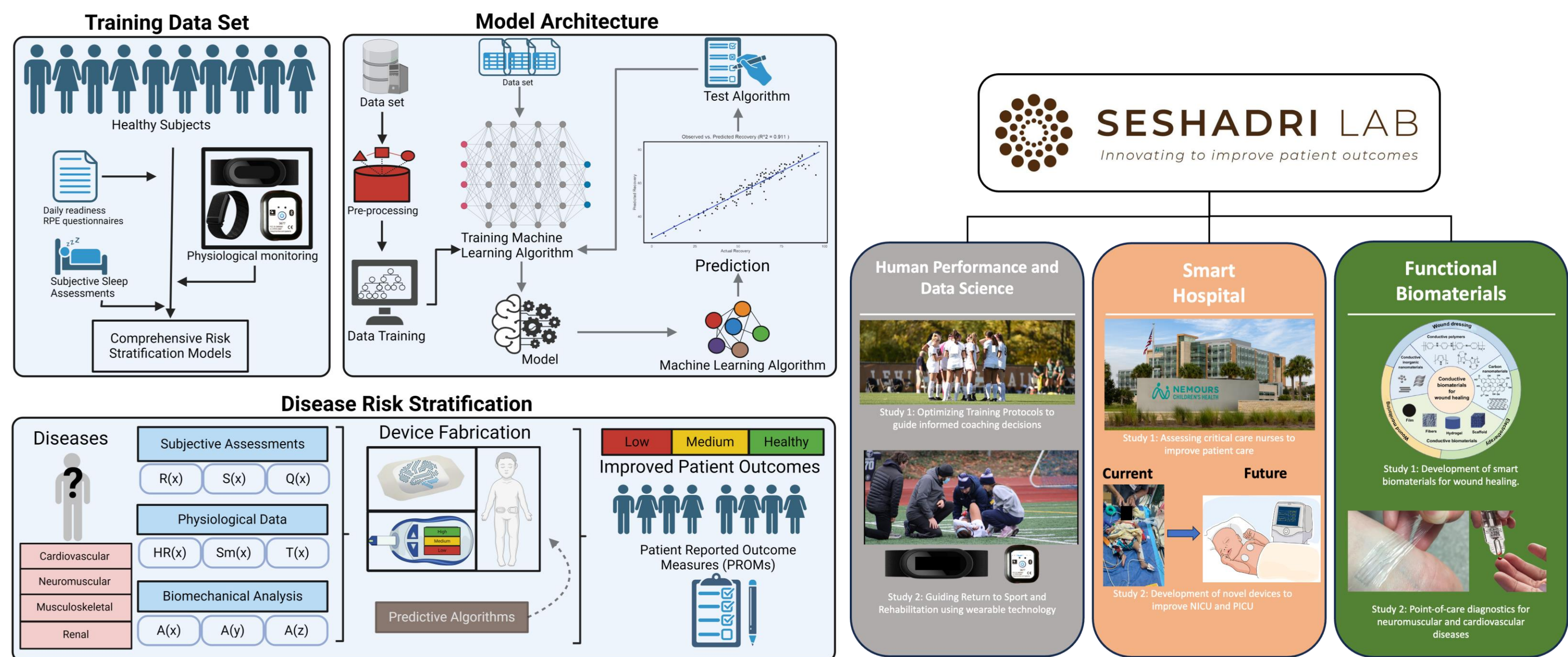




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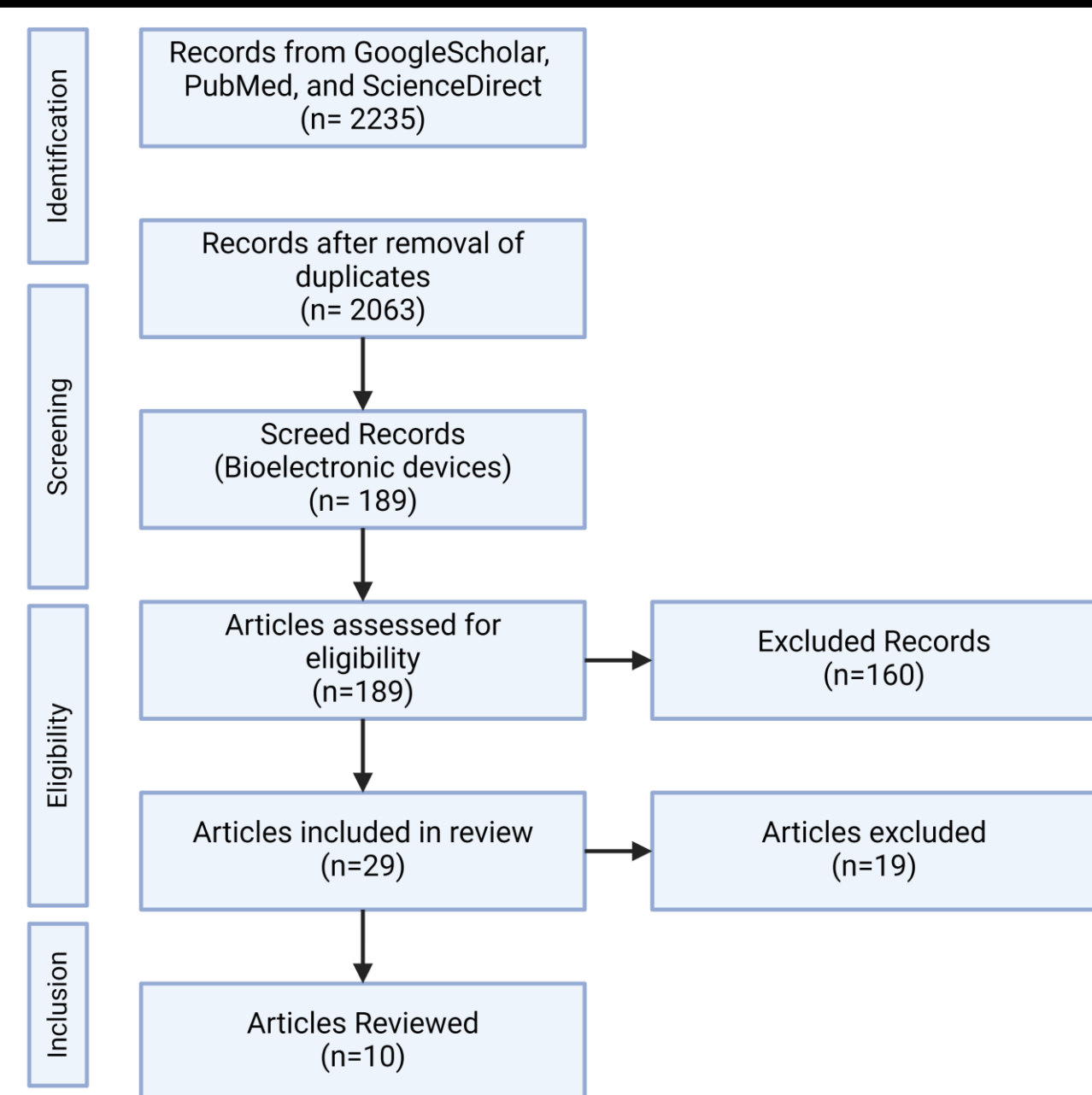
## Introduction

- Chronic wounds affect nearly **2.5% of the United States population**, and even larger fraction for elderly populations.
- Chronic wounds are **persistent** wounds typically halted in the inflammatory phase and mainly affect **elderly** and **underdeveloped populations**.
- Electroceutical devices pose a new way to treat chronic wounds as they **promote cell migration, adhesion, and angiogenesis**.



**Figure 1: Seshadri Laboratory overview to improve patient outcomes.** Human Performance: predictive analytics for performance optimization. Smart Hospitals: analytics and devices for remote monitoring. Functional Biomaterials: novel materials and devices to solve unmet clinical needs.

## Methods



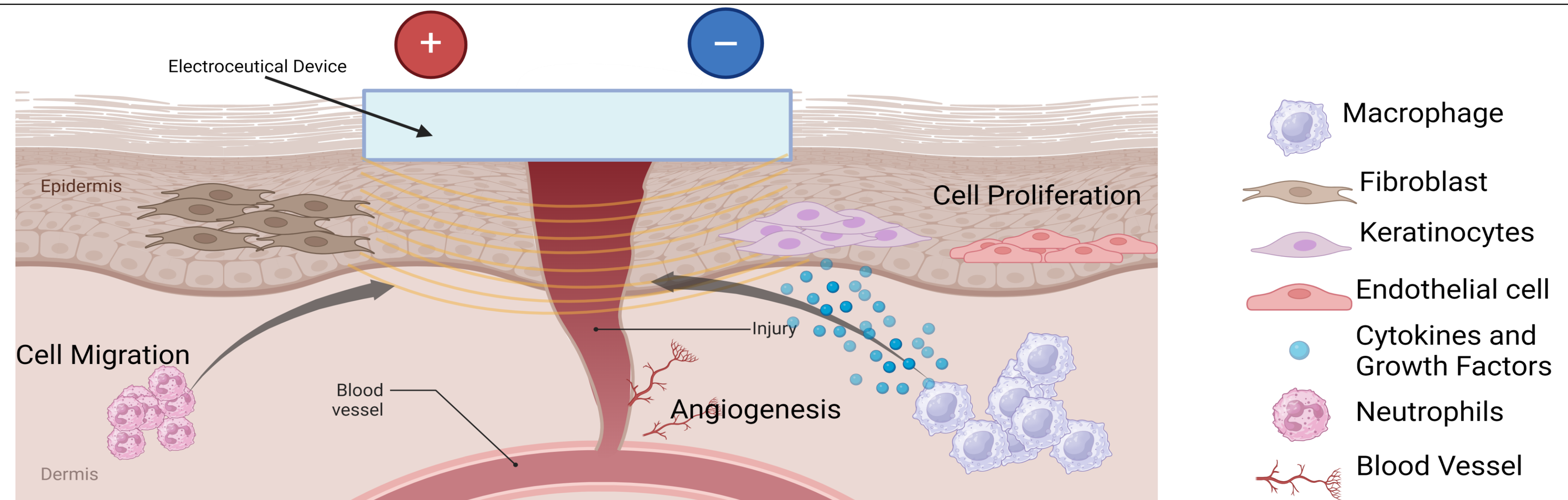
**Figure 2: PRISMA flow chart**

- A literature search was conducted on studies from 2000 to 2023 using **Google Scholar, PubMed, and ScienceDirect**.
- Inclusion criteria:** electroceutical devices that harness electrical stimulation for chronic wound healing.
- Exclusion criteria:** devices used to monitor physiological parameters, administer medications, other wound healing modalities without electro-stimulation, and electroceutical devices for acute wound healing.

## Results

**Table 1: Sampling of electroceutical devices and their effect on healing chronic wounds**

Type of device	Type of current generated	Stimulation pattern/effect	Effects	Results	Reference
EGS Model 300 Electrical Stimulators	High voltage pulsed current (Direct Current)	Stimulates cell proliferation and migration	Cell electro taxis Wound contraction	Wound contraction significantly improved	(Physical Therapy, 2003)
Decubitus Direct Current Treatment (DDCT)	Direct/Alternating Current	Wound electric activity stimulation	Wound contraction	Wound contraction rate significantly improved	(Arch Gerontol Geriatr, 2005)
Wireless closed loop, smart bandage with sensors and stimulators	Direct current	Stimulates Vascular Endothelial Growth Factors (VEGF)	Pro-regenerative healing genes	Increase in wound impedance, Angiogenesis	(Nature Biotechnology, 2023)
Direct current electric field electrode generator	Direct current	Endogenous electric field stimulation	Cellular electrotaxis/ keratinocyte proliferation	Keratinocytes electrotaxis	(Bioelectrochemistry, 2019)
Wearable piezo-triboelectric nanogenerator device	Piezo & triboelectric (Direct Current)	Biomechanical electric impulse generator	Endothelial cells and fibroblast activation	Endothelial cells/ Fibroblast migration	(Nano Energy, 2022)
Alternative capacitive electric field (ACEF) exposure system	ACEF	Alternative capacitive electric field	Epidermal cells, Fibroblast, macrophages	Cell polarization, enhanced cell activity and migration	(Medicine in Novel Technology and Devices, 2020)
Interdigital array (IDA) electrode (TENG)	Triboelectric nanogenerator	A direct current electric stimulator	Vascular Endothelial Growth Factor (VEGF), CD31 marker	Enhance wound vascularization	(Nano Energy, 2022)
Flexible ePatch	Silver nanowire (AgNW) methacrylate alginate	Direct current stimulated by compressional force	Growth factors activation	Fibroblast electrotaxis	(Biomaterials, 2022)
Poly(L-lactic acid)/Vit. B2-based piezoelectric device	Piezoelectric generator	Direct current generator	Fibroblast activation	Fibroblast migration	(E. Polymer J., 2023)
Bioelectric Signal Therapy (BST) Device	Electric Stimulation	Alternating current	Nerves	Activation of cutaneous sensory nerves	(Int Wound J., 2015)



**Figure 3: Mechanism of action detailing the use of electrical stimulation for chronic wound healing.** Electroceuticals activate intracellular pathways which release growth factors, facilitate cell migration through electrotaxis influencing cell adhesion, and trigger the release of pro-angiogenic factors which enable tissue regeneration.

## Discussion and Future Work

- Future research into devices that enable **patient specific treatment** plans is necessary and lacking to maximize efficacy treatment efficacy
- Devices must be engineered in **clinically-relevant form factors** to match the size and **irregular shape** of chronic wounds presented in clinics
- Testing must be done on wounds that are of **clinical significance**
- Opportunity to integrate **edge computing** to assess **healing** and **tailor electroceutical therapy** for real-time treatment capabilities
- Further need for **RCTs** to assess **efficacy** of wearable electroceutical devices for chronic wound healing