will explore computational and physical models that emulate the neural dynamics of biological neurons of peripheral and central nervous system. A particular focus will be dedicated to real-time implementation of spiking artefacts that could be integrated in neurophysiological studies and in closed loop hybrid-bionic systems to restore missing sensorimotor functions.	6	LM-21 R	D	A scelta dello studente	ING-IND/34	No
PROBABILITY AND BIOSTATISTICS (1127I) **Obiettivi** The student will learn the basics of probability theory and statistical inference and will be able to apply appropriate methodologies for applications in biology and, in general, for the study of life sciences. In addition to the planning, collection and analysis of experimental data, the following topics will be discussed: theory of probability, discrete and continuous random variables, descriptive statistics of statistical samples, multivariate random variables, sums of random variables and associated limit theorems, interval estimation, inferential statistics and hypothesis testing, non-Gaussianity and chi-square tests, inference through non-parametric methods, regression analysis, and evaluation of diagnostic tests: sensitivity, specificity, and ROC curves.	6	LM-21 R	D	A scelta dello studente	ING-INF/06	No
ROBOT PROGRAMMING FRAMEWORKS AND IOT PLATFORMS (1079I) **Obiettivi** The course aims at proving theoretical and practical competences in robotic programming frameworks and IoT platforms and it will provide knowledge in software design of autonomous robots and systems. Specific activities will be performed with ROS (Robotic Operating System) and YARP (Yet another robot platform) that will be implemented in simulated environments, also using dedicated SOM (System on Module) development boards. The course will also provide basic knowledge on brain-inspired controllers, based on machine learning approaches. Hands-on laboratory activities will be part of the course: students will be involved in the design and development of an IoT based environment, program the embedded system with sensors and cloud-based computing, design brain-inspired controllers and	6	LM-21 R	D	A scelta dello studente	ING-IND/34	No

integrate them in robotic middleware (ROS and YARP).						
STATISTICAL SIGNAL PROCESSING (765II) **Obiettivi** The course will cover statistical signal processing methods, with application to bioengineering field. The students will become familiar with basic concepts of discrete representation of deterministic and random continuous-time signals, discrete-time random signal analysis, deterministic and random parameter estimation. Various estimation methods will be introduced and compared, such as the method of moments, the maximum likelihood and the linear and non-linear least squares methods. An introduction to Bayesian framework for random parameters and random signals estimation will be provided, with particular emphasis to the problem of linear smoothing, filtering, and prediction. Parametric auto-regressive moving average (ARMA) modeling and identification of discrete-time random signals will be also addressed. Advanced topics in parametric and non-parametric (adaptive and non-adaptive) methods for spectral estimation will be introduced, as well as some basic concepts of time-frequency analysis.	6	LM-21 R	C	Attività formative affini o integrative	ING-INF/03	Si

2° Anno (anno accademico 2026/2027)

Attività Formativa	CFU	Classe	TAF	Ambito	SSD	Obblig.
FINAL EXAMINATION (1087Z) **Obiettivi** The final examination involves the preparation of a report led to a design or research activity, and in its presentation and discussion.	15	LM-21 R	E	Per la prova finale	PROFIN_S	Si
LAB TRAINING (1088Z) **Obiettivi** This activity will consist of Lab training that the student will perform in dedicated facilities and laboratories, with the aim to increase his/her experience in laboratory practice.	3	LM-21 R	F	Tirocini formativi e di orientamento	NN	Si

Percorso di Studio: NEURAL ENGINEERING (1)

CFU totali: 144, di cui 108 derivanti da AF obbligatorie e 36 da AF a scelta

Sede Didattica	Università di Pisa

1° Anno (anno accademico 2025/2026)

Attività Formativa	CFU	Classe	TAF	Ambito	SSD	Obblig.
ADVANCED MATERIALS FOR BIONICS (1081I) **Obiettivi** The aim of the course is to provide a solid background in Materials Science and Engineering as relevant for Bionics Engineering. Together with basic understanding of the various classes of materials, their structure, composition, structural and functional	6	LM-21 R	D	A scelta dello studente	ING-IND/34	No

properties, the students will learn about more advanced concepts and recent developments of modern Materials Science, lying at the interface between chemistry, physics, engineering and biology. The course is structured in three sections. In the first section (1-Basic Materials Science & Engineering) basic and traditional topics of Materials Science will be covered/refreshed to provide a common basis among students with different background knowledge. Topics include: nomenclature and classification of materials, basic physical and chemical knowledge of solid matter, structure/properties correlation in materials, hierarchical structuring, phase transitions, fundamentals of mechanical behaviour, viscoelasticity, basic characterization tools. Various classes of engineering relevant materials will be reviewed: metals, ceramics, polymers, composites. In the second section (2 – Advanced Materials Concepts) more advanced concepts will be introduced, regarding: biocompatibility of Materials, complex behaviour of soft matter, nanotechnology and nanostructures, biological materials, bioinspired materials, stimuli-responsive materials, electro-active polymers, advanced investigation and fabrication techniques for micro- and nano-structures. In the third section (3 Technology & Bionics Applications) relevant examples of applications of materials in Bionics will be reviewed, including: advanced functional surfaces and interfaces, structural materials for bionics, materials for bioelectronics, materials for sensors & actuators in robotics.						
ANALYSIS OF BIONIC AND ROBOTIC SYSTEMS (1128I) **Obiettivi** In particular, the “Principles of Bionics and Biorobotics Engineering” module will introduce the wide and interdisciplinary field of bionics and related scientific areas, such as biorobotics, neuroengineering and bioengineering. Bionics aims at gathering specific knowledge through the analysis/modeling of living organisms/ecosystems and applies it to the development of newly inspired advanced devices. Bionics also focuses on artificial systems deeply connected to body tissues, and/or interacting with organisms. The application of bionics principles is nowadays widespread in many engineering sub-fields. During this course, the pillars of bionics and robotics are presented to allow the proper understanding of the whole loop from scientific insights to engineering innovation. In particular, the course focuses on the key principles of biological locomotion, swarm robotics, artificial organs, neurorobotics, neuroprostheses, neural interfaces with the nervous system, morphological computation, energy issues, principles of structural bionic design and main manufacturing techniques, as well as the fundamentals of robot mechanics. At the end of the module “Principles of Bionics and Biorobotics Engineering”, the student: ● Will possess the main knowledge about bionic and robotics engineering	12	LM-21 R	B	Bioingegneria	ING-INF/06, ING-IND/34	Si

principles; ● Will be able to orient him/herself in the scientific literature; ● Will be able to formulate innovative hypotheses and to devise new solutions on bionic design and bioinspired robotic paradigms. To profitably attend this module, no specialistic knowledge is required. However, consolidated competences of physics and mathematics are needed. In addition, even if not strictly needed, competences concern mechanics, signal processing, and electronics are desirable. The “Principles of Bionics and Biorobotics Engineering” module topics are the following: ● Historical evolution of bionics, related to robotics and bioengineering; ● Model organisms and biological locomotion principles in different media, and applications in robotics; ● Bionic energy management: comparison between organisms and robots; ● Fabrication technologies at different scales; ● Bioinspired structural design and advanced materials; ● Fundamentals of robot mechanics (schematic of the joints, homogeneous transformations, Jacobian, methods for kinematic and dynamic studies); ● Swarm robotics; ● Principles to design effective neural interfaces and neuroprostheses ● Ethical issues and legal considerations. The “Modeling of multi-physics phenomena” module provides a basic, practical knowledge of computational mechanics of solids (linear/non-linear elasticity) and fluids (incompressible flows of Newtonian fluids). and computational electromagnetism at low frequencies, mainly associated to bioelectric phenomena and neural models. The first part of the course deals with the theory of the Finite Element Method and introduces numerical algorithms and practices for the solution of non-linear and time-dependent problems, which are common to all the aforementioned computational disciplines. Then, the numerical implementations of several physical models in a commercial FE software will be shown during hands-on sessions, along with applications to design problems involving sensors and bioinspired devices. **Moduli** PRINCIPLES OF BIONICS AND BIOROBOTICS ENGINEERING (1) 6 MODELING OF MULTI-PHYSICS PHENOMENA (2) 6						
APPLIED BRAIN SCIENCE (001MA) **Obiettivi** This course is divided in two modules “Behavioral and Cognitive Neuroscience” and “Computational neuroscience”. In the class “Behavioral and cognitive neuroscience”, the student will learn the following topics: introduction to cognitive and social neuroscience; introduction to neuronal functioning, brain metabolism and intrinsic brain activity; basic principles of brain imaging methodologies, their uses for research and clinical purposes; introduction to the advanced methods for brain imaging analyses; the neurobiological correlates of human cognition and behavior; the mental representation of the external	12	LM-21 R	B	Discipline biomediche	M-PSI/02, INF/01	Si

world; the functional neuroanatomy of perception and imagery; introduction to consciousness and sleep; introduction to psycholinguistics; emotions and behavior; motor control and action representation, and their implications for the development of brain-computer interfaces. The objectives of "Computational neuroscience" class include bio-inspired neural modelling, spiking and reservoir computing neural networks, advanced computational neural models for learning, architectures and learning methods for dynamical/recurrent neural networks for temporal data and the analysis of their properties, the role of computational neuroscience in real-world applications (by case studies). **Moduli** COMPUTATIONAL NEUROSCIENCE (2) INTEGRATIVE CEREBRAL FUNCTION (001MA-A)	 6 6					
ARTIFICIAL INTELLIGENT SYSTEMS FOR HUMAN IDENTIFICATION (1092I) **Obiettivi** This course provides fundamentals about techniques to verify or recognize the identity of a living person based on the analysis of biological/physiological traits and/or behavioural features. The topics of the course will be: - Biometrics overview (history of biometrics, applications); - Recognition, identification and verification; - Privacy, security and ethics; - Overview of image processing; - Physiological biometric systems: fingerprint recognition, face recognition, iris recognition, retina recognition, hand recognition, vein patterns; - Behavioral biometric systems: keystroke dynamics, signature recognition, voice recognition, gait recognition; - Multi-modal biometric systems; - Biometric applications.	6	LM-21 R	D	A scelta dello studente	ING-INF/06	No
BIOINSPIRED COMPUTATIONAL METHODS (705II) **Obiettivi** The course aims to introduce the main concepts and techniques used in bioinspired computational methods. The course is divided in two modules “Neural and fuzzy computation” and “Biological data mining”. The first module intends to offer students the opportunity to learn the basic concepts and models of computational intelligence, to have a thorough understanding of the associated computational techniques, such as artificial neural networks, fuzzy systems and genetic algorithms, and to know how to apply them to a wide variety of application areas. The second module will focus on the basic aspects of biological data mining: data pre-processing, frequent pattern mining, classification, prediction, clustering and outlier detection. **Moduli** NEURAL AND FUZZY COMPUTATION (2) BIOLOGICAL DATA MINING (1)	12 6 6	LM-21 R	C	Attività formative affini o integrative	ING-INF/05	Si
ELECTRONICS FOR BIONICS ENGINEERING (846II) **Obiettivi**	6	LM-21 R	D	A scelta dello studente	ING-INF/01	No

The student who successfully completes the course will be able to demonstrate a solid knowledge of the main issues related to the design of sensor based electronic systems for bionics engineering. He or she will acquire the ability to analyse and design the building blocks of an analogue front-end for the acquisition, conditioning and conversion of biological sensor data, and will master the design methodologies adopted for instrumentation amplifiers, passive and active filters, analogue-to-digital and digital-to-analogue converters. He or she will then familiarise with standard digital interfaces utilised to transfer digitalised sensor data to an embedded microcontroller or microprocessor. The student will deepen his or her learning on the conditioning and digitalization chain of biological sensor data by familiarising with standard digital interfaces utilised to transfer digitalised sensor data to an embedded microcontroller or microprocessor. Finally, he or she will be exposed to state-of-the-art design methodologies adopted for tightly energy-/power-constrained electronic systems in wearable and implantable devices, and will have the opportunity to consolidate his or her learning by working with advanced EDA tools.						
NEUROANATOMY AND COGNITIVE NEUROSCIENCE (0080M)	6	LM-21 R	B	Discipline biomediche	M-PSI/02	Si
NEUROMORPHIC ENGINEERING (706II) **Obiettivi** The course will explore computational and physical models that emulate the neural dynamics of biological neurons of peripheral and central nervous system. A particular focus will be dedicated to real-time implementation of spiking artefacts that could be integrated in neurophysiological studies and in closed loop hybrid-bionic systems to restore missing sensorimotor functions.	6	LM-21 R	D	A scelta dello studente	ING-IND/34	No
PROBABILITY AND BIOSTATISTICS (1127I) **Obiettivi** The student will learn the basics of probability theory and statistical inference and will be able to apply appropriate methodologies for applications in biology and, in general, for the study of life sciences. In addition to the planning, collection and analysis of experimental data, the following topics will be discussed: theory of probability, discrete and continuous random variables, descriptive statistics of statistical samples, multivariate random variables, sums of random variables and associated limit theorems, interval estimation, inferential statistics and hypothesis testing, non-Gaussianity and chi-square tests, inference through non-parametric methods, regression analysis, and evaluation of diagnostic tests: sensitivity, specificity, and ROC curves.	6	LM-21 R	D	A scelta dello studente	ING-INF/06	No
ROBOT PROGRAMMING FRAMEWORKS AND IOT PLATFORMS (1079I) **Obiettivi** The course aims at proving theoretical and practical competences in robotic programming frameworks and IoT platforms and it will provide knowledge in	6	LM-21 R	D	A scelta dello studente	ING-IND/34	No

software design of autonomous robots and systems. Specific activities will be performed with ROS (Robotic Operating System) and YARP (Yet another robot platform) that will be implemented in simulated environments, also using dedicated SOM (System on Module) development boards. The course will also provide basic knowledge on brain-inspired controllers, based on machine learning approaches. Hands-on laboratory activities will be part of the course: students will be involved in the design and development of an IoT based environment, program the embedded system with sensors and cloud-based computing, design brain-inspired controllers and integrate them in robotic middleware (ROS and YARP).						
STATISTICAL SIGNAL PROCESSING (765II) **Obiettivi** The course will cover statistical signal processing methods, with application to bioengineering field. The students will become familiar with basic concepts of discrete representation of deterministic and random continuous-time signals, discrete-time random signal analysis, deterministic and random parameter estimation. Various estimation methods will be introduced and compared, such as the method of moments, the maximum likelihood and the linear and non-linear least squares methods. An introduction to Bayesian framework for random parameters and random signals estimation will be provided, with particular emphasis to the problem of linear smoothing, filtering, and prediction. Parametric auto-regressive moving average (ARMA) modeling and identification of discrete-time random signals will be also addressed. Advanced topics in parametric and non-parametric (adaptive and non-adaptive) methods for spectral estimation will be introduced, as well as some basic concepts of time-frequency analysis.	6	LM-21 R	C	Attività formative affini o integrative	ING-INF/03	Si

2° Anno (anno accademico 2026/2027)

Attività Formativa	CFU	Classe	TAF	Ambito	SSD	Obblig.
BIONIC SENSES (710II) **Obiettivi** The course “Bionic senses” refers to engineering artificial sensing and perceptual systems through biological principles to implement neuro-prostheses to restore lost functions, for human augmentation and bioinspired perceptional machines. The basis of the needed methodology and technology will be given tutorially. The course will introduce the physiology of senses and psychophysics and will introduce engineering solutions for bionics touch, vision and hearing.	6	LM-21 R	B	Bioingegneria	ING-INF/06	Si
FINAL EXAMINATION (1087Z) **Obiettivi** The final examination involves the preparation of a report led to a design or research activity, and in its presentation and discussion.	15	LM-21 R	E	Per la prova finale	PROFIN_S	Si
HUMAN-COMPUTER INTERACTION AND	12	LM-21 R	B	Bioingegneri	INF/01,	Si

AFFECTIVE COMPUTING (1229I) **Moduli** HUMAN-COMPUTER INTERACTION. TOOLS AND STRATEGIES (1229I-A) AFFECTIVE COMPUTING (1229I)	 6 6			a	ING-INF/06	
LAB TRAINING (1088Z) **Obiettivi** This activity will consist of Lab training that the student will perform in dedicated facilities and laboratories, with the aim to increase his/her experience in laboratory practice.	3	LM-21 R	F	Tirocini formativi e di orientamento	NN	Si
NEURAL PROSTHESES (700II) **Obiettivi** The course on “Neural prostheses” is composed of two modules: “Neural interfaces and bioelectronic medicine” and “Neural tissue engineering”. During the course on “Neural interfaces and bioelectronic medicine” the students will acquire the basic principles underlying the design and development of implantable neural interfaces for different parts of the nervous system They will also develop a broad view on i) existing neuroprosthetic systems to restore motor functions, ii) neural stimulation therapies for motor disorders, and iii) novel solutions based on the stimulation of the autonomic nervous system, and will be able to identify current limitations and challenges for future applications. Finally, the students will learn the conceptual and practical bases for the development of a novel neuroprosthesis (group project). The course “Neural tissue engineering” will introduce the students to the methods, protocols and engineering tools for mimicking both the central nervous system (CNS) and peripheral nervous system (PNS) at the microscale. Specifically, after a brief introduction on the physiopathology of human nervous system and its buiding blocks (i.e. neurons and glia cells), the course will focus on biomaterials and biofabrication techniques, traditional and advanced in vitro systems as well as computational methods for modeling, monitoring and characterizing neural structure and function. **Moduli** NEURAL TISSUE ENGINEERING (2) NEURAL INTERFACES AND BIOELECTRONIC MEDICINE (1)	12 6 6	LM-21 R	B	Bioingegneria	ING-INF/06	Si
NEURAL SIGNAL PROCESSING AND MEASUREMENT TECHNIQUES (1226I) **Moduli** ADVANCED NEURAL SIGNAL PROCESSING (1226I-A) METHODS AND TECHNIQUES OF MEASUREMENT AND SIGNAL PROCESSING (1226I)	12 6 6	LM-21 R	B	Bioingegneria	ING-INF/06	Si

Percorso di Studio: BIOROBOTICS (2)

CFU totali: 144, di cui 108 derivanti da AF obbligatorie e 36 da AF a scelta

1° Anno (anno accademico 2025/2026)

Attività Formativa	CFU	Classe	TAF	Ambito	SSD	Obblig.
ADVANCED MATERIALS FOR BIONICS (1081I) **Obiettivi** The aim of the course is to provide a solid background in Materials Science and Engineering as relevant for Bionics Engineering. Together with basic understanding of the various classes of materials, their structure, composition, structural and functional properties, the students will learn about more advanced concepts and recent developments of modern Materials Science, lying at the interface between chemistry, physics, engineering and biology. The course is structured in three sections. In the first section (1-Basic Materials Science & Engineering) basic and traditional topics of Materials Science will be covered/refreshed to provide a common basis among students with different background knowledge. Topics include: nomenclature and classification of materials, basic physical and chemical knowledge of solid matter, structure/properties correlation in materials, hierarchical structuring, phase transitions, fundamentals of mechanical behaviour, viscoelasticity, basic characterization tools. Various classes of engineering relevant materials will be reviewed: metals, ceramics, polymers, composites. In the second section (2 – Advanced Materials Concepts) more advanced concepts will be introduced, regarding: biocompatibility of Materials, complex behaviour of soft matter, nanotechnology and nanostructures, biological materials, bioinspired materials, stimuli-responsive materials, electro-active polymers, advanced investigation and fabrication techniques for micro- and nano-structures. In the third section (3 Technology & Bionics Applications) relevant examples of applications of materials in Bionics will be reviewed, including: advanced functional surfaces and interfaces, structural materials for bionics, materials for bioelectronics, materials for sensors & actuators in robotics.	6	LM-21 R	D	A scelta dello studente	ING-IND/34	No
ANALYSIS OF BIONIC AND ROBOTIC SYSTEMS (1128I) **Obiettivi** In particular, the “Principles of Bionics and Biorobotics Engineering” module will introduce the wide and interdisciplinary field of bionics and related scientific areas, such as biorobotics, neuroengineering and bioengineering. Bionics aims at gathering specific knowledge through the analysis/modeling of living organisms/ecosystems and applies it to the development of newly inspired advanced devices. Bionics also focuses on artificial systems deeply connected to body tissues, and/or interacting with organisms. The application of bionics principles is nowadays widespread in many engineering sub-fields.	12	LM-21 R	B	Bioingegneria	ING-INF/06, ING-IND/34	Si

During this course, the pillars of bionics and robotics are presented to allow the proper understanding of the whole loop from scientific insights to engineering innovation. In particular, the course focuses on the key principles of biological locomotion, swarm robotics, artificial organs, neurorobotics, neuroprostheses, neural interfaces with the nervous system, morphological computation, energy issues, principles of structural bionic design and main manufacturing techniques, as well as the fundamentals of robot mechanics. At the end of the module “Principles of Bionics and Biorobotics Engineering”, the student: ● Will possess the main knowledge about bionic and robotics engineering principles; ● Will be able to orient him/herself in the scientific literature; ● Will be able to formulate innovative hypotheses and to devise new solutions on bionic design and bioinspired robotic paradigms. To profitably attend this module, no specialistic knowledge is required. However, consolidated competences of physics and mathematics are needed. In addition, even if not strictly needed, competences concern mechanics, signal processing, and electronics are desirable. The “Principles of Bionics and Biorobotics Engineering” module topics are the following: ● Historical evolution of bionics, related to robotics and bioengineering; ● Model organisms and biological locomotion principles in different media, and applications in robotics; ● Bionic energy management: comparison between organisms and robots; ● Fabrication technologies at different scales; ● Bioinspired structural design and advanced materials; ● Fundamentals of robot mechanics (schematic of the joints, homogeneous transformations, Jacobian, methods for kinematic and dynamic studies); ● Swarm robotics; ● Principles to design effective neural interfaces and neuroprostheses ● Ethical issues and legal considerations. The “Modeling of multi-physics phenomena” module provides a basic, practical knowledge of computational mechanics of solids (linear/non-linear elasticity) and fluids (incompressible flows of Newtonian fluids). and computational electromagnetism at low frequencies, mainly associated to bioelectric phenomena and neural models. The first part of the course deals with the theory of the Finite Element Method and introduces numerical algorithms and practices for the solution of non-linear and time-dependent problems, which are common to all the aforementioned computational disciplines. Then, the numerical implementations of several physical models in a commercial FE software will be shown during hands-on sessions, along with applications to design problems involving sensors and bioinspired devices.							
Moduli							
PRINCIPLES OF BIONICS AND BIOROBOTICS ENGINEERING (1)	6						
MODELING OF MULTI-PHYSICS PHENOMENA (2)	6						

ARTIFICIAL INTELLIGENT SYSTEMS FOR HUMAN IDENTIFICATION (1092I) **Obiettivi** This course provides fundamentals about techniques to verify or recognize the identity of a living person based on the analysis of biological/physiological traits and/or behavioural features. The topics of the course will be: - Biometrics overview (history of biometrics, applications); - Recognition, identification and verification; - Privacy, security and ethics; - Overview of image processing; - Physiological biometric systems: fingerprint recognition, face recognition, iris recognition, retina recognition, hand recognition, vein patterns; - Behavioral biometric systems: keystroke dynamics, signature recognition, voice recognition, gait recognition; - Multi-modal biometric systems; - Biometric applications.	6	LM-21 R	D	A scelta dello studente	ING-INF/06	No
BIOINSPIRED AND SOFT ROBOTICS (1078I) **Obiettivi** “Mechanics of smart materials and structures” aims at providing a working knowledge of modeling tools to analyze and understand the mechanical response of smart materials and structures. These include the variational formulation of equilibrium and stability problems, up to the foundations of the Finite Element Method (FEM). The course will enable the student to formulate and solve models for the equilibrium response of structures in the large deformation regime. The student will be introduced to advanced modeling tools and their applications in bioinspired and soft robotics. Advanced design principles (based e.g., on morphing structures, deployable structures, multi-stable devices) will be discussed through the analysis of their theoretical basis and the solution of practical problems. “Soft robotics technologies” aims at providing an advanced knowledge on soft robotics and soft mechatronics technologies. The course will enable the student to implement a comparative analysis for the choice of the most suitable technologies for specific engineering problems. Different transduction principles will be analysed from the basic physics to their exploitation as sensors or actuators. The student will be introduced to advanced design principles (e.g. bioinspiration and morphological computation) and tools (e.g. FEM) also through hands-on lab activities. **Moduli**	12	LM-21 R	B	Bioingegneria	ING-IND/34	Si
MECHANICS OF SMART MATERIALS AND STRUCTURES (1)	6					
SOFT ROBOTICS TECHNOLOGIES (2)	6					
BIOINSPIRED COMPUTATIONAL METHODS (705II) **Obiettivi** The course aims to introduce the main concepts and techniques used in bioinspired computational methods. The course is divided in two modules “Neural and fuzzy computation” and “Biological data mining”. The first module intends to offer students the opportunity to learn the basic concepts and models of computational intelligence, to have a	12	LM-21 R	C	Attività formative affini o integrative	ING-INF/05	Si

thorough understanding of the associated computational techniques, such as artificial neural networks, fuzzy systems and genetic algorithms, and to know how to apply them to a wide variety of application areas. The second module will focus on the basic aspects of biological data mining: data pre-processing, frequent pattern mining, classification, prediction, clustering and outlier detection. **Moduli** NEURAL AND FUZZY COMPUTATION (2) BIOLOGICAL DATA MINING (1)	 6 6					
ELECTRONICS FOR BIONICS ENGINEERING (846II) **Obiettivi** The student who successfully completes the course will be able to demonstrate a solid knowledge of the main issues related to the design of sensor based electronic systems for bionics engineering. He or she will acquire the ability to analyse and design the building blocks of an analogue front-end for the acquisition, conditioning and conversion of biological sensor data, and will master the design methodologies adopted for instrumentation amplifiers, passive and active filters, analogue-to-digital and digital-to-analogue converters. He or she will then familiarise with standard digital interfaces utilised to transfer digitalised sensor data to an embedded microcontroller or microprocessor. The student will deepen his or her learning on the conditioning and digitalization chain of biological sensor data by familiarising with standard digital interfaces utilised to transfer digitalised sensor data to an embedded microcontroller or microprocessor. Finally, he or she will be exposed to state-of-the-art design methodologies adopted for tightly energy-/power-constrained electronic systems in wearable and implantable devices, and will have the opportunity to consolidate his or her learning by working with advanced EDA tools.	6	LM-21 R	D	A scelta dello studente	ING-INF/01	No
NEUROANATOMY AND COGNITIVE NEUROSCIENCE (0080M)	6	LM-21 R	B	Discipline biomediche	M-PSI/02	Si
NEUROMORPHIC ENGINEERING (706II) **Obiettivi** The course will explore computational and physical models that emulate the neural dynamics of biological neurons of peripheral and central nervous system. A particular focus will be dedicated to real-time implementation of spiking artefacts that could be integrated in neurophysiological studies and in closed loop hybrid-bionic systems to restore missing sensorimotor functions.	6	LM-21 R	D	A scelta dello studente	ING-IND/34	No
PROBABILITY AND BIOSTATISTICS (1127I) **Obiettivi** The student will learn the basics of probability theory and statistical inference and will be able to apply appropriate methodologies for applications in biology and, in general, for the study of life sciences. In addition to the planning, collection and analysis of experimental data, the following topics will be discussed: theory of probability, discrete and	6	LM-21 R	D	A scelta dello studente	ING-INF/06	No

continuous random variables, descriptive statistics of statistical samples, multivariate random variables, sums of random variables and associated limit theorems, interval estimation, inferential statistics and hypothesis testing, non-Gaussianity and chi-square tests, inference through non-parametric methods, regression analysis, and evaluation of diagnostic tests: sensitivity, specificity, and ROC curves.						
ROBOT PROGRAMMING FRAMEWORKS AND IOT PLATFORMS (1079I) **Obiettivi** The course aims at proving theoretical and practical competences in robotic programming frameworks and IoT platforms and it will provide knowledge in software design of autonomous robots and systems. Specific activities will be performed with ROS (Robotic Operating System) and YARP (Yet another robot platform) that will be implemented in simulated environments, also using dedicated SOM (System on Module) development boards. The course will also provide basic knowledge on brain-inspired controllers, based on machine learning approaches. Hands-on laboratory activities will be part of the course: students will be involved in the design and development of an IoT based environment, program the embedded system with sensors and cloud-based computing, design brain-inspired controllers and integrate them in robotic middleware (ROS and YARP).	6	LM-21 R	D	A scelta dello studente	ING-IND/34	No
STATISTICAL SIGNAL PROCESSING (765II) **Obiettivi** The course will cover statistical signal processing methods, with application to bioengineering field. The students will become familiar with basic concepts of discrete representation of deterministic and random continuous-time signals, discrete-time random signal analysis, deterministic and random parameter estimation. Various estimation methods will be introduced and compared, such as the method of moments, the maximum likelihood and the linear and non-linear least squares methods. An introduction to Bayesian framework for random parameters and random signals estimation will be provided, with particular emphasis to the problem of linear smoothing, filtering, and prediction. Parametric auto-regressive moving average (ARMA) modeling and identification of discrete-time random signals will be also addressed. Advanced topics in parametric and non-parametric (adaptive and non-adaptive) methods for spectral estimation will be introduced, as well as some basic concepts of time-frequency analysis.	6	LM-21 R	C	Attività formative affini o integrative	ING-INF/03	Si

2° Anno (anno accademico 2026/2027)

Attività Formativa	CFU	Classe	TAF	Ambito	SSD	Obblig.
ADVANCED INTERVENTIONAL AND THERAPEUTIC TECHNOLOGIES (1103I) **Obiettivi** The course “Advanced interventional and therapeutic	12	LM-21 R	B	Bioingegneria	ING-IND/34	Si

technologies” is composed of two modules: “Robotics for minimally invasive and targeted therapy” and “Bionic organs and tissues”. The overall course aims to provide students with knowledge and methodological tools typical of (i) robotics in the surgical/diagnostic domain, (ii) targeted therapies based on micro/nano smart materials, and (iii) mechatronics and bioengineering for bionic organs/tissues and regenerative purposes. In particular, in the “Robotics for minimally invasive and targeted therapy” module, the students will gather knowledge and methodologies concerning the design of robots and intelligent instruments for surgery and interventional tasks, from the macro to the micro size, towards targeted therapy. At the end of the course, the students will be able to identify the most appropriate targeting/therapeutic solutions for different human body districts, at different scales and for different pathologies. Thanks to the analysis of the surgical robots available in the teacher’s Institute, the students will be able to relate the theoretical knowledge with real practical scenarios. The module “Bionic organs and tissues” aims to teach students how to design and develop artificial and bioartificial technologies at different scales, bionic organs and tissues, smart materials for advanced therapy, organ function replacement, drug delivery and tissue regeneration. Principles of anatomy and physiology of different organs and tissues will be provided. Mechatronic/micro-mechatronic solutions, as well as “wet bioengineering” ones, alternative to or synergic with traditional medical/surgical procedures, will be also highlighted. Hands-on laboratory activities are part of this module: in particular, students will be involved in practical activities concerning cell cultures. **Moduli** BIONIC ORGANS AND TISSUES (2) ROBOTIC FOR MINIMAL INVASIVE AND TARGETED THERAPY (1)	 6 6					
DESIGN PRINCIPLES FOR BIONIC TISSUE ENGINEERING (1104I) **Obiettivi** This course will guide students in the design of cell and tissue-based systems for application to the development of in vitro models, artificial organs and delivery systems using technology based on 3D scaffolds, stem cells, organoids, and spheroids Starting from a quantitative description of cell, tissue and organ assembly and of their requirements in terms of resources, microenvironmental conditions, cooperation and competition, the course covers fundamental design principles. It also provides a comprehensive overview of stem cell, organoid and on-chip technology as well as mathematical models of morphogenesis, self-assembly, growth and differentiation. Project work will include design and simulation of in vitro models. Course contents: Basic principles of biochemistry and cell biology. Quantitative models of cell-material interaction,	6	LM-21 R	B	Bioingegneria	ING-INF/06	Si

mechanobiology, cell assembly and 3D organisation. Allometric (power law) relationships in organisms. Design criteria for 3D tissue constructs based on resource supply and diffusion limitations. Stem cell technology, induced pluripotent stem cells, organoids (intestine, liver, brain). Fluidic bioreactors and organ and body on a chip design using computational methods.						
FINAL EXAMINATION (1087Z) **Obiettivi** The final examination involves the preparation of a report led to a design or research activity, and in its presentation and discussion.	15	LM-21 R	E	Per la prova finale	PROFIN_S	Si
LAB TRAINING (1088Z) **Obiettivi** This activity will consist of Lab training that the student will perform in dedicated facilities and laboratories, with the aim to increase his/her experience in laboratory practice.	3	LM-21 R	F	Tirocini formativi e di orientamento	NN	Si
REHABILITATION AND ASSISTIVE TECHNOLOGIES (1105I) **Obiettivi** The objectives of the module “Biomechanics of human motion” are to provide an introduction to the biomechanics of the human movements and then to understand the main role underlying the control of spatial multiple degree-of-freedom human motion. These objectives will be reached by means of both theoretical lessons and practical activities in a lab of human movement analysis, preparing the student to understanding the main concept of physical/motor rehabilitation and of bioinspired robotics. The objectives of the module “Robotic and data-driven rehabilitation” are to provide elements to understand current trends in rehabilitation robotics. The course will focus on fundamental principles of robotics modelling, in order to provide theoretical tools to critically analyze robot architectures in the context of rehabilitation robotics. Concepts of ergonomics, anthropometry and universal design will be introduced, together with theoretical and practical knowledge of structural materials and technical textile materials used for the construction of rehabilitation machines. During the course the most relevant rehabilitation robots of the state of the art will be presented in conjunction with relevant clinical studies. **Moduli** ROBOTIC AND DATA-DRIVEN REHABILITATION (1) BIOMECHANICS OF HUMAN MOTION (2)	12 6 6	LM-21 R	B	Bioingegneria	ING-IND/34	Si
WEARABLE ROBOTICS (1033I) **Obiettivi** The course is composed of two modules: Prostheses and Exoskeletons. The overall goal is to introduce students to the main challenges to design wearable powered robots for movement assistance, rehabilitation, augmentation and/or functional replacement. Along with the analyses of the main components involved in the development of an	12	LM-21 R	B	Bioingegneria	ING-IND/34	Si

effective human-robot interaction, students will be engaged in laboratory and hands-on activities with working devices. In particular: Within the module “Prostheses” students will be introduced to and will experiment the architecture and function of the microcontroller. Within the module “Exoskeletons” students will learn how to conceive, rapid-prototype and test multi-layered control architectures running on real-time targets endowed with FPGA processors.						
Moduli						
EXOSKELETONS (2)	6					
PROSTHESES (1)	6					

Piano di Studio: WBER-LM-25-25-25

Anno Regolamento Didattico	2025/2026
Anno di Coorte	2025/2026
Anno di Revisione	2025/2026

Schema di piano: 1 - NEURAL ENGINEERING

Percorso di Studio	1 - NEURAL ENGINEERING
Stato Piano generato	Approvato
Schema Statutario	Sì
Totale CFU	120
Totale CFU Obbligatori	108

Anno di Corso: 1° (2025/2026)

Regola 1: OBBLIGATORI COMUNI 1 ANNO (Obbligatoria)
Attività Obbligatorie. 4AF.

CFU obbligatori	36
Sovrannumeraria	NO
Abilita scelta da libretto	NO

Attività Formativa	CFU	TAF	Ambito	Settori	Statutaria	Controllo Anno
ANALYSIS OF BIONIC AND ROBOTIC SYSTEMS (1128I)	12		ANALYSIS OF BIONIC AND ROBOTIC SYSTEMS		Sì	No
Moduli						
MODELING OF MULTI-PHYSICS PHENOMENA (2)	6	B	MODELING OF MULTI-PHYSICS PHENOMENA	ING-INF/06		
PRINCIPLES OF BIONICS AND BIOROBOTICS ENGINEERING (1)	6	B	PRINCIPLES OF BIONICS AND BIOROBOTICS ENGINEERING	ING-IND/34		
BIOINSPIRED COMPUTATIONAL METHODS (705II)	12		BIOINSPIRED COMPUTATIONAL METHODS		Sì	No
Moduli						
BIOLOGICAL DATA MINING (1)	6	C	BIOLOGICAL DATA MINING	ING-INF/05		

NEURAL AND FUZZY COMPUTATION (2)	6	C	NEURAL AND FUZZY COMPUTATION	ING-INF/05		
NEUROANATOMY AND COGNITIVE NEUROSCIENCE (0080M)	6	B	NEUROANATOMY AND COGNITIVE NEUROSCIENCE	M-PSI/02	Sì	No
STATISTICAL SIGNAL PROCESSING (765II)	6	C	STATISTICAL SIGNAL PROCESSING	ING-INF/03	Sì	No

Regola 2: OBBLIGATORI CURR NE 1 AN (Obbligatoria)
Attività Obbligatorie. 1AF.

CFU obbligatori	12
Sovrannumeraria	NO
Abilita scelta da libretto	NO

Attività Formativa	CFU	TAF	Ambito	Settori	Statutaria	Controllo Anno
APPLIED BRAIN SCIENCE (001MA)	12		APPLIED BRAIN SCIENCE		Sì	No
Moduli						
COMPUTATIONAL NEUROSCIENCE (2)	6	C	COMPUTATIONAL NEUROSCIENCE	INF/01		
INTEGRATIVE CEREBRAL FUNCTION (001MA-A)	6	B	INTEGRATIVE CEREBRAL FUNCTION	M-PSI/02		

Regola 3: FREE CHOICE (Gruppo scelta esami)
Gruppo Scelta Esami. 12 CFU

Sovrannumeraria	NO
Abilita scelta da libretto	NO

Attività Formativa	CFU	TAF	Ambito	Settori	Statutaria	Controllo Anno
ADVANCED MATERIALS FOR BIONICS (1081I)	6	D	ADVANCED MATERIALS FOR BIONICS	ING-IND/34	No	No
ARTIFICIAL INTELLIGENT SYSTEMS FOR HUMAN	6	D	ARTIFICI	ING-	No	No

IDENTIFICATION (1092I)			AL INTELLIGENT SYSTEMS FOR HUMAN IDENTIFICATION	INF/06		
ELECTRONICS FOR BIONICS ENGINEERING (846II)	6	D	ELECTRONICS FOR BIONICS ENGINEERING	ING-INF/01	No	No
NEUROMORPHIC ENGINEERING (706II)	6	D	NEUROMORPHIC ENGINEERING	ING-IND/34	No	No
PROBABILITY AND BIOSTATISTICS (1127I)	6	D	PROBABILITY AND BIOSTATISTICS	ING-INF/06	No	No
ROBOT PROGRAMMING FRAMEWORKS AND IOT PLATFORMS (1079I)	6	D	ROBOT PROGRAMMING FRAMEWORKS AND IOT PLATFORMS	ING-IND/34	No	No

Anno di Corso: 2° (2026/2027)

Regola 4: OBBLIGATORI CURR NE 2 ANNO (Obbligatoria)
Attività Obbligatorie. 6AF.

CFU obbligatori	60
Sovrannumeraria	NO
Abilita scelta da libretto	NO

Attività Formativa	CFU	TAF	Ambito	Settori	Statutaria	Controllo Anno
BIONIC SENSES (710II)	6	B	BIONIC SENSES	ING-INF/06	Sì	No
FINAL EXAMINATION (1087Z)	15	E	FINAL EXAMINATION	PROFIN_S	Sì	No
HUMAN-COMPUTER INTERACTION AND AFFECTIVE COMPUTING (1229I)	12		HUMAN-COMPUTER INTERACTION AND AFFECTIVE		Sì	No

Moduli			COMPUTING			
AFFECTIVE COMPUTING (1229I)	6	B	AFFECTIVE COMPUTING	ING-INF/06		
HUMAN-COMPUTER INTERACTION. TOOLS AND STRATEGIES (1229I-A)	6	C	HUMAN-COMPUTER INTERACTION. TOOLS AND STRATEGIES	INF/01		
LAB TRAINING (1088Z)	3	F	LAB TRAINING	NN	Sì	No
NEURAL PROSTHESES (700II)	12		NEURAL PROSTHESES		Sì	No
Moduli						
NEURAL INTERFACES AND BIOELECTRONIC MEDICINE (1)	6	B	NEURAL INTERFACES AND BIOELECTRONIC MEDICINE	ING-INF/06		
NEURAL TISSUE ENGINEERING (2)	6	B	NEURAL TISSUE ENGINEERING	ING-INF/06		
NEURAL SIGNAL PROCESSING AND MEASUREMENT TECHNIQUES (1226I)	12		NEURAL SIGNAL PROCESSING AND MEASUREMENT TECHNIQUES		Sì	No
Moduli						
ADVANCED NEURAL SIGNAL PROCESSING (1226I-A)	6	B	ADVANCED NEURAL SIGNAL PROCESSING	ING-INF/06		
METHODS AND TECHNIQUES OF MEASUREMENT AND SIGNAL PROCESSING (1226I)	6	B	METHODS AND TECHNIQUES OF MEASUREMENT AND SIGNAL PROCESSING	ING-INF/06		

Schema di piano: 2 - BIOROBOTICS

Percorso di Studio	2 - BIOROBOTICS
Stato Piano generato	Approvato
Schema Statutario	Sì
Totale CFU	120
Totale CFU Obbligatori	108

Anno di Corso: 1° (2025/2026)

Regola 1: OBBLIGATORI COMUNI 1 ANNO (Obbligatoria)
Attività Obbligatorie. 4AF.

CFU obbligatori	36
Sovrannumeraria	NO
Abilita scelta da libretto	NO

Attività Formativa	CFU	TAF	Ambito	Settori	Statutaria	Controllo Anno
ANALYSIS OF BIONIC AND ROBOTIC SYSTEMS (1128I)	12		ANALYSIS OF BIONIC AND ROBOTIC SYSTEMS		Sì	No
Moduli						
MODELING OF MULTI-PHYSICS PHENOMENA (2)	6	B	MODELING OF MULTI-PHYSICS PHENOMENA	ING-INF/06		
PRINCIPLES OF BIONICS AND BIOROBOTICS ENGINEERING (1)	6	B	PRINCIPLES OF BIONICS AND BIOROBOTICS ENGINEERING	ING-IND/34		
BIOINSPIRED COMPUTATIONAL METHODS (705II)	12		BIOINSPIRED COMPUTATIONAL METHODS		Sì	No
Moduli						
BIOLOGICAL DATA MINING (1)	6	C	BIOLOGICAL DATA MINING	ING-INF/05		
NEURAL AND FUZZY COMPUTATION (2)	6	C	NEURAL	ING-		

			AND FUZZY COMPUTATION	INF/05		
NEUROANATOMY AND COGNITIVE NEUROSCIENCE (0080M)	6	B	NEUROANATOMY AND COGNITIVE NEUROSCIENCE	M-PSI/02	Sì	No
STATISTICAL SIGNAL PROCESSING (765II)	6	C	STATISTICAL SIGNAL PROCESSING	ING-INF/03	Sì	No

Regola 2: OBBLIGATORI CURR BIO 1 AN (Obbligatoria)
Attività Obbligatorie. 1AF.

CFU obbligatori	12
Sovrannumeraria	NO
Abilita scelta da libretto	NO

Attività Formativa	CFU	TAF	Ambito	Settori	Statutaria	Controllo Anno
BIOINSPIRED AND SOFT ROBOTICS (1078I)	12		BIOINSPIRED AND SOFT ROBOTICS		Sì	No
Moduli						
MECHANICS OF SMART MATERIALS AND STRUCTURES (1)	6	B	MECHANICS OF SMART MATERIALS AND STRUCTURES	ING-IND/34		
SOFT ROBOTICS TECHNOLOGIES (2)	6	B	SOFT ROBOTICS TECHNOLOGIES	ING-IND/34		

Regola 3: FREE CHOICE (Gruppo scelta esami)
Gruppo Scelta Esami. 12 CFU

Sovrannumeraria	NO
Abilita scelta da libretto	NO

Attività Formativa	CFU	TAF	Ambito	Settori	Statutaria	Controllo Anno
ADVANCED MATERIALS FOR BIONICS (1081I)	6	D	ADVANCED MATERIA	ING-IND/34	No	No

			LS FOR BIONICS			
ARTIFICIAL INTELLIGENT SYSTEMS FOR HUMAN IDENTIFICATION (1092I)	6	D	ARTIFICIAL INTELLIGENT SYSTEMS FOR HUMAN IDENTIFICATION	ING-INF/06	No	No
ELECTRONICS FOR BIONICS ENGINEERING (846II)	6	D	ELECTRONICS FOR BIONICS ENGINEERING	ING-INF/01	No	No
NEUROMORPHIC ENGINEERING (706II)	6	D	NEUROMORPHIC ENGINEERING	ING-IND/34	No	No
PROBABILITY AND BIOSTATISTICS (1127I)	6	D	PROBABILITY AND BIOSTATISTICS	ING-INF/06	No	No
ROBOT PROGRAMMING FRAMEWORKS AND IOT PLATFORMS (1079I)	6	D	ROBOT PROGRAMMING FRAMEWORKS AND IOT PLATFORMS	ING-IND/34	No	No

Anno di Corso: 2° (2026/2027)

Regola 4: OBBLIGATORI CURR BIO 2 ANNO (Obbligatoria)
Attività Obbligatorie. 6AF.

CFU obbligatori	60
Sovrannumeraria	NO
Abilita scelta da libretto	NO

Attività Formativa	CFU	TAF	Ambito	Settori	Statutaria	Controllo Anno
ADVANCED INTERVENTIONAL AND THERAPEUTIC TECHNOLOGIES (1103I)	12		ADVANCED INTERVENTIONAL AND THERAPEUTIC TECHNOLOGIES		Sì	No
Moduli						
BIONIC ORGANS AND TISSUES (2)	6	B	BIONIC	ING-		

			ORGANS AND TISSUES	IND/34		
ROBOTIC FOR MINIMAL INVASIVE AND TARGETED THERAPY (1)	6	B	ROBOTIC FOR MINIMAL INVASIVE AND TARGETED THERAPY	ING-IND/34		
DESIGN PRINCIPLES FOR BIONIC TISSUE ENGINEERING (1104I)	6	B	DESIGN PRINCIPLES FOR BIONIC TISSUE ENGINEERING	ING-INF/06	Sì	No
FINAL EXAMINATION (1087Z)	15	E	FINAL EXAMINATION	PROFIN_S	Sì	No
LAB TRAINING (1088Z)	3	F	LAB TRAINING	NN	Sì	No
REHABILITATION AND ASSISTIVE TECHNOLOGIES (1105I)	12		REHABILITATION AND ASSISTIVE TECHNOLOGIES		Sì	No
Moduli						
BIOMECHANICS OF HUMAN MOTION (2)	6	B	BIOMECHANICS OF HUMAN MOTION	ING-IND/34		
ROBOTIC AND DATA-DRIVEN REHABILITATION (1)	6	B	ROBOTIC AND DATA-DRIVEN REHABILITATION	ING-IND/34		
WEARABLE ROBOTICS (1033I)	12		WEARABLE ROBOTICS		Sì	No
Moduli						
EXOSKELETONS (2)	6	B	EXOSKELETONS	ING-IND/34		
PROSTHESES (1)	6	B	PROSTHESES	ING-IND/34		

Obiettivi attività formative

1° Anno (anno accademico 2025/2026)

- ADVANCED MATERIALS FOR BIONICS (1081I)
  Obiettivi Formativi
  The aim of the course is to provide a solid background in Materials Science and Engineering as relevant for Bionics Engineering. Together with basic understanding of the various classes of materials, their structure, composition, structural and functional properties, the students will learn about more advanced concepts and recent developments of modern Materials Science, lying at the interface between chemistry, physics, engineering and biology. The course is structured in three sections. In the first section (1-Basic Materials Science & Engineering) basic and traditional topics of Materials Science will be covered/refreshed to provide a common basis among students with different background knowledge. Topics include: nomenclature and classification of materials, basic physical and chemical knowledge of solid matter, structure/properties correlation in materials, hierarchical structuring, phase transitions, fundamentals of mechanical behaviour, viscoelasticity, basic characterization tools. Various classes of engineering relevant materials will be reviewed: metals, ceramics, polymers, composites. In the second section (2 – Advanced Materials Concepts) more advanced concepts will be introduced, regarding: biocompatibility of Materials, complex behaviour of soft matter, nanotechnology and nanostructures, biological materials, bioinspired materials, stimuli-responsive materials, electro-active polymers, advanced investigation and fabrication techniques for micro- and nano-structures. In the third section (3 Technology & Bionics Applications) relevant examples of applications of materials in Bionics will be reviewed, including: advanced functional surfaces and interfaces, structural materials for bionics, materials for bioelectronics, materials for sensors & actuators in robotics.

- ANALYSIS OF BIONIC AND ROBOTIC SYSTEMS (1128I)
  Obiettivi Formativi
  In particular, the “Principles of Bionics and Biorobotics Engineering” module will introduce the wide and interdisciplinary field of bionics and related scientific areas, such as biorobotics, neuroengineering and bioengineering. Bionics aims at gathering specific knowledge through the analysis/modeling of living organisms/ecosystems and applies it to the development of newly inspired advanced devices. Bionics also focuses on artificial systems deeply connected to body tissues, and/or interacting with organisms. The application of bionics principles is nowadays widespread in many engineering sub-fields. During this course, the pillars of bionics and robotics are presented to allow the proper understanding of the whole loop from scientific insights to engineering innovation. In particular, the course focuses on the key principles of biological locomotion, swarm robotics, artificial organs, neurorobotics, neuroprostheses, neural interfaces with the nervous system, morphological computation, energy issues, principles of structural bionic design and main manufacturing techniques, as well as the fundamentals of robot mechanics. At the end of the module “Principles of Bionics and Biorobotics Engineering”, the student: ● Will possess the main knowledge about bionic and robotics engineering principles; ● Will be able to orient him/herself in the scientific literature; ● Will be able to formulate innovative hypotheses and to devise new solutions on bionic design and bioinspired robotic paradigms. To profitably attend this module, no specialistic knowledge is required. However, consolidated competences of physics and mathematics are needed. In addition, even if not strictly needed, competences concern mechanics, signal processing, and electronics are desirable. The “Principles of Bionics and Biorobotics Engineering” module topics are the following: ● Historical evolution of bionics, related to robotics and bioengineering; ● Model organisms and biological locomotion principles in different media, and applications in robotics; ● Bionic energy management: comparison between organisms and robots; ● Fabrication technologies at different scales; ● Bioinspired structural design and advanced materials; ● Fundamentals of robot mechanics (schematic of the joints, homogeneous transformations, Jacobian, methods for kinematic and dynamic studies); ● Swarm robotics; ● Principles to design effective neural interfaces and neuroprostheses ● Ethical issues and legal considerations. The “Modeling of multi-physics phenomena” module provides a basic, practical

knowledge of computational mechanics of solids (linear/non-linear elasticity) and fluids (incompressible flows of Newtonian fluids). and computational electromagnetism at low frequencies, mainly associated to bioelectric phenomena and neural models. The first part of the course deals with the theory of the Finite Element Method and introduces numerical algorithms and practices for the solution of non-linear and time-dependent problems, which are common to all the aforementioned computational disciplines. Then, the numerical implementations of several physical models in a commercial FE software will be shown during hands-on sessions, along with applications to design problems involving sensors and bioinspired devices.

- ARTIFICIAL INTELLIGENT SYSTEMS FOR HUMAN IDENTIFICATION (1092I)
  Obiettivi Formativi
  This course provides fundamentals about techniques to verify or recognize the identity of a living person based on the analysis of biological/physiological traits and/or behavioural features. The topics of the course will be: - Biometrics overview (history of biometrics, applications); - Recognition, identification and verification; - Privacy, security and ethics; - Overview of image processing; - Physiological biometric systems: fingerprint recognition, face recognition, iris recognition, retina recognition, hand recognition, vein patterns; - Behavioral biometric systems: keystroke dynamics, signature recognition, voice recognition, gait recognition; - Multi-modal biometric systems; - Biometric applications.

- BIOINSPIRED COMPUTATIONAL METHODS (705II)
  Obiettivi Formativi
  The course aims to introduce the main concepts and techniques used in bioinspired computational methods. The course is divided in two modules “Neural and fuzzy computation” and “Biological data mining”. The first module intends to offer students the opportunity to learn the basic concepts and models of computational intelligence, to have a thorough understanding of the associated computational techniques, such as artificial neural networks, fuzzy systems and genetic algorithms, and to know how to apply them to a wide variety of application areas. The second module will focus on the basic aspects of biological data mining: data pre-processing, frequent pattern mining, classification, prediction, clustering and outlier detection.

- ELECTRONICS FOR BIONICS ENGINEERING (846II)
  Obiettivi Formativi
  The student who successfully completes the course will be able to demonstrate a solid knowledge of the main issues related to the design of sensor based electronic systems for bionics engineering. He or she will acquire the ability to analyse and design the building blocks of an analogue front-end for the acquisition, conditioning and conversion of biological sensor data, and will master the design methodologies adopted for instrumentation amplifiers, passive and active filters, analogue-to-digital and digital-to-analogue converters. He or she will then familiarise with standard digital interfaces utilised to transfer digitalised sensor data to an embedded microcontroller or microprocessor. The student will deepen his or her learning on the conditioning and digitalization chain of biological sensor data by familiarising with standard digital interfaces utilised to transfer digitalised sensor data to an embedded microcontroller or microprocessor. Finally, he or she will be exposed to state-of-the-art design methodologies adopted for tightly energy-/power-constrained electronic systems in wearable and implantable devices, and will have the opportunity to consolidate his or her learning by working with advanced EDA tools.

- NEUROANATOMY AND COGNITIVE NEUROSCIENCE (0080M)

- NEUROMORPHIC ENGINEERING (706II)
  Obiettivi Formativi
  The course will explore computational and physical models that emulate the neural dynamics of biological neurons of peripheral and central nervous system. A particular focus will be dedicated to real-time implementation of spiking artefacts that could be integrated in neurophysiological studies and in closed loop hybrid-bionic systems to restore missing sensorimotor functions.

- PROBABILITY AND BIOSTATISTICS (1127I)
  Obiettivi Formativi
  The student will learn the basics of probability theory and statistical inference and will be able to apply appropriate methodologies for applications in biology and, in general, for the study of life sciences. In addition to the planning, collection and analysis of experimental data, the following topics will be discussed: theory of probability, discrete and continuous random variables, descriptive statistics of statistical samples, multivariate random variables, sums of random variables and associated limit theorems, interval estimation, inferential statistics and hypothesis testing, non-Gaussianity and chi-square tests, inference through non-parametric methods, regression analysis, and evaluation of diagnostic tests: sensitivity, specificity, and ROC curves.

- ROBOT PROGRAMMING FRAMEWORKS AND IOT PLATFORMS (1079I)
  Obiettivi Formativi
  The course aims at proving theoretical and practical competences in robotic programming frameworks and IoT platforms and it will provide knowledge in software design of autonomous robots and systems. Specific activities will be performed with ROS (Robotic Operating System) and YARP (Yet another robot platform) that will be implemented in simulated environments, also using dedicated SOM (System on Module) development boards. The course will also provide basic knowledge on brain-inspired controllers, based on machine learning approaches. Hands-on laboratory activities will be part of the course: students will be involved in the design and development of an IoT based environment, program the embedded system with sensors and cloud-based computing, design brain-inspired controllers and integrate them in robotic middleware (ROS and YARP).

- STATISTICAL SIGNAL PROCESSING (765II)
  Obiettivi Formativi
  The course will cover statistical signal processing methods, with application to bioengineering field. The students will become familiar with basic concepts of discrete representation of deterministic and random continuous-time signals, discrete-time random signal analysis, deterministic and random parameter estimation. Various estimation methods will be introduced and compared, such as the method of moments, the maximum likelihood and the linear and non-linear least squares methods. An introduction to Bayesian framework for random parameters and random signals estimation will be provided, with particular emphasis to the problem of linear smoothing, filtering, and prediction. Parametric auto-regressive moving average (ARMA) modeling and identification of discrete-time random signals will be also addressed. Advanced topics in parametric and non-parametric (adaptive and non-adaptive) methods for spectral estimation will be introduced, as well as some basic concepts of time-frequency analysis.

2° Anno (anno accademico 2026/2027)

- FINAL EXAMINATION (1087Z)
  Obiettivi Formativi
  The final examination involves the preparation of a report led to a design or research activity, and in its presentation and discussion.

- LAB TRAINING (1088Z)
  Obiettivi Formativi
  This activity will consist of Lab training that the student will perform in dedicated facilities and laboratories, with the aim to increase his/her experience in laboratory practice.

1° Anno (anno accademico 2025/2026)

- ADVANCED MATERIALS FOR BIONICS (1081I)
  Obiettivi Formativi
  The aim of the course is to provide a solid background in Materials Science and Engineering as relevant for Bionics Engineering. Together with basic understanding of the various classes of materials, their

structure, composition, structural and functional properties, the students will learn about more advanced concepts and recent developments of modern Materials Science, lying at the interface between chemistry, physics, engineering and biology. The course is structured in three sections. In the first section (1-Basic Materials Science & Engineering) basic and traditional topics of Materials Science will be covered/refreshed to provide a common basis among students with different background knowledge. Topics include: nomenclature and classification of materials, basic physical and chemical knowledge of solid matter, structure/properties correlation in materials, hierarchical structuring, phase transitions, fundamentals of mechanical behaviour, viscoelasticity, basic characterization tools. Various classes of engineering relevant materials will be reviewed: metals, ceramics, polymers, composites. In the second section (2 – Advanced Materials Concepts) more advanced concepts will be introduced, regarding: biocompatibility of Materials, complex behaviour of soft matter, nanotechnology and nanostructures, biological materials, bioinspired materials, stimuli-responsive materials, electro-active polymers, advanced investigation and fabrication techniques for micro- and nano-structures. In the third section (3 Technology & Bionics Applications) relevant examples of applications of materials in Bionics will be reviewed, including: advanced functional surfaces and interfaces, structural materials for bionics, materials for bioelectronics, materials for sensors & actuators in robotics.

- ANALYSIS OF BIONIC AND ROBOTIC SYSTEMS (1128I)
  Obiettivi Formativi
  In particular, the “Principles of Bionics and Biorobotics Engineering” module will introduce the wide and interdisciplinary field of bionics and related scientific areas, such as biorobotics, neuroengineering and bioengineering. Bionics aims at gathering specific knowledge through the analysis/modeling of living organisms/ecosystems and applies it to the development of newly inspired advanced devices. Bionics also focuses on artificial systems deeply connected to body tissues, and/or interacting with organisms. The application of bionics principles is nowadays widespread in many engineering sub-fields. During this course, the pillars of bionics and robotics are presented to allow the proper understanding of the whole loop from scientific insights to engineering innovation. In particular, the course focuses on the key principles of biological locomotion, swarm robotics, artificial organs, neurorobotics, neuroprostheses, neural interfaces with the nervous system, morphological computation, energy issues, principles of structural bionic design and main manufacturing techniques, as well as the fundamentals of robot mechanics. At the end of the module “Principles of Bionics and Biorobotics Engineering”, the student: ● Will possess the main knowledge about bionic and robotics engineering principles; ● Will be able to orient him/herself in the scientific literature; ● Will be able to formulate innovative hypotheses and to devise new solutions on bionic design and bioinspired robotic paradigms. To profitably attend this module, no specialistic knowledge is required. However, consolidated competences of physics and mathematics are needed. In addition, even if not strictly needed, competences concern mechanics, signal processing, and electronics are desirable. The “Principles of Bionics and Biorobotics Engineering” module topics are the following: ● Historical evolution of bionics, related to robotics and bioengineering; ● Model organisms and biological locomotion principles in different media, and applications in robotics; ● Bionic energy management: comparison between organisms and robots; ● Fabrication technologies at different scales; ● Bioinspired structural design and advanced materials; ● Fundamentals of robot mechanics (schematic of the joints, homogeneous transformations, Jacobian, methods for kinematic and dynamic studies); ● Swarm robotics; ● Principles to design effective neural interfaces and neuroprostheses ● Ethical issues and legal considerations. The “Modeling of multi-physics phenomena” module provides a basic, practical knowledge of computational mechanics of solids (linear/non-linear elasticity) and fluids (incompressible flows of Newtonian fluids). and computational electromagnetism at low frequencies, mainly associated to bioelectric phenomena and neural models. The first part of the course deals with the theory of the Finite Element Method and introduces numerical algorithms and practices for the solution of non-linear and time-dependent problems, which are common to all the aforementioned computational disciplines. Then, the numerical implementations of several physical models in a commercial FE software will be shown during hands-on sessions, along with applications to design problems involving sensors and bioinspired devices.

- APPLIED BRAIN SCIENCE (001MA)
  Obiettivi Formativi
  This course is divided in two modules “Behavioral and Cognitive Neuroscience” and “Computational neuroscience”. In the class “Behavioral and cognitive neuroscience”, the student will learn the following topics: introduction to cognitive and social neuroscience; introduction to neuronal functioning, brain metabolism and intrinsic brain activity; basic principles of brain imaging methodologies, their uses for research and clinical purposes; introduction to the advanced methods for brain imaging analyses; the neurobiological correlates of human cognition and behavior; the mental representation of the external world; the functional neuroanatomy of perception and imagery; introduction to consciousness and sleep; introduction to psycholinguistics; emotions and behavior; motor control and action representation, and their implications for the development of brain-computer interfaces. The objectives of "Computational neuroscience" class include bio-inspired neural modelling, spiking and reservoir computing neural networks, advanced computational neural models for learning, architectures and learning methods for dynamical/recurrent neural networks for temporal data and the analysis of their properties, the role of computational neuroscience in real-world applications (by case studies).

- ARTIFICIAL INTELLIGENT SYSTEMS FOR HUMAN IDENTIFICATION (1092I)
  Obiettivi Formativi
  This course provides fundamentals about techniques to verify or recognize the identity of a living person based on the analysis of biological/physiological traits and/or behavioural features. The topics of the course will be: - Biometrics overview (history of biometrics, applications); - Recognition, identification and verification; - Privacy, security and ethics; - Overview of image processing; - Physiological biometric systems: fingerprint recognition, face recognition, iris recognition, retina recognition, hand recognition, vein patterns; - Behavioral biometric systems: keystroke dynamics, signature recognition, voice recognition, gait recognition; - Multi-modal biometric systems; - Biometric applications.

- BIOINSPIRED COMPUTATIONAL METHODS (705II)
  Obiettivi Formativi
  The course aims to introduce the main concepts and techniques used in bioinspired computational methods. The course is divided in two modules “Neural and fuzzy computation” and “Biological data mining”. The first module intends to offer students the opportunity to learn the basic concepts and models of computational intelligence, to have a thorough understanding of the associated computational techniques, such as artificial neural networks, fuzzy systems and genetic algorithms, and to know how to apply them to a wide variety of application areas. The second module will focus on the basic aspects of biological data mining: data pre-processing, frequent pattern mining, classification, prediction, clustering and outlier detection.

- ELECTRONICS FOR BIONICS ENGINEERING (846II)
  Obiettivi Formativi
  The student who successfully completes the course will be able to demonstrate a solid knowledge of the main issues related to the design of sensor based electronic systems for bionics engineering. He or she will acquire the ability to analyse and design the building blocks of an analogue front-end for the acquisition, conditioning and conversion of biological sensor data, and will master the design methodologies adopted for instrumentation amplifiers, passive and active filters, analogue-to-digital and digital-to-analogue converters. He or she will then familiarise with standard digital interfaces utilised to transfer digitalised sensor data to an embedded microcontroller or microprocessor. The student will deepen his or her learning on the conditioning and digitalization chain of biological sensor data by familiarising with standard digital interfaces utilised to transfer digitalised sensor data to an embedded microcontroller or microprocessor. Finally, he or she will be exposed to state-of-the-art design methodologies adopted for tightly energy-/power-constrained electronic systems in wearable and implantable devices, and will have the opportunity to consolidate his or her learning by working with advanced EDA tools.

- NEUROANATOMY AND COGNITIVE NEUROSCIENCE (0080M)

- NEUROMORPHIC ENGINEERING (706II)
  Obiettivi Formativi
  The course will explore computational and physical models that emulate the neural dynamics of biological neurons of peripheral and central nervous system. A particular focus will be dedicated to real-time implementation of spiking artefacts that could be integrated in neurophysiological studies and in closed loop hybrid-bionic systems to restore missing sensorimotor functions.

- PROBABILITY AND BIOSTATISTICS (1127I)
  Obiettivi Formativi
  The student will learn the basics of probability theory and statistical inference and will be able to apply appropriate methodologies for applications in biology and, in general, for the study of life sciences. In addition to the planning, collection and analysis of experimental data, the following topics will be discussed: theory of probability, discrete and continuous random variables, descriptive statistics of statistical samples, multivariate random variables, sums of random variables and associated limit theorems, interval estimation, inferential statistics and hypothesis testing, non-Gaussianity and chi-square tests, inference through non-parametric methods, regression analysis, and evaluation of diagnostic tests: sensitivity, specificity, and ROC curves.

- ROBOT PROGRAMMING FRAMEWORKS AND IOT PLATFORMS (1079I)
  Obiettivi Formativi
  The course aims at proving theoretical and practical competences in robotic programming frameworks and IoT platforms and it will provide knowledge in software design of autonomous robots and systems. Specific activities will be performed with ROS (Robotic Operating System) and YARP (Yet another robot platform) that will be implemented in simulated environments, also using dedicated SOM (System on Module) development boards. The course will also provide basic knowledge on brain-inspired controllers, based on machine learning approaches. Hands-on laboratory activities will be part of the course: students will be involved in the design and development of an IoT based environment, program the embedded system with sensors and cloud-based computing, design brain-inspired controllers and integrate them in robotic middleware (ROS and YARP).

- STATISTICAL SIGNAL PROCESSING (765II)
  Obiettivi Formativi
  The course will cover statistical signal processing methods, with application to bioengineering field. The students will become familiar with basic concepts of discrete representation of deterministic and random continuous-time signals, discrete-time random signal analysis, deterministic and random parameter estimation. Various estimation methods will be introduced and compared, such as the method of moments, the maximum likelihood and the linear and non-linear least squares methods. An introduction to Bayesian framework for random parameters and random signals estimation will be provided, with particular emphasis to the problem of linear smoothing, filtering, and prediction. Parametric auto-regressive moving average (ARMA) modeling and identification of discrete-time random signals will be also addressed. Advanced topics in parametric and non-parametric (adaptive and non-adaptive) methods for spectral estimation will be introduced, as well as some basic concepts of time-frequency analysis.

2° Anno (anno accademico 2026/2027)

- BIONIC SENSES (710II)
  Obiettivi Formativi
  The course “Bionic senses” refers to engineering artificial sensing and perceptual systems through biological principles to implement neuro-prostheses to restore lost functions, for human augmentation and bioinspired perceptional machines. The basis of the needed methodology and technology will be given tutorially. The course will introduce the physiology of senses and psychophysics and will introduce engineering solutions for bionics touch, vision and hearing.

- FINAL EXAMINATION (1087Z)
  Obiettivi Formativi
  The final examination involves the preparation of a report led to a design or research activity, and in its presentation and discussion.

- HUMAN-COMPUTER INTERACTION AND AFFECTIVE COMPUTING (1229I)

- LAB TRAINING (1088Z)
  Obiettivi Formativi
  This activity will consist of Lab training that the student will perform in dedicated facilities and laboratories, with the aim to increase his/her experience in laboratory practice.

- NEURAL PROSTHESES (700II)
  Obiettivi Formativi
  The course on “Neural prostheses” is composed of two modules: “Neural interfaces and bioelectronic medicine” and “Neural tissue engineering”. During the course on “Neural interfaces and bioelectronic medicine” the students will acquire the basic principles underlying the design and development of implantable neural interfaces for different parts of the nervous system They will also develop a broad view on i) existing neuroprosthetic systems to restore motor functions, ii) neural stimulation therapies for motor disorders, and iii) novel solutions based on the stimulation of the autonomic nervous system, and will be able to identify current limitations and challenges for future applications. Finally, the students will learn the conceptual and practical bases for the development of a novel neuroprosthesis (group project). The course “Neural tissue engineering” will introduce the students to the methods, protocols and engineering tools for mimicking both the central nervous system (CNS) and peripheral nervous system (PNS) at the microscale. Specifically, after a brief introduction on the physiopathology of human nervous system and its buiding blocks (i.e. neurons and glia cells), the course will focus on biomaterials and biofabrication techniques, traditional and advanced in vitro systems as well as computational methods for modeling, monitoring and characterizing neural structure and function.

- NEURAL SIGNAL PROCESSING AND MEASUREMENT TECHNIQUES (1226I)

1° Anno (anno accademico 2025/2026)

- ADVANCED MATERIALS FOR BIONICS (1081I)
  Obiettivi Formativi
  The aim of the course is to provide a solid background in Materials Science and Engineering as relevant for Bionics Engineering. Together with basic understanding of the various classes of materials, their structure, composition, structural and functional properties, the students will learn about more advanced concepts and recent developments of modern Materials Science, lying at the interface between chemistry, physics, engineering and biology. The course is structured in three sections. In the first section (1-Basic Materials Science & Engineering) basic and traditional topics of Materials Science will be covered/refreshed to provide a common basis among students with different background knowledge. Topics include: nomenclature and classification of materials, basic physical and chemical knowledge of solid matter, structure/properties correlation in materials, hierarchical structuring, phase transitions, fundamentals of mechanical behaviour, viscoelasticity, basic characterization tools. Various classes of engineering relevant materials will be reviewed: metals, ceramics, polymers, composites. In the second section (2 – Advanced Materials Concepts) more advanced concepts will be introduced, regarding: biocompatibility of Materials, complex behaviour of soft matter, nanotechnology and nanostructures, biological materials, bioinspired materials, stimuli-responsive materials, electro-active polymers, advanced investigation and fabrication techniques for micro- and nano-structures. In the third section (3 Technology & Bionics Applications) relevant examples of applications of materials in Bionics will be reviewed, including: advanced functional surfaces and interfaces, structural materials for bionics, materials for bioelectronics, materials for sensors & actuators in robotics.

- ANALYSIS OF BIONIC AND ROBOTIC SYSTEMS (1128I)
  Obiettivi Formativi
  In particular, the “Principles of Bionics and Biorobotics Engineering” module will introduce the wide and interdisciplinary field of bionics and related scientific areas, such as biorobotics, neuroengineering and bioengineering. Bionics aims at gathering specific knowledge through the analysis/modeling of living organisms/ecosystems and applies it to the development of newly inspired advanced devices. Bionics also focuses on artificial systems deeply connected to body tissues, and/or interacting with organisms. The application of bionics principles is nowadays widespread in many engineering sub-fields. During this course, the pillars of bionics and robotics are presented to allow the proper understanding of the whole loop from scientific insights to engineering innovation. In particular, the course focuses on the key principles of biological locomotion, swarm robotics, artificial organs, neurorobotics, neuroprostheses, neural interfaces with the nervous system, morphological computation, energy issues, principles of structural bionic design and main manufacturing techniques, as well as the fundamentals of robot mechanics. At the end of the module “Principles of Bionics and Biorobotics Engineering”, the student: ● Will possess the main knowledge about bionic and robotics engineering principles; ● Will be able to orient him/herself in the scientific literature; ● Will be able to formulate innovative hypotheses and to devise new solutions on bionic design and bioinspired robotic paradigms. To profitably attend this module, no specialistic knowledge is required. However, consolidated competences of physics and mathematics are needed. In addition, even if not strictly needed, competences concern mechanics, signal processing, and electronics are desirable. The “Principles of Bionics and Biorobotics Engineering” module topics are the following: ● Historical evolution of bionics, related to robotics and bioengineering; ● Model organisms and biological locomotion principles in different media, and applications in robotics; ● Bionic energy management: comparison between organisms and robots; ● Fabrication technologies at different scales; ● Bioinspired structural design and advanced materials; ● Fundamentals of robot mechanics (schematic of the joints, homogeneous transformations, Jacobian, methods for kinematic and dynamic studies); ● Swarm robotics; ● Principles to design effective neural interfaces and neuroprostheses ● Ethical issues and legal considerations. The “Modeling of multi-physics phenomena” module provides a basic, practical knowledge of computational mechanics of solids (linear/non-linear elasticity) and fluids (incompressible flows of Newtonian fluids). and computational electromagnetism at low frequencies, mainly associated to bioelectric phenomena and neural models. The first part of the course deals with the theory of the Finite Element Method and introduces numerical algorithms and practices for the solution of non-linear and time-dependent problems, which are common to all the aforementioned computational disciplines. Then, the numerical implementations of several physical models in a commercial FE software will be shown during hands-on sessions, along with applications to design problems involving sensors and bioinspired devices.

- ARTIFICIAL INTELLIGENT SYSTEMS FOR HUMAN IDENTIFICATION (1092I)
  Obiettivi Formativi
  This course provides fundamentals about techniques to verify or recognize the identity of a living person based on the analysis of biological/physiological traits and/or behavioural features. The topics of the course will be: - Biometrics overview (history of biometrics, applications); - Recognition, identification and verification; - Privacy, security and ethics; - Overview of image processing; - Physiological biometric systems: fingerprint recognition, face recognition, iris recognition, retina recognition, hand recognition, vein patterns; - Behavioral biometric systems: keystroke dynamics, signature recognition, voice recognition, gait recognition; - Multi-modal biometric systems; - Biometric applications.

- BIOINSPIRED AND SOFT ROBOTICS (1078I)
  Obiettivi Formativi
  “Mechanics of smart materials and structures” aims at providing a working knowledge of modeling tools to analyze and understand the mechanical response of smart materials and structures. These include the variational formulation of equilibrium and stability problems, up to the foundations of the Finite Element Method (FEM). The course will enable the student to formulate and solve models for the equilibrium response of structures in the large deformation regime. The student will be introduced to advanced modeling tools and their applications in bioinspired and soft robotics. Advanced design principles (based

e.g., on morphing structures, deployable structures, multi-stable devices) will be discussed through the analysis of their theoretical basis and the solution of practical problems. “Soft robotics technologies” aims at providing an advanced knowledge on soft robotics and soft mechatronics technologies. The course will enable the student to implement a comparative analysis for the choice of the most suitable technologies for specific engineering problems. Different transduction principles will be analysed from the basic physics to their exploitation as sensors or actuators. The student will be introduced to advanced design principles (e.g. bioinspiration and morphological computation) and tools (e.g. FEM) also through hands-on lab activities.

- BIOINSPIRED COMPUTATIONAL METHODS (705II)
  Obiettivi Formativi
  The course aims to introduce the main concepts and techniques used in bioinspired computational methods. The course is divided in two modules “Neural and fuzzy computation” and “Biological data mining”. The first module intends to offer students the opportunity to learn the basic concepts and models of computational intelligence, to have a thorough understanding of the associated computational techniques, such as artificial neural networks, fuzzy systems and genetic algorithms, and to know how to apply them to a wide variety of application areas. The second module will focus on the basic aspects of biological data mining: data pre-processing, frequent pattern mining, classification, prediction, clustering and outlier detection.

- ELECTRONICS FOR BIONICS ENGINEERING (846II)
  Obiettivi Formativi
  The student who successfully completes the course will be able to demonstrate a solid knowledge of the main issues related to the design of sensor based electronic systems for bionics engineering. He or she will acquire the ability to analyse and design the building blocks of an analogue front-end for the acquisition, conditioning and conversion of biological sensor data, and will master the design methodologies adopted for instrumentation amplifiers, passive and active filters, analogue-to-digital and digital-to-analogue converters. He or she will then familiarise with standard digital interfaces utilised to transfer digitalised sensor data to an embedded microcontroller or microprocessor. The student will deepen his or her learning on the conditioning and digitalization chain of biological sensor data by familiarising with standard digital interfaces utilised to transfer digitalised sensor data to an embedded microcontroller or microprocessor. Finally, he or she will be exposed to state-of-the-art design methodologies adopted for tightly energy-/power-constrained electronic systems in wearable and implantable devices, and will have the opportunity to consolidate his or her learning by working with advanced EDA tools.

- NEUROANATOMY AND COGNITIVE NEUROSCIENCE (0080M)

- NEUROMORPHIC ENGINEERING (706II)
  Obiettivi Formativi
  The course will explore computational and physical models that emulate the neural dynamics of biological neurons of peripheral and central nervous system. A particular focus will be dedicated to real-time implementation of spiking artefacts that could be integrated in neurophysiological studies and in closed loop hybrid-bionic systems to restore missing sensorimotor functions.

- PROBABILITY AND BIOSTATISTICS (1127I)
  Obiettivi Formativi
  The student will learn the basics of probability theory and statistical inference and will be able to apply appropriate methodologies for applications in biology and, in general, for the study of life sciences. In addition to the planning, collection and analysis of experimental data, the following topics will be discussed: theory of probability, discrete and continuous random variables, descriptive statistics of statistical samples, multivariate random variables, sums of random variables and associated limit theorems, interval estimation, inferential statistics and hypothesis testing, non-Gaussianity and chi-square tests, inference through non-parametric methods, regression analysis, and evaluation of diagnostic tests: sensitivity, specificity, and ROC curves.

- ROBOT PROGRAMMING FRAMEWORKS AND IOT PLATFORMS (1079I)
  Obiettivi Formativi
  The course aims at proving theoretical and practical competences in robotic programming frameworks and IoT platforms and it will provide knowledge in software design of autonomous robots and systems. Specific activities will be performed with ROS (Robotic Operating System) and YARP (Yet another robot platform) that will be implemented in simulated environments, also using dedicated SOM (System on Module) development boards. The course will also provide basic knowledge on brain-inspired controllers, based on machine learning approaches. Hands-on laboratory activities will be part of the course: students will be involved in the design and development of an IoT based environment, program the embedded system with sensors and cloud-based computing, design brain-inspired controllers and integrate them in robotic middleware (ROS and YARP).

- STATISTICAL SIGNAL PROCESSING (765II)
  Obiettivi Formativi
  The course will cover statistical signal processing methods, with application to bioengineering field. The students will become familiar with basic concepts of discrete representation of deterministic and random continuous-time signals, discrete-time random signal analysis, deterministic and random parameter estimation. Various estimation methods will be introduced and compared, such as the method of moments, the maximum likelihood and the linear and non-linear least squares methods. An introduction to Bayesian framework for random parameters and random signals estimation will be provided, with particular emphasis to the problem of linear smoothing, filtering, and prediction. Parametric auto-regressive moving average (ARMA) modeling and identification of discrete-time random signals will be also addressed. Advanced topics in parametric and non-parametric (adaptive and non-adaptive) methods for spectral estimation will be introduced, as well as some basic concepts of time-frequency analysis.

2° Anno (anno accademico 2026/2027)

- ADVANCED INTERVENTIONAL AND THERAPEUTIC TECHNOLOGIES (1103I)
  Obiettivi Formativi
  The course “Advanced interventional and therapeutic technologies” is composed of two modules: “Robotics for minimally invasive and targeted therapy” and “Bionic organs and tissues”. The overall course aims to provide students with knowledge and methodological tools typical of (i) robotics in the surgical/diagnostic domain, (ii) targeted therapies based on micro/nano smart materials, and (iii) mechatronics and bioengineering for bionic organs/tissues and regenerative purposes. In particular, in the “Robotics for minimally invasive and targeted therapy” module, the students will gather knowledge and methodologies concerning the design of robots and intelligent instruments for surgery and interventional tasks, from the macro to the micro size, towards targeted therapy. At the end of the course, the students will be able to identify the most appropriate targeting/therapeutic solutions for different human body districts, at different scales and for different pathologies. Thanks to the analysis of the surgical robots available in the teacher’s Institute, the students will be able to relate the theoretical knowledge with real practical scenarios. The module “Bionic organs and tissues” aims to teach students how to design and develop artificial and bioartificial technologies at different scales, bionic organs and tissues, smart materials for advanced therapy, organ function replacement, drug delivery and tissue regeneration. Principles of anatomy and physiology of different organs and tissues will be provided. Mechatronic/micro-mechatronic solutions, as well as “wet bioengineering” ones, alternative to or synergic with traditional medical/surgical procedures, will be also highlighted. Hands-on laboratory activities are part of this module: in particular, students will be involved in practical activities concerning cell cultures.

- DESIGN PRINCIPLES FOR BIONIC TISSUE ENGINEERING (1104I)
  Obiettivi Formativi
  This course will guide students in the design of cell and tissue-based systems for application to the development of in vitro models, artificial organs and delivery systems using technology based on 3D scaffolds, stem cells, organoids, and spheroids Starting from a quantitative description of cell, tissue and organ assembly and of their requirements in terms of resources, microenvironmental conditions,

cooperation and competition, the course covers fundamental design principles. It also provides a comprehensive overview of stem cell, organoid and on-chip technology as well as mathematical models of morphogenesis, self-assembly, growth and differentiation. Project work will include design and simulation of in vitro models. Course contents: Basic principles of biochemistry and cell biology. Quantitative models of cell-material interaction, mechanobiology, cell assembly and 3D organisation. Allometric (power law) relationships in organisms. Design criteria for 3D tissue constructs based on resource supply and diffusion limitations. Stem cell technology, induced pluripotent stem cells, organoids (intestine, liver, brain). Fluidic bioreactors and organ and body on a chip design using computational methods.

- FINAL EXAMINATION (1087Z)
  Obiettivi Formativi
  The final examination involves the preparation of a report led to a design or research activity, and in its presentation and discussion.

- LAB TRAINING (1088Z)
  Obiettivi Formativi
  This activity will consist of Lab training that the student will perform in dedicated facilities and laboratories, with the aim to increase his/her experience in laboratory practice.

- REHABILITATION AND ASSISTIVE TECHNOLOGIES (1105I)
  Obiettivi Formativi
  The objectives of the module “Biomechanics of human motion” are to provide an introduction to the biomechanics of the human movements and then to understand the main role underlying the control of spatial multiple degree-of-freedom human motion. These objectives will be reached by means of both theoretical lessons and practical activities in a lab of human movement analysis, preparing the student to understanding the main concept of physical/motor rehabilitation and of bioinspired robotics. The objectives of the module “Robotic and data-driven rehabilitation” are to provide elements to understand current trends in rehabilitation robotics. The course will focus on fundamental principles of robotics modelling, in order to provide theoretical tools to critically analyze robot architectures in the context of rehabilitation robotics. Concepts of ergonomics, anthropometry and universal design will be introduced, together with theoretical and practical knowledge of structural materials and technical textile materials used for the construction of rehabilitation machines. During the course the most relevant rehabilitation robots of the state of the art will be presented in conjunction with relevant clinical studies.

- WEARABLE ROBOTICS (1033I)
  Obiettivi Formativi
  The course is composed of two modules: Prostheses and Exoskeletons. The overall goal is to introduce students to the main challenges to design wearable powered robots for movement assistance, rehabilitation, augmentation and/or functional replacement. Along with the analyses of the main components involved in the development of an effective human-robot interaction, students will be engaged in laboratory and hands-on activities with working devices. In particular: Within the module “Prostheses” students will be introduced to and will experiment the architecture and function of the microcontroller. Within the module “Exoskeletons” students will learn how to conceive, rapid-prototype and test multi-layered control architectures running on real-time targets endowed with FPGA processors.