

The case against human hands - from first principles

Notes from a chat with Claude, October 3–4, 2026.

Question: Explain and expand the "Case Against Human Hands" summary: break it down to first principles, irreducible axioms and irrefutable constraints, then reason up using only logic.

I'll build this from the ground up. First come the facts that can't be argued away, then what logically follows from them, and finally a check of Kyle's conclusion against the result. Numbers used only for illustration are labeled as such.

1. Axioms: what can't be argued away

Contact

1. **Manipulation means pushing on objects through contact.** Every grasp, twist and lift is force passed through a surface.
2. **Non-living materials don't heal.**
 - Surfaces that touch under load wear away. Wear grows with load $\times$ sliding distance and falls with hardness (Archard's law).
 - Parts bent repeatedly under real load fatigue: each cycle uses up part of a finite life.
 - Damage only accumulates.
3. **Grip is limited by friction.** A contact can push sideways at most μ (the friction coefficient) times as hard as it presses. The allowed push directions form a **friction cone** around the surface's perpendicular, with half-angle $\arctan \mu$:
 - about 45° for grippy rubber ($\mu \approx 1$);
 - about 17° for hard plastic ($\mu \approx 0.3$).

High friction and contact that molds to the object both come from soft materials. Soft means low hardness, so by axiom 2 the grippiest surfaces wear fastest.

Actuators and structure

4. **Motors get worse as they shrink.** For electric motors of the same shape, limited by heat, continuous torque scales with size^3 . The power needed for a given torque scales with $1/\text{size}^5$. Halve a motor's size and you get about 1/11 the torque, or need about 32 $\times$ the power for the same torque.
5. **Weight at the end of a lever costs every joint behind it.** Torque needed = mass $\times$ gravity $\times$ distance, and resistance to rotation grows with distance².

Probability

6. **A system that needs all its parts fails at the sum of their failure rates.** Twelve similar parts fail twelve times as often as one.

Manufacturing

7. **Volume cuts labor, overhead and margin, not parts.** A mechanism's cost floor is set by its part count, materials, tolerances and assembly time.

Information

8. **Light travels in straight lines.** A camera sees shape without touching anything, but no camera outside a closed grasp can see the contact patch inside it. Force and slip must be measured at the contact, measured at the motor, or inferred.
9. **A learned policy needs data in its own body's action space.** That data's cost depends on how cheaply people can produce it for that body.

Tasks

10. **Dexterity has to come from somewhere.** A task needs a certain number of independently controllable motions; placing an object at any position and angle needs six. They can come from fingers, arms, the environment (pushing against a table, gravity) or tools, but they must come from one of these.

Biology (needed to judge his comparison)

- **B1.** Living tissue repairs itself; the outer skin renews roughly monthly.
- **B2.** Every gram of body has to be fed.
- **B3.** Evolution modifies inherited body plans rather than designing from scratch. Every land vertebrate has four limbs because its ancestors did.

2. What follows

D1. The contact surface must either heal or be a consumable (from 2 and 3). Wear concentrates where contact happens. Biology regenerates it; a machine must make it cheap and quick to replace.

- Example: ETH's ORCA hand reported its first tactile skin wearing out after 2,000–4,000 cycles.
 - At 60 grasps an hour for 16 hours a day, that's a new skin every 2–4 days, or 90–180 a year per hand.
 - At 10 minutes per swap, that's 15–30 hours of downtime a year per hand.
 - That's tolerable only if swaps are fast and cheap.
- This rule doesn't single out grippers. A hand with snap-on fingertip covers follows it too.

D2. Grip versus durability can't be engineered away (from 2 and 3). Grippier means softer, and softer means faster wear. Skin escapes the trade-off only by healing (B1); machines pay for it in consumables.

D3. Fingers are too small to hold strong motors (from 4).

- Pressing 10 N with a 5 cm finger needs 0.5 N·m at the knuckle. A finger-sized motor gives a few thousandths of a newton-metre, about 1% of that. That leaves two options:
 - **Gear it about 100:1 inside the finger.** That means many tiny, highly stressed gear teeth, plus friction and play. The finger also stops being *back-drivable*: pushing on it no longer turns the motor, so the motor can't feel the push.

- **Put the motors in the forearm and pull tendons through the wrist.** Those cables flex every cycle, so they fatigue, and they stretch, so they need re-tensioning.
- Biology faced the same space problem and chose tendons. A finger has room for very little muscle, while grip force is set by the task. So most finger strength comes from forearm muscles whose nine flexor tendons run through the carpal tunnel.
- Tendons aren't a biological habit to avoid copying; the size problem forces them. The difference is maintenance: biological tendons sit in lubricated sheaths and get repaired, while ORCA's tendons need periodic tensioning.
- A parallel gripper has one motor, which can be big with mild gearing.

D4. Failure rate grows with the number of moving parts (from 6). Illustration with assumed numbers:

- Each finger actuator fails once per 5,000 hours; each tendon path once per 10,000 hours.
- A 12-actuator hand: $12/5,000 + 12/10,000$ failures per hour, so one failure every ~280 hours. Two hands fail every ~140 hours, about every 9 days at 16 hours a day.
- A one-motor gripper of the same quality fails every 5,000 hours, about every 10 months.
- To match the gripper, each hand part would need to be ~18× more reliable, and reliability costs money.

D5. Weight at the hand costs payload everywhere (from 5). A 1 kg hand on a 0.6 m arm uses torque that could have lifted a 1 kg object. That pushes motors back toward the forearm, which leads back to tendons (D3).

D6. Machines can sense contact away from the contact (from 8, 4 and D3). There are three ways to know what a grasp is doing:

- **Skin:** measures directly, but wears out (D1) and needs many wires across the wrist.
- **Motor current:** current is proportional to torque, but only readable through low-friction, lightly geared transmissions.
- **Cameras:** see shape and slip after the fact, and are blind inside the grasp. That includes wrist cameras.

A one-motor gripper with mild gearing can feel its grip force through motor current, so it senses contact where the hardware is big and durable. A finger geared 100:1 mostly can't (D3), which pushes dexterous hands toward skins. This is the strongest first-principles support for Kyle's "wrist cameras and cheap tips."

D7. Volume will make hands cheap to buy, not cheap to own (from 7).

- **Hand floor** $\approx$ motors $\times$ (motor + gearing + sensor) + frame + electronics. Hobby-class servos cost about \$15–40, so a 6–12-motor hand has a parts floor in the low hundreds of dollars, not 5,000. *Linkerbot's* 560 hand shows prices heading there.
- **Arm floor:** 6–7 larger motors at 100–300 each plus structure and in the low thousands, as *YAM* (2,999) and *PiPER* (\$1,999) show.
- **So at volume, a simple hand may cost less than the extra arm Kyle proposes.** His own watch and drive data show price declines of 87–99.5%, which supports scale. Today's \$5,000 hands are low-volume retail prices, not a floor.
- **What volume can't fix is D1–D4.** Wear, fatigue and failure counts are physics and probability. The lasting version of his argument is about cost of ownership, not purchase price.

D8. You can't avoid needing dexterity, only choose where to pay for it (from 10).

- **Fingers:** fast and compact; paid for in reliability (D3–D4).
- **More arms:** objects handed between arms; paid for in space, weight, collision planning and data (D10).
- **The environment:** set the object down and re-grasp, push it against a surface, let gravity pivot it ("extrinsic dexterity"); paid for in time and control skill.
- **Tools:** robot-specific end effectors and tool changers; paid for in changeover time, and only possible where you control the setting.

Two opposing pads can hold almost any rigid object that has two roughly facing surfaces, and soft pads also resist twisting. That is why grippers cover "most tasks." What two pads can't do is turn the object inside the grasp, or press a trigger while holding the handle. Those motions must come from one of the other sources.

D9. Human tools assume human hands (from 10). Handles, triggers, scissor rings and buttons are interfaces built for fingers. Either the robot adapts to the tool (fingers), or the tool adapts to the robot (robot-specific tools and fixtures). Adapting tools is cheap in a factory you control and expensive in homes you don't.

D10. Human data fits human-like bodies best (from 9).

- **Gripper:** loses finger detail but maps cleanly. UMI even uses the gripper itself as the demonstration device.
- **Hand:** keeps finger motion but not forces or friction, because skin and robot pads differ (axiom 3).
- **Third arm:** has no human counterpart. No video shows it, and teleoperating it needs a second operator.

D11. Biology's choice proves nothing either way (from B1–B3).

- The hand is a local optimum under biology's constraints:
 - Self-repair makes soft, sensor-dense skin viable: about 17,000 touch receptors on the palm side of one hand.
 - Energy cost punishes extra limbs and extra brain.
 - Ancestry fixed four limbs long before hands existed.
- Kyle is right that this doesn't argue *for* robot hands, but by the same logic it doesn't argue against them. Only the robot's own constraints decide.
- One refinement: biology put touch in the fingertips exactly where the eyes are blind (axiom 8). Wrist cameras share that blind spot, so they replace touch only when paired with motor-current sensing (D6).

3. Reasoning up: the three designs

	Two hands	Two grippers	Three grippers
Internal wear parts	many	one motor each	one motor each
Failures (D4)	frequent	rare	rare
Contact sensing (D6)	skins	motor + camera	motor + camera
Turning objects in the grasp (D8)	yes	set down and re-grasp	hand between arms
Finger-operated tools (D9)	yes	no	no

	Two hands	Two grippers	Three grippers
Fit to human data (D10)	best	good, coarse	none for arm 3
Price today	highest	lowest	low
Price at volume (D7)	moderate	lowest	similar to two hands

The derivation gives a decision rule rather than a universal answer:

value per robot-hour = tasks done × value per task – (purchase share + consumables + repairs + downtime) – data cost

- **Grippers win when:**

- the tasks are mostly power grasps plus re-grasps;
- you can adapt the setting;
- uptime dominates the economics;
- data comes from teleop or UMI-style devices.

That describes most commercial work cells today.

- **Hands win when:**

- tasks need turning objects in the grasp or finger-operated tools;
- you can't change the environment, as in homes;
- human video is the main data source;
- wear can be contained with replaceable skins, sealed transmissions and swappable fingers.

So "grippers for a defined commercial task today, an open bet for general-purpose humanoids" is what the logic concludes, not a hedge.

4. Kyle's argument against the derivation

Holds:

- Put complexity in big, serviceable modules (D3–D5).
- Treat contact surfaces as consumables (D1–D2).
- Sense force where hardware is durable (D6).
- Fewer actuators means far fewer failures (D4).

Breaks:

- **Economies of scale.** His own data shows big declines, and the first-principles floor for simple hands is low (D7). Only the cost-of-ownership version survives.
- **The third arm.** It adds space, weight and collision complexity, and has no human data (D10). Extrinsic dexterity or tool changers (D8) usually supply the same motions more cheaply.

- **"Most tasks."** True for power grasps in controlled settings; false where finger-operated tools or turning objects in the grasp dominate (D8–D9). It depends on the task mix.
- **A hidden assumption.** He treats reliability as the binding constraint. In deployment it usually is. In research, and for general-purpose robots, the first question is whether a task is possible at all, and that favors fingers.

5. If you look at hands as a company

The derivation shows where a hand company could win, and it isn't purchase price, since volume will push that down anyway. It would win on:

- replaceable skins and tips;
- fingers you can swap in minutes;
- sealed transmissions under low cycle stress;
- force sensing through the motors, not only skins;
- published failure-rate data.

For gloves data, axiom 3 is the catch. A glove that records only finger angles misses the forces and friction the robot needs, so its value depends on measuring them.