Information Search and Planning

Rough Sources Table

SHE COMM & COLLAB in YELLOW –
SHE DEVELOPMENT in TURQOISE
BIOLOGY ASPECTS in GREEN

Description	Link and key points
Bionic fingertip gives sensations to amputee (Thomson, H 2016)	https://www.newscientist.com/article/2079808-bionic-fingertip-gives-amputee-a-feel-for-different-textures/ - Recent = grip and lift - Electrochemical sensors that deform when touched; computer changes this into electrode signals that stimulate nerves similar to real touch - on way to better because less invasive surgery - realistic touch prothsesis - team in Switzerland; refers to work in Italy - bio robotics institute - previous study by Dustin Tyler in USA – he got force and pressure but not texture -
Woman receives bionic hand with sense of touch (Walsh, F 2018)	https://www.bbc.com/news/health-42430895 • International team first developed worlds first feeling bionic hand in 2014 – but equipment it was attached to was too large!! • The development team included engineers, neuroscientists, surgeons, electronics and robotics specialists from Italy, Switzerland and Germany. • Sense hard or soft • A robotic prosthesis better than the human hand is still a long way off, but the team believe it might eventually be a reality. • The scientific team say they hope to miniaturise the technology even further so that a sensory bionic hand can be commercialised. •
Bringing Sensation to Bionic limbs (Franz, J 2017) Journal Article:	https://www.sciencefriday.com/segments/bringing-sensation-to-bionic-limbs/ • Biomechatronics • Good biology behind it • Link to published article • Amputation – loose muscle groups that work in pairs and give feedback of where your are etc.

Commented [TaKB1]: When you submit yours for Part A, it may not be this long – this is my complete research reference when I was ready to sit down and write the final report. But it gives you an idea of what it could look like.

Commented [TaKB2]: I, in the end decided to leave this SHE out and focus on Development.

Commented [TaKB3]: I went ahead and made my in text for each reference before I wrote the report so it was easy to pop in when needed as writing.

Commented [TaKB4]: When doing research I just kept adding to this table – if I found a good source I would pop the URL in and cut past good quotes or make points that I could come back to and use or discard.

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<td>(Srinivasan, S et al. 2017)</td>
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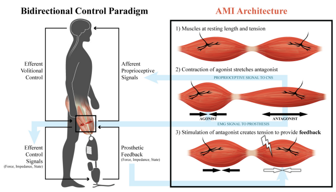
Currently – amputees with prosthetics have to follow their limbs with sight to know where the limb is! This is because they are not getting feedback through muscle/nerves
Affects fine motor control!
Restoring muscle pairs with rengerative muscle tissue linked into nerves
Improve and modulate position, velocity and stiffness of prosthetic device = improvement in every way.
Can, with muscle groups, then program to control limb and tell it how to move.
Benefit – not just recent amputees but also revision of ones from long ago!
KEY: prosthesis communicates with brain to provide sensory feedback to user, and even to the prosthesis itself to move properly



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<td>Restoring movement sensation in upper limb amputation patients

(Cleveland Clinic 2018)</td>
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https://www.sciencedaily.com/releases/2018/03/180314145024.htm

This breakthrough may enhance the ability to control their prostheses, independently manage activities of daily living and improve quality of life.
"These findings have important implications for improving human-machine interactions and bring us closer than ever before to providing people with amputation with complete restoration of natural arm function."
To improve the relationship between the mind and the prosthesis, the researchers investigated whether they could use a movement illusion to help patients better control their bionic hands.
This is important because when an able-bodied person moves, the brain constantly receives feedback regarding the movement's progress. This unconscious sense prevents errors in movement, like overreaching, and allows the body to make necessary adjustments. People with amputation lose this essential feedback, however, and as a result, cannot control their prostheses without having to watch them carefully at all times.

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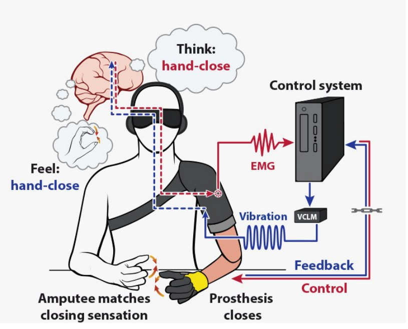
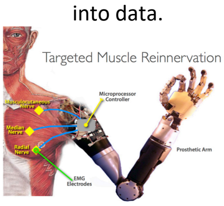
	• provided patients with better spatial awareness and improved fine motor control without having to visually monitor the prostheses. • "The ultimate goal of our research is to use movement sensation to streamline the relationship between patients and their technology, to better integrate their prosthetics as a natural part of themselves," said Marasco. •
Researches restore elusive sixth sense to lost limbs (Gonzalez, R 2018)	https://www.wired.com/story/researchers-restore-feeling-to-lost-limbskinda/ • Good contrast to old tech (2006) • The socket relays electrical signals from those muscles to the computerized, motor-driven hand, which she operates with her mind. I want to close my hand, she thinks, and the hand complies. • What's remarkable is that she knows what her bionic appendage is up to, in spite of her blindfold and the noise-cancelling headphones that cover her ears. Kitts can feel the hand's movement, sense its position in space • NEUROPHYSIOLOGISTS CALL AWARENESS of the movement and position of one's body parts kinesthesia. (The more general term is proprioception, though it refers more to position than movement.) When an able-bodied person moves her hand, sensorimotor signals inform her brain where and how it's moving. Kinesthesia is what lets her seize a falling bottle of shampoo in the shower, or shoulder her backpack with her right hand while staring at the phone in her left. The sensation is commonly regarded as a sixth sense; it's entirely distinct from touch, yet kinesthesia is equally if not more important for complex motor tasks.  • The method hinges on an extraordinary phenomenon that neurophysiologists call vibration-induced kinesthetic illusions: Vibrating a tendon at a frequency between 70 and 115 Hz

	makes you feel like its associated joint is moving. The illusions can involve multiple joints, and are potent enough to fool people into sensing that their arms are bending into weird, or even impossible, shapes. They can also implicate other body parts. • To be truly helpful, the researchers needed to combine the perception of hand movement with the intention of hand movement. • To do it, they developed a bidirectional neural-machine interface. Like existing prosthetics, it could relay electrical signals from patients' reinnervated muscles to a bionic hand. To this one-directional system, the researchers then added a kinesthetic feedback signal; when the hand moved in response to a test subject's thoughts, it also triggered vibrations at their reinnervation sites, producing the kinesthetic illusion.
Sensing bionic limbs are here – and they work (Templeton, G 2015)	https://www.extremetech.com/extreme/214244-sensing-bionic-limbs-are-here-and-they-work • Sensing is quickly becoming a limiting factor in bionic control. • Sensation coming from a bionic source does not have to be speed-limited by the diffusion of ions in solution, as are sensory neurons, or temperature-limited by the safety constraints of flesh. Bionic sensation could plausibly let a person put their hand down on a frying pan to test its temperature — and to judge it with their *brain*, the same as they would any reasonable level of heat. • DARPA is funding this research because of the incredible potential it has to improve the lives of thousands of wounded veterans — but there's also plenty of emergent military and industrial value to be had, in any project of this type. We live in an age when data is both money and power, and this genuinely altruistic medical research is slowly turning thought into data.  •
Prosthetics you can feel	https://www.technologyreview.com/s/608366/prosthetics-you-can-feel/

(MIT) (Trafton, A 2017)	• With the help of muscle grafts and feedback from existing nerves, amputees would be able to sense where their prosthetics are in space and feel how much force is being applied to them. • This type of system could help reduce the rate at which patients decide to reject their prosthetic limbs, which is around 20 percent. • The surgery aims to restore some of the physical basis for proprioception, the body's sense of its own position and movement. Most muscles that control limb movement occur in what are known as agonist-antagonist pairs: one muscle stretches when the other contracts, and both send sensory information back to the brain. • "Using this framework, the patient will not have to think about how to control their artificial limb," Herr says. "When a patient imagines moving their phantom limb, signals will be sent through nerves to the surgically constructed muscle pairs. Implanted muscle electrodes will then sense these signals for the control of synthetic motors in the external prosthesis."
Future prosthetics: toward the bionic human (Stuart, N 2018)	https://www.theengineer.co.uk/future-prosthetic/ • One of the biggest challenges comes in healthcare, where engineers literally have to match nature. Engineering some device that will have to fulfil the same function as a natural part of the body or coordinate with natural processes is about as difficult as it gets. And replacing missing or lost limbs provides some of the most striking examples of the progress we have made. Archaeologists have found examples of replacement body parts from ancient Egypt, Greece and Rome. These range from the crude — wooden peg legs and strap-on toes — to primitive, There are two main challenges involved in developing prosthetics. The first is in designing the mechanical limb itself. With increasing miniaturisation of electric motors and advances in computing power, this is becoming less of a challenge than the second, still-towering difficulty; finding ways to interface the machine with the amputee's body. How can somebody who has lost a limb control a prosthetic? Is it possible to think about moving a prosthetic arm and move it with brain power alone; or to get even closer to the natural condition, and move it without barely any conscious thought? Can the sense of touch be replicated by a machine, even with today's advanced sensors? And how about the sense which we rely on but is so

	fundamental that we are barely aware of it: proprioception — knowing exactly where our limbs and extremities are without having to look? How close can an amputee be returned to natural function with technology? And how is that technology likely to develop in the coming decades? Kianoush Nazarpour, a bioengineer from Newcastle University, is one of those researching ways of improving existing technology. It is understandable that amputees wouldn't want to risk implantation, especially when this technology is not fully developed, he told *The Engineer*. "By definition, if you need an amputation, you've already had a very traumatic experience, and the surgery to remove a damaged limb is even more trauma and risk. You can see why people wouldn't want to expose themselves to another extreme procedure when they might end up with something no better — or even not as good— as something they can already have, and that's before you consider the risk of infection." "People who get myoelectric limbs can typically start to learn to control them in about five minutes, because the visual impact of being able to see what your hand is reaching for, for example, is very powerful. Learning to interpret sensory input is an order of magnitude more difficult, and takes correspondingly longer."
The problem with modern-day, high-tech prosthetics (Resnick, B 2010)	https://www.popularmechanics.com/science/health/a6302/high-tech-prosthetics-fitting/ Today, state-of-the-art prosthetics are mechanical limbs controlled by nerve impulses and microprocessors. While these enhancements can make life easier for amputees, "The challenge of prosthetics is that we are putting dead things on living people," says Riley, who is a prosthetist and a below-the-knee amputee. Overall, the success of a limb depends more on the disposition of the amputee than the interface technology utilized. .... NOTE – so.. with better intergration they will have better attitude towards it and more success!
Mobility comes at a high cost	https://www.canberratimes.com.au/national/act/mobility-comes-at-a-high-cost-20120616-20gnj.html

(Thomson, P 2012)	Each leg cost $8500 and then he added bits and pieces. Flexible feet cost him $7000 and he uses several hundred dollars worth of shuttle locks so he can detach the leg more easily and inner liners to stop blisters. ''I work to pay for parts,'' Morrison says. Parts for prosthetic legs are expensive. A woman who wants to wear shoes with heels can buy an ankle which is adjusted by moving the pin for $2500. A bionic foot which adapts itself to the bumps in the ground like a normal foot costs $35,000. The problem for people such as Morrison and Kelly is that this leg is fifteen times more expensive than the kind they can afford.
Getting to grips with bionic costs (Fanning, P et al. 2018)	http://www.eurekamagazine.co.uk/design-engineering-features/technology/getting-to-grips-with-bionic-costs/173342/ Recent advances in robotic prosthetic hands have been little short of extraordinary, but have remained out of the price range of many who need them. However, a number of engineers and start-ups are looking to change that. The downside, of course, is that such solutions don't come cheap. While robotic prosthetic arms have generally come down in price from six figures to five, they remain far beyond the price bracket of most who need them. In the UK, the National Health Service still doesn't offer such limbs as standard, meaning that only those with independent means or extremely good health insurance can hope to benefit from this life-changing technology. Meanwhile, of course, most people in the developing world can only dream of having access to this sort of technology. The race is on, therefore, to provide the latest prosthetics to those who might ordinarily lack the means to afford them. There are a number of initiatives to achieve this, but one of the most successful and high profile is Bristol-based Open Robotics. Founded by 2014 British Engineering Excellence Awards winner Joel Gibbard and Samantha Payne, the company is committed to developing affordable robotic systems that enhance the human body. Currently, multi-grip bionic hands cost anywhere between £25,000 to £60,000 per hand. They are only available through private clinics and

	are considered to be too expensive for the NHS, despite, although NHS patients still regularly petition for them. Another area in which Open Bionics is innovating is in the development of multi-grip bionic hands for children under 14. During its clinical trials with the NHS, which began in June 2017, Open Bionics has fitted multi-grip bionic hands to children as young as eight. This was a world first and it is this device that will be the first to go to market.
Gaining Proprioreception with prosthetics (Grant, B 2017)	https://www.the-scientist.com/?articles.view/articleNo/49554/title/Gaining-Proprioception-with-Prosthetics/ Prosthetic limbs are rejected by amputees' bodies at a rate of about 20 percent. Researchers at MIT are seeking to reduce that number, using an amputation procedure that encourages increased feedback between muscles, tendons, and the nervous system so that an artificial limb might stimulate them in a more natural way—giving patients a better sense of proprioception, or where their limb is in space. The key to the surgical technique, demonstrated in rats so far, is to emulate the normal agonist-antagonist pairing of muscles (think biceps and triceps) at the amputation site so that the muscles and nerves surrounding a prosthetic can sense and transmit proprioceptive information about the artificial limb and how much force is being applied to it. Herr, himself a double-amputee, and his team operated on seven rats, cutting through muscles and nerves in their hind legs. The researchers then grafted on paired muscles, wiring them up to severed nerves. After healing for four months, the rats' new muscles were contracting and relaxing in tandem, as in naturally paired muscles, and sending electrical signals that reflected the amplitude of the artificial stimulation Herr and his colleagues applied. both my legs are amputated below the knee, and my amputations were done 30-some years ago in a really silly way, in a conventional way—in principle we can do a revision on my limbs and get muscles from another part of my body and create these pairs."

Bionic Prosthetic System Restores Proprioception for Amputee Patients (Treacy, S 2018)	https://electronics360.globalspec.com/article/11935/watch-bionic-prosthetic-system-restores-proprioception-for-amputee-patients Their novel neural interface and communication paradigm that restores proprioception in artificial limbs is called agonist-antagonist myoneural interface (AMI). The AMI can send movement commands from prosthetic wearer's central nervous system to the robotic prosthetic. Their novel neural interface and communication paradigm that restores proprioception in artificial limbs is called agonist-antagonist myoneural interface (AMI). The AMI can send movement commands from prosthetic wearer's central nervous system to the robotic prosthetic. The interface sends proprioceptive feedback, describing the movements the joints need to make back and forth between the prosthetic and the central nervous system. The system is implemented during the limb amputation surgery. During the surgery, the dynamic muscle relationships that develop in the human limb are preserved and then implemented in the artificial limb. "These sensors translate mechanical stretch into electrical signals that can be interpreted by the brain as sensations of position, speed and force." "We knew that in order for us to validate the success of this new approach to amputation, we would need to couple the procedure with a novel prosthesis that could take advantage of the additional capabilities of this new type of residual limb," Matthew J Carty, MD, one of the paper's authors, a surgeon in the Division of Plastic and Reconstructive Surgery and an MIT research scientist, said. "Collaboration was critical, as the design of the procedure informed the design of the robotic limb, and vice versa."

Initial Research Questions – Bionic Sensation (link to homeostasis)

Where is at?	• Can be hooked up to nerves to give basic sensations

Commented [TaKB5]: This table helped me focus my research and organize my thinking as I worked away on it.

	• Cutting edge = texture; already good work on force and pressure.
What did it depend on?	• Development in prosthetics has been the backbone of this – without this we would not be at this level of development and innovation. • Recently – can use to grip or lift
Ethical issues?	• Trying to make one better than a real hand?! • Blurring the line between human-machine interactions!
Costs?	• See articles above – this is the big limitation, but there is a race to change this – needs driving development.
Other fields?	• Bionic vision?? • One article above mentions how many fields this brings together!!
Benefits to humans?	• Renewed senses • Mitigation of the loses – feel more normal • Improving the relationship between mind and prosthesis (• Reducing the number of rejected prosthetic limbs
Environmental issues?	
Potential for future	• Eventually get to full sensing limbs to help grip and feel objects
Personal testimonies?	
Technology issues/development?	• Even in 2014 the gear was not small enough to be portable – but now it is! (new tech) • Miniaturization • Get the brain to control it! • Toward bionic human
How many amputees per year? – USA/Australia?	
Main cause of amputation?	
Main type of amputation?	

Check out:

Commented [TaKB6]: I kept a running list of things I wanted to check out more later if I came across stuff that looked good but didn't have time to get into at the moment.

Centre for Extreme Bionics (MIT)
Cleveland Clinic

Biology Concepts – Highly Relevant to Homeostasis Unit

Commented [TaKB7]: I found making this table useful as I did initial thinking and research – it helped me to see if there was enough biology concepts and where they were going to link in.

Stimulus-response model (p. 242)	- homeostasis involves responding to changes in external environment - detectable change = stimulus - respond to stimulus = stimulus response model *This is exactly what bionic sensation is trying to help with – so that patients can detect and respond using their own nervous system, which increases response, control, and fine motor skills (no longer have to use sight for everything with prosthetic) Key: - Sensory receptor - Effector (getting - Using nerve
Nervous system	- PNS and CNS - Neurons - Sensory vs motor neuron - Nerve fibres (p.250) – important in surgery and connecting to regenerating muscles to integrate body system KEY Proprioceptors!!!! - A sensory receptor that receives stimuli from within the body, especially one that responds to position and movement. - *this is important for bionic sensing, as this is one of things lacking with standard prosthetics – the person cannot tell where their limb is and the body cannot respond to it in order to move it. = slow, cumbersome, hinderance to fine movement and response to stimuli (text, pressure, etc) -
Muscle pairs	Agonist-antagonist muscle pairing (biceps and triceps) – that work together. When one contracts the other relaxes and stretches! Proprioceptors sense this and

	send messages to the brain about where the limb is and what it is doing.