Clone Robotics: a humanoid robot with biomimetic muscles and a water-powered "heart"

1. History of Clone Robotics

The Clone Robotics project formally started around 2021 in Poland, but its technical roots go deeper. Co-founder and CTO Lucas (Łukasz) Ko- zlik has been experimenting with improving McK- ibben-type artificial muscles and human skeletal biomechanics since 2014 (Clone Robotics: A company that can produce bionic robots similar to ...). In 2021, the company was officially founded (originally under the name *Automaton Robotics*) and focused on building inexpensive humanoids with as true to human anatomy as possible (This incredibly life-like robot hand can be made for just $2,800) (Watch this terrifying robotic torso spring into life
| Live Science). The first development milestone was the "Clone Hand", a robotic hand that the team has been working on for eight years and which was unveiled in its 18th version in early 2023 (This incredibly life-like robot hand can be made for just $2,800). This biomimetic hand contains artificial bones, ligaments and muscles and has 27 degrees of freedom of movement, mimicking the complexity of a human hand (This incredibly life-like robot hand can be made for just $2,800).

The development of the Clone Hand has attracted an initial investment of more than $640,000 (from Trevor Blackwell of Y Combinator, among others) and interest from research labs - 16 top labs have already pre-ordered a prototype hand for 2023 (This incredibly life-like robot hand can be made for just $2,800). In the same year, the company launched a crowdfunding campaign and started work on another body segment - a humanoid **torso** with 124 artificial muscles (This incredibly life-like robot hand can be made for just $2,800). In late 2024, Clone Robotics demonstrated a functional upper half of a humanoid dubbed the **Clone Torso**, including a spine, neck, two arms with hands, and a white "skin" (Watch this terrifying robotic torso spring into life| Live Science). A video showing this thoracic segment bursting to life with jerky movements has drawn much attention and comparisons to the *Westworld* series (Watch this terrifying robotic torso spring into life | Live Science).

At the beginning of 2025, the company unveiled the full prototype humanoid **Protoclone** - a headless figure suspended from a frame that realistically twitches its limbs thanks to more than 1,000 artificial muscles (Humanoid 'Protoclone' robot twitches into action while hanging from ceiling in viral video | Live Science). A short clip posted on the X network (Twitter) went viral (tens of millions of hits), causing a mixture of amazement and horror at its "liveliness" (Humanoid 'Protoclone' robot twitches into action while hanging from ceiling in viral video | Live Science). Subsequently, Clone Robotics announced the limited edition **Clone Alpha** - the first 279 units of the commercial humanoid to be reserved for interested parties. To this stage, however, the company has still not publicly demonstrated a fully integrated robot in independent walking or complex activities, and there is some skepticism until it demonstrates Alpha's capabilities in the real world (Meet Clone Alpha: A Humanoid Robot Built with Syn-

thetic Organs and Artificial Muscles) (Meet Clone Alpha: A Humanoid Robot Built with Synthetic Organs and Artificial Muscles).

2. "Muscle" and "heart" technology

Clone Robotics' core innovation is a **biomimetic muscle system** called *Myofiber*. These are artificial muscles inspired by McKibben-type pneumatic muscles that mimic the structure of human muscle tissue. Each such "muscle" takes the form of a flexible tube (mesh-like sheath) with an internal elastic sac. **The principle of function** is similar to that of a biological muscle: when fluid (or gas) is pumped into the inner sac, the sac expands laterally and the muscle contracts along its length due to the sheath - i.e. it performs a contraction similar to a muscle fibre. This design allows a significant force of contraction to be achieved with a relatively low weight of the muscle element. Clone Robotics reports that a single 3g Myofiber artificial muscle can exert a contraction force of around 1 kg and shorten by more than 30% in just 50 ms (Meet Clone Alpha: A Humanoid Robot Built with Synthetic Organs and Artificial Muscles), parameters comparable or better than real skeletal muscles. In addition, the muscles are made monolithically with "tendons" (gripping ends), eliminating weak points and increasing their durability. In proto-type tests, these muscles have lasted roughly **650,000 pulls** without damage (This incredibly life-like robot arm can be made for just $2,800).

The propulsion system of these muscles is a central pump - the robot's "artificial heart". Clone Alpha uses a **500W electric pump** that cycles fluid (distilled water or hydraulic fluid) through the robot's closed "vascular" circuit. The pump can deliver a flow rate of around 40 liters per minute and a pressure of around 100 psi (0.7 MPa), which is adequate for synchronous movement of all major muscle groups. This compact "heart" thus performs a similar role to a human heart - supplying the muscles with "blood" (in this case pressurised fluid) and them to do their work. A network of tubes (*blood vessels*) in the robot's body distribute the fluid, and valves regulate the direction and pressure in the individual muscle circuits.

(Watch this terrifying robotic torso spring into life| Live Science) **Fig. 1: The** upper half of the Clone Robotics humanoid with the rib and muscle fiber structure exposed. The white tubular formations are artificial Myofiber muscles, attached to a skeleton of polymer "bones" (ribs, limbs). In the middle of the chest, components of the pumping and valve system are visible, which function as the robot's "vascular" and "circulatory" system (Meet Clone Alpha: A Humanoid Robot Built with Synthetic Organs and Artificial Muscles) (Watch this terrifying robotic torso spring into life | Live Science). *This biomorphic design differs significantly from traditional robots with electric motors and gears - instead, it uses soft, fluid-powered muscles, much like a living organism* (Meet Clone Alpha: A Humanoid Robot Built with Synthetic Organs and Artificial Muscles).

The entire hydraulic system is designed to be **closed and water cooled**. Waste heat from the pump motor and muscle friction is dissipated by circulating . The company even mentions that the robot uses a principle similar to sweating - when

heating releases water to cool the system, stabilizing the internal temperature for long-term operation (Synthetic Human Features 1,000 Artificial Muscles, Sweat-Like Cooling System). The hydraulic circuit is powered by either an external source or a built-in battery. The earlier Torso prototype used a **battery-powered hydraulic system with a flexible water reservoir** that the robot carried inside its torso (Watch this terrifying robotic torso spring into life | Live Science). This allows operation without a hose attached, although so far with limited endurance (on the order of units of hours). Overall, the muscles, pump, hoses and valves form an integral *synthetic musculoskeletal and cardiovascular system* that is very close in concept to a biological body.

3. System performance parameters

Despite the use of soft elements, the Clone robot achieves impressive **performance parameters** comparable to a human. Each arm contains 37 artificial muscles and can exert enough gripping force to lift a **load** of around **7kg** (This incredibly life-like robot arm can be made for just $2,800) (approx. 15 pounds). As early as 2021, a prototype arm demonstrated lifting a 7kg barbell using water-powered muscles (Meet Clone Alpha: A Humanoid Robot Built with Synthetic Organs and Artificial Muscles), which confirmed the high force density of Myofiber technology. The entire Protoclone humanoid robot is equipped with over **1000 muscle fibers**, which (once development is complete) theoretically gives it the strength and mobility of all the major muscle groups of the human body. A key metric is the force-to-weight ratio - thanks to lightweight materials (carbon skeleton, polymer muscles), the robot achieves high **force-to-weight** efficiency. For example, a set of muscles in one finger weighs only a few hundred grams, but can carry loads on the order of kilograms.

The speed and responsiveness of the movement are also surprisingly good. Artificial muscles can contract by tens of percent of their length in ~50 milliseconds (Meet Clone Alpha: A Humanoid Robot Built with Synthetic Organs and Artificial Muscles), which corresponds to fast reflexive movement. Clone reports that the fingers of the hand can move at superhuman speeds (so-called *superhuman speeds* in demonstrations). The resulting limb movement is smooth, although early prototypes have so far been partially jerky due to imperfect pressure control (Watch this terrifying robotic torso spring into life| Live Science). The precision and subtlety of the movement is ensured by sensors - each muscle has proprioceptive pressure sensors so the robot can feel the force it is applying (Humanoid 'Protoclone' robot twitches into action while hanging from ceiling in viral video | Live Science). By combining 320 pressure sensors (in the muscles), 70 inertial units (to sense joint position) and 4 depth cameras in the head, the system gets **500+ sensory inputs** that constantly inform about the state of the body and the environment (Humanoid 'Protoclone' robot twitches into action while hanging from ceiling in viral video| Live Science). This allows for precise motion control and interaction with the environment.

Kinematics and range of motion: Clone Alpha has a complete anatomical skeleton with all the corresponding joints. Planned number of degrees of freedom (*DoF*)

is over **200 DoF** for the entire body. The upper half of the body alone (torso, arms, neck, fingers) includes 164 articulated joints (Meet Clone Alpha: A Humanoid Robot Built with Synthetic Organs and Artificial Muscles). Each arm and hand has around 26 degrees of freedom (shoulder 3, elbow 1, wrist ~2, fingers 20+ total) (Meet Clone Alpha: A Humanoid Robot Built with Synthetic Organs and Ar- tificial Muscles), so it can perform virtually all the movements of a human limb - shoulder rotation, elbow bending, hand gripping, etc. The joints have been designed to have a similar range to a human (e.g. elbow ~150°, knee ~130°, head rotation ~180°, etc.), with a flexible spine and flexible ankles for a natural gait. Thus, when fully staffed, the robot should have similar mobility to a human (206 bones and only fewer necessary adhesions are reported).

Energy and endurance: battery life is a big issue with such a powerful hydraulic drive. The Clone Alpha integrates a fairly powerful pump (500 W) and hundreds of valves, which means considerable power consumption. So far, competitors have reported rather hourly units of operation for similarly sized humanoids - e.g. China's humanoid China's humanoid robot SE01 has a battery for about **2 hours of operation** (robot stuns Nvidia and SenseTime with human-like walk). It can be expected that the first versions of Clone can operate independently **for 1-2 hours on a single charge**, depending on the load. Less strenuous activities (standing, slow walking) may increase the battery life, while intense activities (lifting heavy objects, fast running) will drain the battery faster. The robot is designed to drive itself to a docking station to recharge when the power drops. While lab demonstrations have often been conducted with a power supply or hose attached, the final product expected to be completely wireless - carrying batteries and a fluid reservoir in its torso (Watch this terrifying robotic torso spring into life| Live Science). However, for long-term operation (e.g., all-day work), it would be necessary to either significantly improve the capacity of the batteries or allow for battery changes during the day.

4. The uniqueness of the Clone Robotics concept

Many new projects are emerging in the humanoid robot market (Tesla **Op- timus**, Figure **01**, Apptronik **Apollo**, Agility **Digit**, etc.), but Clone Robotics' approach is **unique** in many ways. Most competitors rely on traditional actuators - electric motors in joints, servo drives and fixed mechanical gears. Clone, by contrast, has bet on **synthetic "organs"**: it has created artificial muscles, tendons and bones and fused them into a functional fluid-powered whole (Meet Clone Alpha: A Humanoid Robot Built with Synthetic Organs and Artificial Muscles). This biomorphic design is based on the premise that to achieve human dexterity and adaptive motor skills, it is best to mimic the human anatomy itself. Clone Alpha therefore has soft muscles instead of gears, and a network of tiny actuators around the body instead of a central motor. Such a system is **compliant** - it has a natural flexibility, absorbing shock and interaction much like living muscles. This gives it a potential advantage in working safely with humans and in using existing tools designed for the human hand.

Another unique feature is the **attempt at full anthropomorphy** - Clone has all 206

analogues of human bones and about 200 degrees of freedom, i.e. much finer movements than normal humanoids. The human hand, for example, is extremely complex and few robots can imitate it - although the London-based company Shadow Robot has developed a highly sophisticated robotic hand, it costs over $116,000 and uses conventional servo motors. The Clone Hand, by contrast, achieves similar dexterity with hydraulic muscles and a material cost of under $3,000 (This incredibly life-like robot hand can be made for just $2,800). **Affordability vs. performance** is thus a crucial difference - Clone has focused on affordable construction from easily processable materials (carbon composite, silicon, artificial fibers), which could allow it to produce humanoids significantly cheaper than the competition in the future (This incredibly life-like robot hand can be made for just $2,800).

The concept of Clone Robotics is currently unique. Historically, *artificial muscles* have been researched for a long time - from the rubber "Rubbertuators" of the Japanese company Bridgestone in 1980s to various soft robots in academia - but no other company has yet built a complete humanoid that works on these principles. Research in Japan and the US is probably the closest in the field of *soft robotics*, but most commercial humanoids (Tesla, Figure, Agility, Honda Asimo earlier) stick to solid mechanics. Clone thus created the world's first **bipedal musculo- loskeletal android**. The company itself compares it marketing-wise to *the Westworld* project (a realization of fiction), and the media mentions the "demons of sleep paralysis" or the "creepiness" of this approach. The difference from others, then, is also in how faithfully (and, for some, frighteningly) the robot resembles the real human body.

In terms of competition, Clone also differs **in its target focus**. Tesla's Optimus, for example, is presented as a simple robot for routine tasks, and Elon Musk is aiming for a price of around $20,000 apiece, while not needing full human actuation. The Boston Dynamics **Atlas**, on the other hand, is a dynamically balanced humanoid with hydraulic actuators, but it has no arms and serves mainly as a research platform for moving around in the field. Clone, on the other hand, aims at a **universal assistant** with human dexterity - it wants to cover the wide range of tasks that humans can perform today with a single design. That's an extremely challenging metric, but if achieved, such a robot could take on any job that **humans don't want to do** (which is, after all, the founders' motto) (This incredibly life-like robot hand can be made for just $2,800). This is the uniqueness of Clone Robotics - they took the risk of a complex solution with the belief that the result (i.e. a truly human-capable machine at a low cost) would revolutionize robotics.

5. Market position and impact on robotics

Clone Robotics enters the humanoid robot market in a specific position as an innovator with high potential impact. If their concept can be brought to fruition, it could significantly **impact the way robots are used** in industry and the home. The company is presenting its humanoids as AI-enabled learning devices that will help in the home. The Clone Alpha robot is designed as a **"home companion" and helper** for individuals and companies. In promotional

The materials state that he or she would be able to serve and store items, follow the user around the apartment, shake hands with guests, pour drinks, make sandwiches, clean laundry, vacuum floors, or handle dishes. Such versatility would make it a true **"robot servant"** for common household chores. If Clone worked reliably, it could transform household care in much the same way that a washing machine or dishwasher once did - a robot would take over the tedious and strenuous tasks, leaving time for humans to do more skilled work or rest.

In the industrial sector, Clone Robotics sees applications for its humanoids as **flexible workers** on production lines and in logistics. Thanks to their humanoid form, they could operate existing machines and use tools designed for human hands (Hand - Clone), without the need for expensive rebuilding of infrastructure. Co-author Dhanush R. mentions that Clone robots could replace human hands in assembling, packaging or moving objects in factories (Watch this terrifying robotic torso spring into life| Live Science). By being similar in size and strength to a human, they can fit into existing operations - fit through doors, reach shelves, carry boxes. In labor-scarce environments (e.g., night shifts, unpopular manual labor), such an **android worker** could be in high demand. The company explicitly states that it wants to deploy humanoids wherever human hands are needed, but humans are scarce (Watch this terrifying robotic torso spring into life | Live Science).

Another area is **services and care**. A humanoid that is able to interact with humans could work as a receptionist, a baggage porter in a hotel, a shop assistant or a caregiver. Clone can manipulate small objects, open doors, cook a simple meal or administer medication thanks to its fine motor skills. Combined with AI for speech and facial recognition, it could interact with customers or patients in a natural way. The potential for **medical rehab** through tele-operation was also mentioned - the patient would control the robot remotely and exercise their muscles, allowing rehabilitation without risk of injury to the patient (Watch this terrifying robotic torso spring into life | Live Science). Also, dangerous tasks such as decontamination in chemical plants, waste handling or firefighting could be taken over by humanoids, thus protecting human lives. For example, researchers at NVIDIA have suggested the use of humanoids in fighting California wildfires in difficult terrain.

In terms of **market position**, however, it must be said that Clone Robotics is in the prototype and limited series phase. The competition is not sleeping - Tesla is intensively developing its Optimus (it already has working prototypes) and other startups like **Figure AI** or **Engineered Arts** have also introduced humanoid robots. Clone differs from them in technology, but it will have to prove the reliability and safety of its solution to gain the trust of the market. If it succeeds, it **could be a paradigm shift**: showing that a humanoid can be genuinely useful and economic to operate. This could usher in a **new era of robotics**, where universal humanoids capable of learning and adapting to different tasks will take the place of specialised machines (arms in factories, service robots on wheels). Such a change could be as revolutionary as the advent of personal computers - robots would permeate

into many sectors and households, which would increase productivity but also raise social questions about employment and ethics. For now, Clone Alpha is being presented as a *domestic helper*, but in the founders' long-term vision, it represents a first step towards a **"Clone World"** where intelligent androids solve everyday problems.

6. Competition in China

China is one of the leaders in robotics development, so it is not surprising that projects similar to Clone Robotics are being born there. Although the Chinese company has not yet publicly presented a directly identical concept of biomimetic muscles, Chinese developers are keeping up or ahead in other aspects. The Shenzhen-based company **Engi- neered AI (EngineAI)** has recently attracted attention. The latter unveiled a hu- manoid robot**, SE01**, in October 2024, which impressed with a fluid, natural **gait on the street** - so realistic that some on social media considered it a CGI trick. SE01 is about the size of an adult human (170 cm, 55 kg) and is designed for industrial and home applications. However, it is powered by traditional electro-mechanical actuators (cla- sic motors in the joints) and controlled by an advanced algorithm trained using **reinforcement learning** in simulation. Its gait is therefore not the result of artificial muscles, but of superior motor control and balancing - yet it has earned SE01 the nickname
"the most human walking robot" on the Chinese internet. Moreover, EngineAI is backed by strong investors (SenseTime and others) and declares an **emphasis on low-cost mass-market solutions** for the Chinese market. Some of the SE01's specs are similar to Clone Alpha: it claims 32 degrees of freedom (less than Clone, meaning simpler hands), a lifespan of over 10 years, and a battery life of around **2 hours of** operation (China's humanoid robot stuns Nvidia and SenseTime with human-like walk). The SE01 thus presents significant competition in China's humanoid field, albeit technically going down a different path.

In addition to EngineAI, there are other humanoid projects in China. For example, **Robot Era**'s **STAR1** robot has made headlines as the "world's fastest humanoid" - using sneakers, it ran at ~8 mph (13 km/h) in a test in the Gobi Desert (Chi- nese scientists build fastest humanoid robot in the world - it can run at 8 mph
| Live Science). Here again it was a classic motor drive, targeting speed and outdoor endurance rather than biomimetics. Also well-known are the **Walker X** model from UBTech and Xiaomi's experimental **CyberOne** - both are a rainbow of servo-humanoids for walking and interaction, presented in 2021-2022. However, these pro- jects have not yet moved beyond the stage of demonstration prototypes and do not differ in performance from Western competitors.

Interestingly, **Chinese scientists are also intensively researching the artificial muscles themselves**. In November 2024, a team from the Chinese Academy of Sciences (CAS) announced a breakthrough in the field of **carbon-based artificial muscles**. They have developed a muscle made of a thin film called *hydrogenated graphdiyne*, inspired by the spiral structure of a butterfly's socket. This muscle can reversibly and rapidly deform when the carbon bonds are reconfigured, and can support up to 11 times its own weight. In addition, it works at temperatures around -25°C. Although this is still a laboratory prototype for microrobotics, it shows

the direction China is taking - the search for new materials for **powerful and durable artificial muscles**. It is therefore to be expected that Chinese hu- manoids with biomimetic muscles, using for example electroactive polymers or carbon composites for contraction, could emerge in the future.

Overall, **Clone Robotics does not have a direct copy in China**, faces indirect competition there on multiple fronts: advanced servo-humanoids (En- gineAI, Xiaomi), extremely fast runners (Robot Era), and cutting-edge artificial muscle research (CAS). The Chinese humanoid market is also very competitive, and new domestic projects are supported by large investors and the government. Clone will need to leverage its unique soft muscle know-how to stay ahead and look for collaborations or markets in Asia. It is possible that, if Clone Alpha proves successful, Chinese companies will also be interested in licensing the technology and producing it in volume - this could accelerate the spread of biomimetic robots globally.

7. Motor vs. AI: mechanics and intelligence

The Clone Robotics project is often presented through its exceptional mechanics (muscles, joints, skeleton), but an equally important part is the **artificial intelligence and control system**. The goal is not just to create a moving puppet, but **an autonomous robot** that can make decisions and learn. Clone Alpha has a powerful computer (called an *edge GPU* - probably an NVIDIA module) and software called *Cybernet*, which is an internally developed visuomotor model for motion control (Meet Clone Alpha: A Humanoid Robot Built with Synthetic Organs and Artificial Muscles). The Cybernet can be seen as the brain of the robot - it takes care of processing sensory data (cameras, sensors in the muscles) and generating motor commands for the muscles. According to the company, it is a *foundation model* for visual-motor tasks (Meet Clone Alpha: A Humanoid Robot Built with Synthetic Organs and Artificial Muscles), suggesting the use of modern AI techniques (deep learning, neural networks) trained on large amounts of motion data. It is therefore likely Clone uses **machine learning** to teach robots basic skills - similar to the way AI models for robotics are trained at Boston Dynamics or at China's EngineAI (there specifically using reinforcement learning in simulation).

One of the key elements of Clone's software architecture is the **Telekinesis platform** - a training system which the robot learns skills by observation and imitation. The user or instructor can manually guide the robot or show it actions, and the robot brain extracts *movement patterns* from this. For example, for manual manipulation, a mode has been developed where a human wears a control glove and the Clone robotic arm copies it exactly (teleoperation). This allows the robot to learn, for example, the correct grip for grasping a glass without programming from scratch. According to the founders' statement, in 2022 they were already able to *reteach* the robot *a new task in a few minutes* by watching a human demonstrator. The target metric is **one-shot learning** - that the robot would understand a new task from a single demonstration. In the Alpha version, such an adaptive brain will probably still be in its early , but the concept

is clear: Clone is meant to be a teachable assistant that the user *trains* to his specific needs.

In addition to motor skills, Clone focuses on **natural interaction**. Thanks to advances in language processing (LLM as GPT, etc.), it is not a problem for the robot to understand instructions in ordinary speech. Clone Alpha is equipped with a **natural language interface** so that it can *be coaxed in English or English in ordinary sentences*. The large language models allow the robot to understand the context of the task and have a dialogue - e.g., you can tell Clone "Please pass me the glass from the table and pour the water" and it should perform a sequence of steps and possibly ask questions if it doesn't understand something. This **social aspect of AI** is developed internally (the company has its own robotic intelligence team, see job postings for positions like *Research Scientist - Robot Learning*). However, it's likely that Clone isn't building everything from scratch - rather, it's integrating existing AI services (speech recognition, generative models) into its system and training its own models specialized for motor and multimodal perception. It was mentioned on the site that since the advent of large LLMs, it is possible to talk to computers naturally, and Clone intends to take advantage of this.

In short, **Clone Robotics is not just about mechanics**. They consider intelligence to be an equally important component. They combine **motor and AI** into one product - muscles and sensors make the body, Cybernet and algorithms make the mind. In the future, they plan for their androids **to improve themselves**, share learned models (e.g. a cloud-based skills database), and be able to function in dynamic environments. The question was whether they would develop such complex AI themselves or outsource it. From indications so far, it seems that they are developing basic *brains* in-house (at least low-level motion control and sensor integration for sure). On the other hand, for general AI (conversations, planning) they will probably use available platforms - for example, NVIDIA Jetson module with pre-trained networks, cloud AI services, etc. After all, Clone is in strong contact with the AI community - investors and advisors from Y Combinator and similar institutions indicate that they will build on the latest open-source AI tools. So we can expect a hybrid approach: **internal dedicated AI** for muscle control and motion learning, **external AI** for general communication and vision (unless it's efficient to develop your own). Either way, Clone's vision is clear: *a mechanical body inspired by biology brought to life by advanced intelligence* to make the robot truly autonomous and useful.

8. The realism of mass production

One of the most common questions about Clone Robotics is **whether this technology can be mass-produced on a large scale** and at a reasonable price. The current status is that the company has announced a limited **run of 279 Clone Alpha units**. This suggests that production so far is more of a small batch to one-off, suitable for early adopters and development sites. Each robot is very complex - it contains hundreds of muscles and sensors, dozens of pumps/valves, and its own skeleton. It is still time consuming to build and debug such a machine. On the other hand, Clone has tried from the beginning to tailor the design to **low-cost components**. Bones

are inexpensively molded from carbon fiber (This incredibly life-like robot hand can be made for just $2,800), silicone tubing muscles and plastic braid,
a "skin" of soft polymer. Thus, the material is not extremely rare or expensive. The company itself estimates the **BOM (bill of materials) for the hand** to be under $2,800 (This incredibly life-like robot hand can be made for just $2,800). For a full body, this would obviously increase many times over (estimates of raw materials could be in the tens of thousands of dollars), but if production ramped up in volume, unit prices would drop further.

The main challenge of mass-producing Clone will be the **complexity of assembly and calibration**. Compared to robots with pairs of motors, we have *an "organ" system*: a "vascular" network needs to be installed, fluid needs to be filled and vented, pressures need to be fine-tuned, and hundreds of components need to be made to work in perfect harmony. In early proto- types, leaks, hose wear, or valve failures all occurred - all of which must be resolved by robust engineering for the final product. Clone says that to prevent tendon failure, it manufactures the muscles as a single unit with tendon attachments. He will have to standardize other parts similarly. Realistically, the first 279 pieces are more likely to be **hand-assembled** or require a lot of human labor. Only subsequently, if demand and functionality are proven, would there be a phase of investment in automated production - moulds for injection moulding parts, assembly lines, etc.

Moreover, skeptics point out that **integrating all these systems together is extremely difficult**, and until Clone shows a fully functional humanoid, caution is in order (Meet Clone Alpha: A Humanoid Robot Built with Syn- thetic Organs and Artificial Muscles). It is possible that some parameters will be limited in real life (e.g. the robot will not be able to work continuously for long periods of time due to heating or water consumption). These practical limits could prevent mass deployment.

On the other hand, if Clone actually adheres to the *design for manufacture* vision, it could have an *edge* over the competition. Tesla's Optimus does use oscillated motors and Tesla has the know-how from mass-produced cars, but Optimus is still rather simple and its capabilities limited. A clone with complex mechanics may be harder to produce, but the result could take the place of multiple functions at once (i.e. one humanoid instead of several specialized machines). When comparing costs, it has been argued that **if a humanoid could be produced at a cost of around $20,000**, it could fundamentally change the job market. Clone hasn't disclosed the price yet, but suggests it's aiming as low as possible - just the choice of materials and the fact that its design doesn't need gears and high-tech sensors pushes the price down (This incredibly life-like robot hand can be made for just $2,800).

From the experts' point of view, **scaling** will **be a critical test**. The transition from proto-types (TRL 6-7) to industrial production (TRL 8-9) is often a stumbling block in robotics. Clone Robotics may need a partner with manufacturing capacity or a large investment to produce hundreds to thousands of units per year. Whether a humanoid with hundreds of hydraulic muscles can be assembled as quickly as a car is still unanswered. But it is encouraging that none of the used

technology is not exotic: carbon composites, 3D printing, silicone moulds, mini pumps - the industry already knows all this. The idea is to **simplify and modularise integration**. Perhaps Clone will go the way of modular design (e.g. limbs as interchangeable modules), which would make service and production easier.

Realistically, we can expect Clone Alphas to be rare and precious for the first few years (2025-2027). But if they prove their usefulness, a second phase could occur with outside investment in factories and **acceleration of production**. At that point, Clone Robotics could begin to compete with even traditional robotics companies in volume - and then it would become apparent whether their concept would hold up economically. In summary: **the technology is mass-producible in principle, but will require significant engineering effort to make production cheaper and easier**. Success is not guaranteed, but the potential reward (dominance in the humanoid market) is huge, so the effort will definitely be made.

9. Application opportunities and future predictions

The use of humanoid robots like Clone is reflected in many areas and in different time horizons. **In the short term (now up to ~5 years)**, deployment can be expected especially in **R&D environments and with enthusiasts**. The first 279 units of Clone Alpha will likely head to research labs, technology companies, and more affluent early-adopter users. They will use them for further development - tuning, testing in specific scenarios, or as a showpiece (e.g. in futuristic hotels or as an attraction). Just as the first personal computers or cars were initially rather rare, humanoid robots will initially be rare. Clone Robotics reports that unusual entities have been among those interested in their early prototypes, such as **bakeries or lawn maintenance companies** looking to experiment with how a robot could help them (e.g., lift heavy bags of flour, mow grass, etc.). In this horizon, it will be more about validating the concept in practice.

In the medium term (5-10 years), if the technology matures, there could be wider **commercial deployment**. Humanoids could appear in nursing homes as mobility and care assistants, in hospitals for material logistics, in airports for handling suitcases, in warehouses for picking up goods. Imagine, for example, a postal hub where people work today sorting parcels - a humanoid could go in and pick parcels off the conveyor belt and put them in cages, a monotonous job that a sufficiently dexterous robot can do. Or in a hotel, Clone could take on the role of bellman and maintenance man, fixing dripping taps and carrying out luggage. Safety will be an important factor - the robot will only be allowed among humans if it can be shown not to endanger them. This means certifications and standards (similar to how autonomous cars are being addressed today). With soft muscles and sensitive sensors, Clone has an advantage in this regard because it is "soft" and potentially contact sensitive.

In the long term (10 years or more), we can speculate that if humanoid technology takes hold, **many industries** will be **transformed**. Humanoid

robots could become a common part of the household, like a dishwasher or a robotic vacuum cleaner today. They could care for the elderly 24/7, assisting them with hygiene, cooking, companionship - significantly easing the pressure on the care sector in ageing populations. In industry, they could fill gaps in the labour market where there is a shortage of physical labour, or take on jobs that are too dangerous or harmful for humans (mine work, handling chemicals, firefighting, etc.). Combined with advanced AI, they could also function as **teaching assistants** (home tutors), **companions to** beings, or even artificial **athletes or entertainers** (e.g. in parks like Westworld, as often mentioned in connection with Clone).

Estimating **when (or if) humanoids like Clone will become a normal part of life** depends on many factors. Technologically, it is realistic to have prototypes capable of basic tasks within 5 years - we can already partially see that. However, achieving reliability, cost and social acceptance may take another decade. Some experts say a truly universal, fully autonomous hu- manoid is **10-15 years away**, others are more optimistic. Clone's founders believe that "it won't be long before a robotic servant can handle all household chores," suggesting a horizon of perhaps <10 years. It is possible that we will see a gradual emergence - first robots helping humans (which is less of a), then gradually more autonomous units. Much also depends on price and business model: if a humanoid could be rented for a few hundred dollars a month, for example, companies would be to jump in. Agility Robotics already offers its two-legged robot Digit as a form of "robotics as a service". Clone could opt for a similar model, where users pay not a one-time tens of thousands of dollars, but a monthly fee for the robot's service. This would accelerate wider adoption.

Overall, the **Clone Robotics concept has the potential to change robotics**, but the road to *everyday use* is still long. If we were to make a prediction: in the second half of this century we will see more test implementations of humanoids in real-world operations (warehouses, hospitals, home pi- loti). During the 1930s, there may be a tipping point where costs come down so much that companies start buying humanoids instead of humans in larger numbers, and wealthier households buy a "robot butler" as a luxury item. A truly mass deployment in ordinary households could happen around 2040, but only if all the technical and ethical problems are solved. It is also possible that simpler variants - e.g. semi-humanoids (just a torso on a wheeled chassis) or specialised two-handed robots in the home - will take hold, leaving full-fledged bipedal humanoids for the most complex tasks. It will all depend on the **price/performance** ratio and how much society accepts machines alongside humans. In any case, Clone Robotics has brought this vision closer to reality, and the coming years will show whether we will indeed have *clones* at our side, doing our will, or whether we will be left with a few fascinating but marginal demonstrations.

10. Price and availability

To be fair, **the price of the Clone Alpha humanoid for end users has not yet been announced**, but it certainly won't be a cheap affair. The fact that this is a limited edition of hundreds of units suggests that the company is targeting research and industrial buyers rather than the general household. Estimates vary, but rival Tesla Optimus, for example, is targeting a price of around *$20,000 per unit*. Clone Robotics is a smaller company without a mass production base, so it's likely that the first Alpha versions will easily cost on **the order of tens of thousands of dollars**, if not more. Some sources say it "won't be cheap" (Synthetic Human Features 1,000 Artificial Muscles, Sweat-Like Cooling System). It is possible that the company will adopt a strategy of not publicly stating the exact price and negotiating it individually with each interested party (e.g., through pre-orders and partnerships).

To give you an idea, we can compare the sub-components: the aforementioned **Clone Hand** has a material cost of under $2,800 (This incredibly life-like robot hand can be made for just $2,800), but that doesn't include labor and margin. Shadow Robot is selling its high-end dextrose hand for ~$100,000. Clone would like to break even with a price an order of magnitude lower, which he hinted at for the hand, but it's more complicated for the whole robot. In addition to the arms, there are the legs, the torso, the head, the electronics - all of which multiply the price. If we roughly estimate that the materials for a single humanoid will cost, say, $30k and the labor another tens of , the final price tag could be somewhere between **$70k and $150k (1.5 to .5 million CZK)** apiece at this early stage. That's an amount that the average household will definitely not buy a robot for. The target audience is labs (which have grants) or companies that see the return on investment in possible future profits, or simply wealthy technology enthusiasts.

In the future, Clone has the ambition to reduce the price dramatically. If it could be mass produced (see previous point), it could theoretically go down to tens of thousands in price even for end users. The authors often mention the analogy with PCs or smartphones - these also started out extremely expensive and are now affordable. So in the outlook (5-10 years from now) a home humanoid could cost similar to a mid-range car, maybe **$20-30k**. It would be a luxury, but not unattainable. Elon Musk has even said that producing a humanoid may be cheaper than a car, because it doesn't need such a robust design for high speeds or crash tests. If that true, a robot could cost as little as $15,000. Clone Robotics would have to simplify the design (perhaps modular variants with fewer DOF for cheaper models) and ramp up mass production, but it's not out of the question.

In terms **of availability**, the first Clone Alpha units should head to customers perhaps in late 2025 or during 2026 (the company started pre-orders in January 2025). However, the product won't be available to mainstream consumers in the next few years - even if you have the money, it's officially targeting a limited group. It is possible that after the Alpha series sells out, Clone will prepare an improved series (Beta or another designation) in larger numbers, and gradually expand the range of customers. But it will be more like a decade before a humanoid can be bought as easily as a washing machine.

Another aspect of price is **operation and maintenance**. To the price of the machine itself you have to add the cost of electricity (a 500W pump at hourly operation is not negligible, about 0.5 kWh per hour, which at 8h per day makes ~4 kWh - at today's prices of a few tens of crowns, it's not so bad). Worse may be the cost of servicing - replacing worn parts, seals, batteries, etc. Initially, these services will be handled directly by Clone Robotics engineers or trained partners, which will be expensive. In the future, a service network would have to be built up, similar to that for cars. All this translates into the *TCO (total cost of ownership)* of such a humanoid. So for households, it is not just about the purchase price, but also about having "another household member" to care for (albeit differently than a living one).

In summary: **Clone is not yet available to ordinary consumers and the price is in the clouds for them**. But as technology advances and competition spreads, prices will come down. In 10 years, the humanoid market may resemble today's car market - basic models available for the middle class, high-end models costing hundreds of thousands of dollars for special purposes. Clone Robotics, with its emphasis on inexpensive materials and performance, could be one of those pushing prices down. Just the fact that one of their missions is a *low-cost humanoid for every home* suggests that they don't want to settle for the luxury segment, but are aiming for the masses - gradually, of course.

11. Criticism and controversy

The Clone Robotics technology is arousing not only enthusiasm but also **critical responses and concerns**. One of the most obvious is the **public reaction to the visuals of the prototypes** - social networks have been filled with comments like "this is my nightmare demon" or insinuations that *Westworld* wasn't actually fiction. The Protoclone, in the form of a white, faceless man twitching on a rope, was found creepy by many and evoked the **Uncanny Valley effect** (an impression of disturbing inhumanity). While the company can humanise the design of the final product (e.g. by fitting a more friendly head or covers), the question remains how people will react to **humanoid machines in everyday life**. Controversy may arise when such a robot appears in public - it may arouse fear, disgust or, on the contrary, exaggerated expectations. This is more the social side of things, which humanoid manufacturers will have to address sensitively (e.g. by choosing a *not-so-realistic* appearance, so as not to appear as "robot doubles" of humans - Clone so far chooses a stylized face without details, which may be intentionally less scary than hyper-realistic androids).

From a technical point of view, a common criticism is **the complexity and unnecessary difficulty of the humanoid approach**. Some roboticists argue that building robots to be human-like is inefficient - that it is better to develop simpler, specialized robots for each task. After all, a humanoid is a huge engineering challenge (so many degrees of freedom, need for balance, full-body coordination). Instead, they say, robotic arms mounted on a mobile platform in the home, or handling arms in a factory, which are simpler and already reliable, would suffice. Clone Robotics goes against this current, arguing that *the world is tailored for the human form* and only a humanoid can serve it universally. Critics, however, argue that it does, but at the cost of enormous complexity. This debate is not yet

Decided - Clone will have to prove that his approach is practically worthwhile. If it turns out that humanoid maintenance is too expensive or breaks down frequently, the skeptics will get the upper hand. Success, on the other hand, would shut them up.

Another potential controversy is **safety and ethics**. A humanoid with human strength raises questions: what if there is an accident and the robot injures the human? What about cybersecurity - could it be hacked and misused as a weapon, for example? Such concerns are real and developers need to take them into account. Clone relies in part on its soft construction (artificial muscle is more pliable than a metal servo) to reduce the risk of injury. In addition, feedback from sensors will allow the actuator to quickly detect a collision and release the thrust (called *back-drivability* - the property that the actuator can be easily pushed back, which their hydraulic muscles have to some extent). However, the public will certainly be watching for incidents - all it would take is one instance of a robot hurting someone (perhaps squeezing too hard on a hand), and controversy would ensue. Regulations in this area have yet to emerge.

Reliability and endurance is another critical point. Opponents point out that the water system is prone to leaks and maintenance - tubing can burst, liquid can become contaminated with algae, etc. Clone will have to prove that their engineering can handle these problems (perhaps by using special materials, filtering the fluid, redundant circuits, etc.). Also, batteries - 2 hours of operation is not enough if the robot were to work all day. So the criticism is directed to **practical limits**: robots may be able to demonstrate a few stunts, but in real deployment they will fail due to discharge or malfunction. The company tries to allay these concerns by referring to durability (claiming that the design is made with durability and robustness in mind), but until we see deployed units in use for, say, a year, a question mark remains.

Related to this is **skepticism about the integration of AI and real-world capabilities**. Clone has not yet demonstrated a fully walking robot or complex manipulation in an uncontrolled environment (Meet Clone Alpha: A Humanoid Robot Built with Syn- thetic Organs and Artificial Muscles). Some experts are therefore reserved - until they see the robot in action, they take the statement with a grain of salt. The history of robotics is littered with ambitious projects that promised "revolutionary" humanoids and ultimately failed (e.g., Honda's Asimo was a technological gem, but it never found a commercial application and development was abandoned). Clone is getting attention so far, but it also has to manage **expectations vs. reality**. If the first units delivered don't live up to the promised performance, there could be a wave of disappointment and negative reviews, which is always a risk for a startup.

The last chapter of the controversy is the **social impact**. Although Clone Robotics does not directly address this, it will be heard in society: If humanoids replace humans at work, what will that do to employment? Is there a risk of increased unemployment, a widening of inequalities (rich robot owners vs. unemployed workers)? These questions are yet to be addressed. They may provoke resistance from trade unions against the introduction of robots, or, conversely, pressure on governments to regulate and tax the deployment of robots. Equally, the ethical aspects - is it okay to have a robot servant, will humans treat it decently, or will it encourage mistreatment that could

carry over into interpersonal relationships? These **socio-ethical controversies** transcend the specific Clone technology, but Clone Robotics as a pioneer in humanoids will have to co-create them.

In short, the main criticisms of Clone Robotics target **(a) the** extreme complexity and question of the usefulness of such a human-conceived robot, **(b) the** as yet unproven reliability and integration, **(c)** concerns about safety and societal impacts, and **(d) the** "creepiness" factor. Every revolutionary technology goes through this - similarly, people used to fear the first cars (there were accidents), or computers (fear of losing their jobs). It's very likely that as Clone or robots like it become more common, society will get used to them and find a modus operandi to live with them. For now, however, Clone Robotics is at the point where it has yet to deliver tangible proof to the skeptics - a functional, useful, and safe humanoid in a real-world environment. Until then, criticism and controversy will be a natural part of the discourse around this technology.

(Humanoid 'Protoclone' robot twitches into action while hanging from ceiling in viral video | Live Science) **Fig. 2:** A prototype of Clone Robotics' full-scale humanoid robot **Protoclone** in action. The robot's body is suspended for balance and it gradually activates its muscles - we can see the taut muscle cords on its arms, legs and torso. The black head section hides the cameras (eyes) and computer. This footage, released in January 2025, sparked a mixture of amazement at the realistic movements and fear of a "nightmare coming to life before our eyes" on the internet (Humanoid 'Protoclone' robot twitches into action while hanging from ceiling in viral video| Live Sci- ence). *Clone Robotics has thus drawn attention to itself, but it must also face the fears that its almost horror-like humanoid has raised.*

12. Conclusion and evaluation

Clone Robotics brings a bold and innovative concept to the world of robotics - using *artificial muscles* instead of traditional motors and *synthetic bones and tendons* instead of metal frames. The history of the project shows a gradual progression from a robotic arm to a whole humanoid, driven by a passion and vision to mimic the human body and abilities. Technologically, it is a cutting-edge demonstration of biomimetics: a hydraulic "musculo-vascular" system powered by a powerful pump that gives the robot human-like strength, speed and finesse of movement. The performance parameters suggest that the robot can compete with humans in terms of manipulation (lifting ten-pound objects, moving its limbs very quickly), albeit limited in time for the time being due to energy requirements. Clone Robotics thus profiles itself as unique - at a time when others are building rather simple humanoids, they have created an anatomically full-fledged *android*.

Market-wise, their approach has the potential to fill gaps where human hands are needed but not enough - from factories to services to households. If robots could be produced cheaply and in large numbers, they could truly **revolutionise work** in a similar way to computers or the internet. However, competition is not sleeping, especially in China we are seeing other paths to the same goal (humanoids with motors and advanced AI). It will be fascinating to see if *the soft biomimetics of Clone* or the *hard mechatronics of Tesla/EngineAI* will come to fruition - or if both will eventually converge somewhere in the middle.

AI is also an integral part of Clone - they realize that without a "brain" the best body is useless. That's why they're investing in proprietary learning algorithms and integrating the latest AI models for perception and decision-making. This makes Clone an interdisciplinary project at the intersection of robotics, artificial intelligence, biomechanics and systems engineering. The risks are many: from the technical (reliability of hydraulics) to the social (public acceptance of humanoids). Critical voices warn against exaggerated expectations - it may turn out that simpler robots would have been enough. But it's only through bold experiments like Clone Robotics that boundaries are pushed. Even if we may not ultimately need a robot with 206 bones, insights from this project could spawn new hybrid designs (such as combining artificial muscles and motors) or improve prosthetic devices and rehabilitation robots.

Clone Robotics can therefore be seen as a **pioneer of a new era of robots** that are more like us humans - physically and perhaps once intellectually. The article summarizes the history from the first muscle fibers to the first steps of the whole robot, explains the workings of the water-powered "muscle and heart", discusses performance and limitations, compares uniqueness with competitors, looks into the Chinese scene, discusses the symbiosis of mechanics and AI, and reflects on manufacturing, the future, cost, and controversy. It remains to add that this whole story is still being written - 2025 may be a turning point in that humanoid robots are no longer just science fiction on paper, but are actually being born in workshops and heading out into the world. Clone Robotics is one of the drivers of this trend. If we're going to have a robotic helper opening doors for us at home in a few years, there's a decent chance it's going to be thanks to the technologies being developed in their lab right now.

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