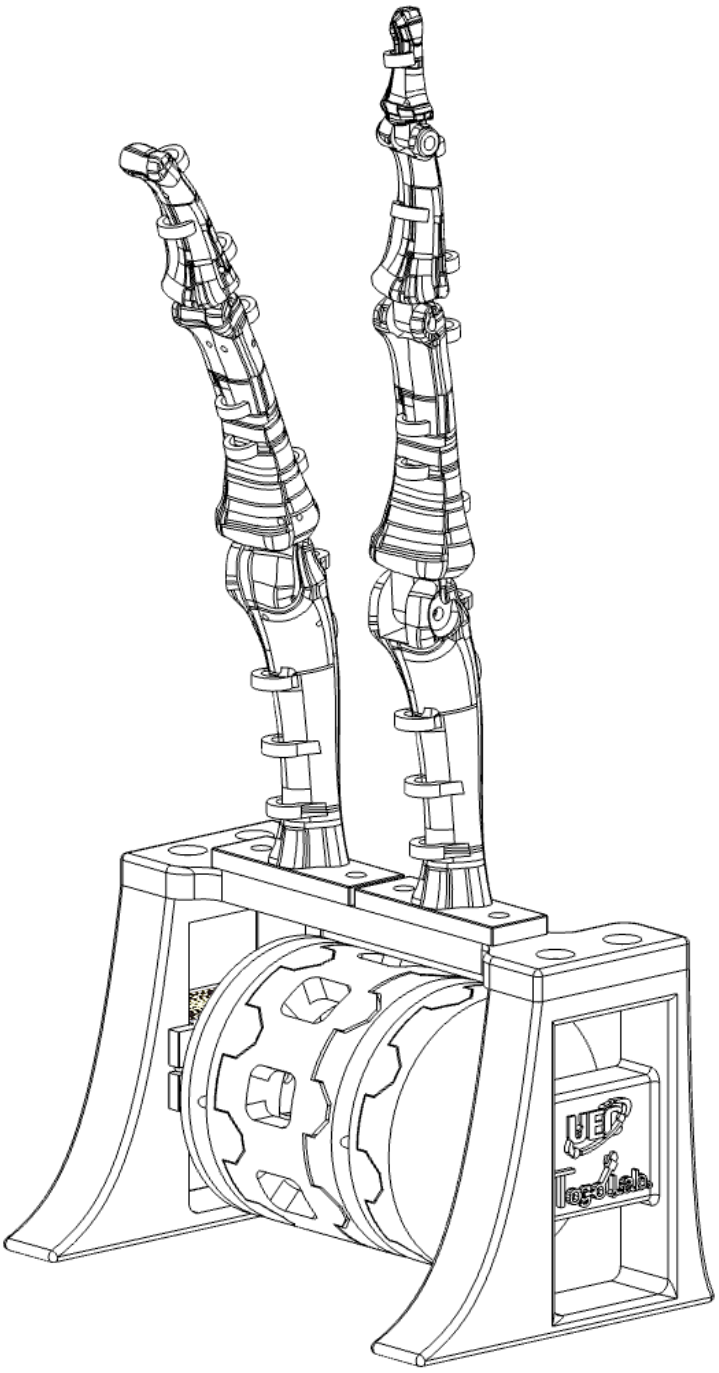
Anthropomimetic Middle Finger Robot Assembly Manual



Togo Lab.

Ver. 1.1

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Let's explore! 39

Introduction

We are delighted that you have decided to take on the challenge of assembling this anthropomimetic middle finger robot kit. The purpose of this kit is to allow a wide range of people to experience the fabrication process of various anthropomimetic robots developed in the Togo Laboratory at the University of Electro-Communications, Japan. Anthropomimetic robots are developed as part of the field of “humanization robotics”, which seeks to uncover the mechanisms that enable humans to perform dexterous and skillful movements by making robotic body structures as close to those of humans as possible.

From the perspective of robotics, this kit incorporates state-of-the-art research concepts represented by keywords such as biomimetics, tendon-driven mechanisms, underactuated mechanisms, sliding–rolling joints, and joint viscoelasticity. In addition, you will also build, in parallel, a middle finger robot based on a conventional revolute joint, which is the traditional joint structure used in robotics. We encourage you to experience and compare the differences between these two approaches. Unfortunately, basic robotic components such as sensors and microcontrollers are omitted from this kit. We hope you will explore robotics further and modify this kit with your own ideas and hands.

From an anatomical perspective, this kit can serve as an opportunity to gain a deeper understanding of the structure of your own fingers. At the same time, many anatomical features of the human body are intentionally simplified or omitted in this kit. Through the assembly process, you may come to appreciate just how complex and sophisticated your own fingers truly are.

Whether you are a complete beginner or an experienced maker, we hope you will enjoy this kit and gain hands-on insight into a wide range of knowledge about robotics and human body structures.

The University of Electro-Communications
Shunta Togo

About the kit

List of components

(A) Controller

(B) Servo motor

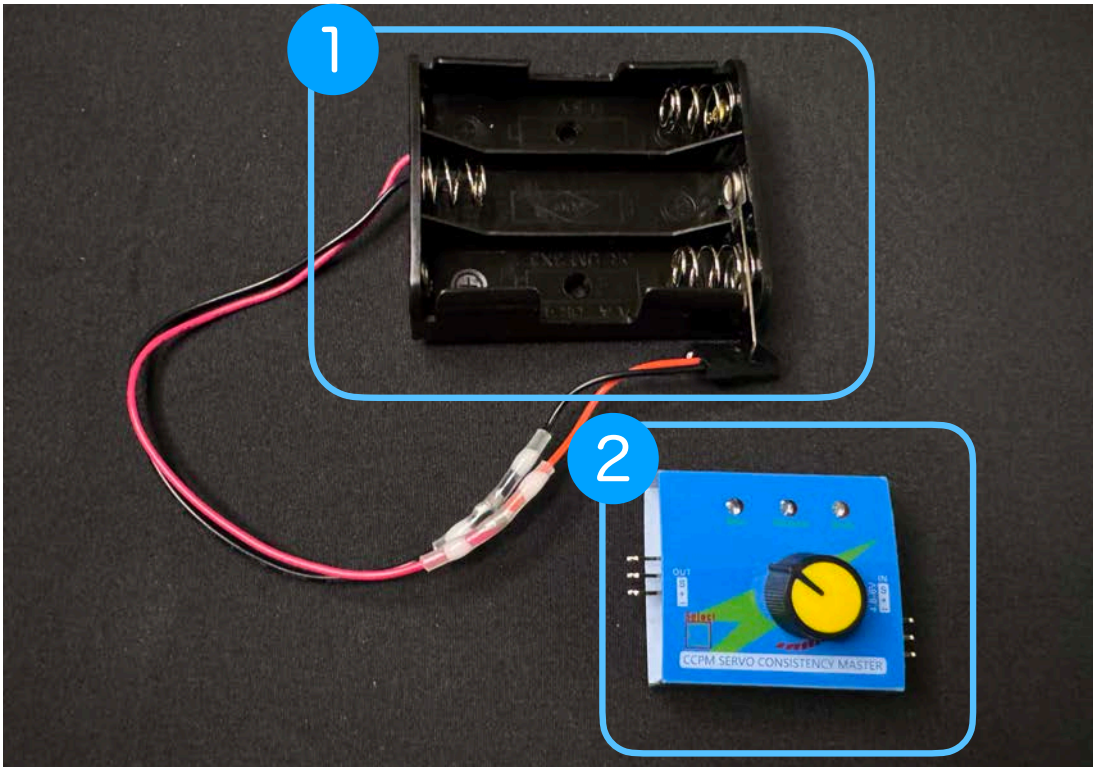
(C) Battery

(D) Resin parts

(E) Finger and base parts

About the kit

(A) Controller



(1) Battery box [3 x AA batteries, with switch]

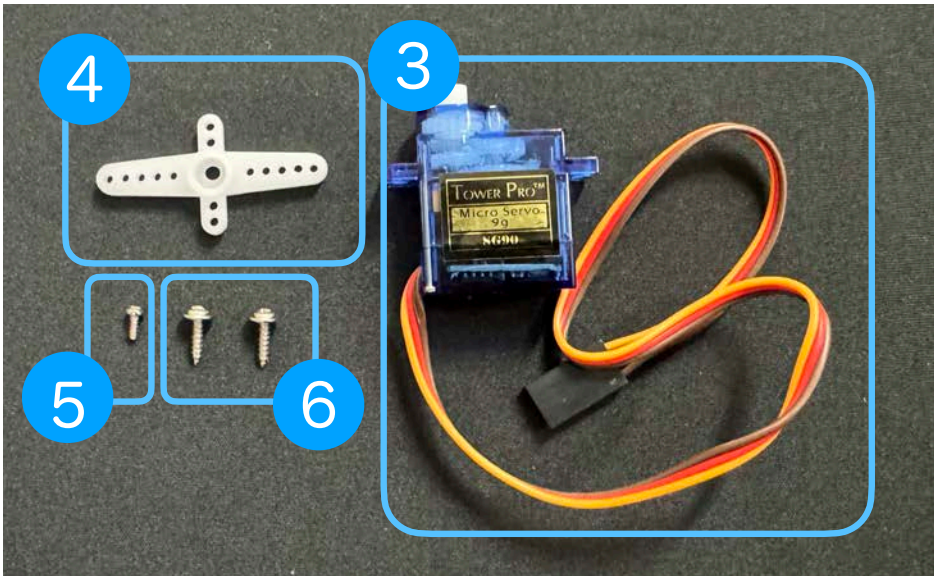
+ Servo cable

+ Heat-shrink solder connectors: 2pcs

(2) Controller [Servo motor tester]

About the kit

(B) Servo motor



(3) Servo motor [SG90]

(4) Servo horn [Included with (3)]

(5) Horn fixing screw [Included with (3)]

(6) Servo motor mounting screw: 2 pcs

[Included with (3)]

About the kit

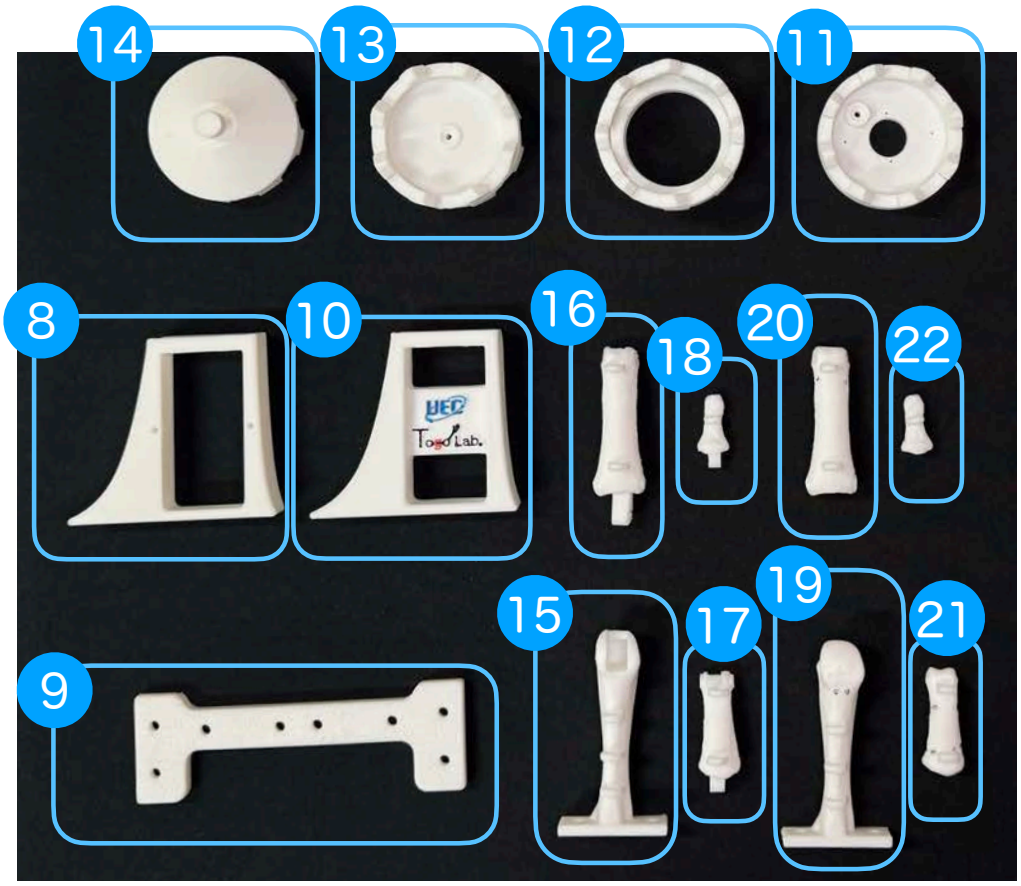
(C) Battery

(7) AA Alkaline Batteries: 3 pcs

[Each AA battery provides 1.5 V.By connecting three batteries in series, a total of 4.5 V is supplied.]

About the kit

(D) Resin parts



(8) Base (Left)
(9) Base (Center)
(10) Base (Right)
(11) Pulley 1
(12) Pulley 2
(13) Pulley 3
(14) Pulley 4
(15) Metacarpal (R)
(16) Proximal phalanx (R)
(17) Middle phalanx (R)
(18) Distal phalanx (R)
(19) Metacarpal (H)
(20) Proximal phalanx (H)
(21) Middle phalanx (H)
(22) Distal phalanx (H)

Source of bone geometry data

BodyParts3D

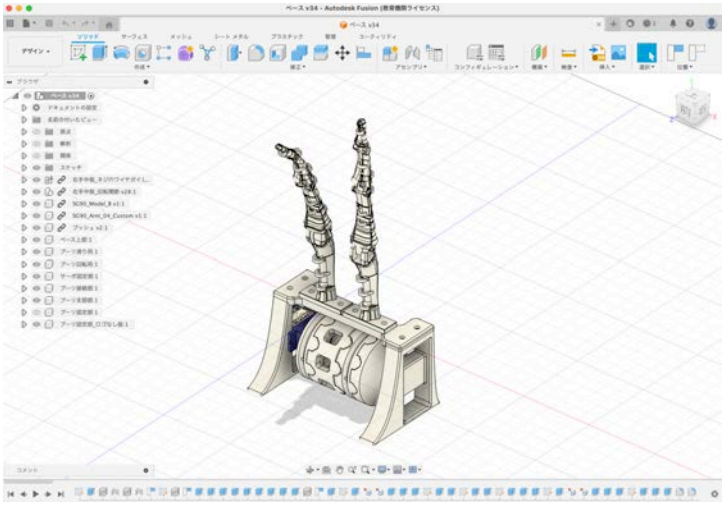
(R): Revolute joint
(H): Human-like joint

About the kit

(D) Resin parts

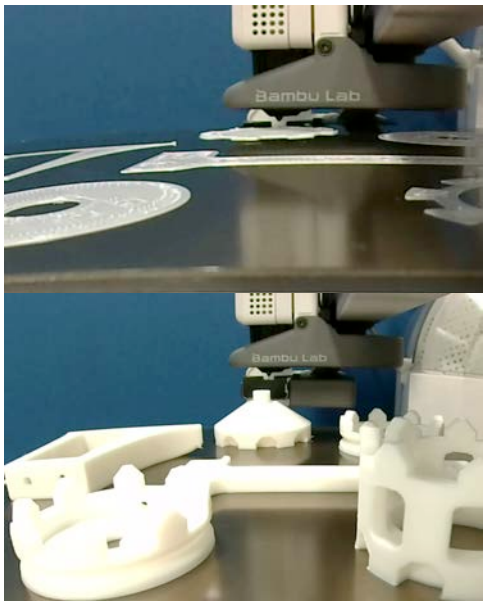
How the resin parts are made

(1) Design of the resin parts



Software used: AUTODESK Fusion
Note: Free licenses are available for educational institutions.

(2) 3D print of the resin parts



3D Printer: Bambu Lab A1 mini
Filament: Bambu Lab PLA Basic
Layer height: 0.2 mm
Infill density: 15%
Infill pattern: Grid
Printing time: Approx. 5 hours per set
Nozzle diameter: 0.4 mm
(Only part (10) Base (Right), is printed with a 0.2 mm nozzle.)

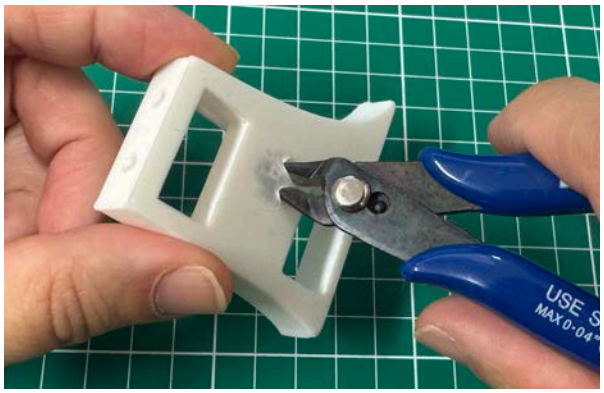
About the kit

How the resin parts are made

(D) Resin parts

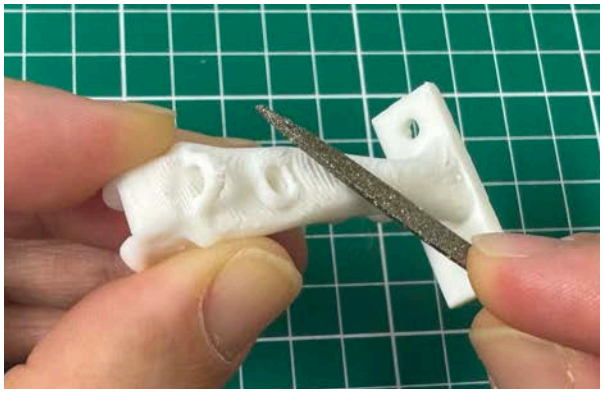
(3) Post-processing of the resin parts

1 Removal of support material



2 Adjustment of screw holes

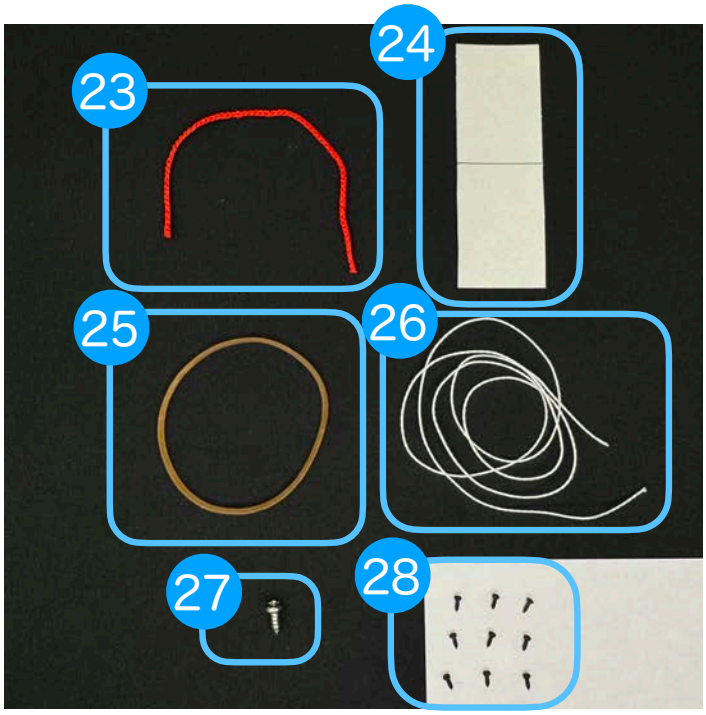
3 Sanding



Note: The resin parts included in this kit have already undergone basic post-processing.

About the kit

(E) Finger and base parts



Contents of the human-like MP joint pouch

(23) Ligament (approx. 98 mm)

[Made by chain-stitching braided PE fishing line (8-strand braid, 5#)]

(24) Joint capsule sheet (20 × 610 mm)

(25) Rubber band [Folded length: 60 mm]

(26) Muscle wire [Braided PE fishing line (8-strand braid, 5#)]

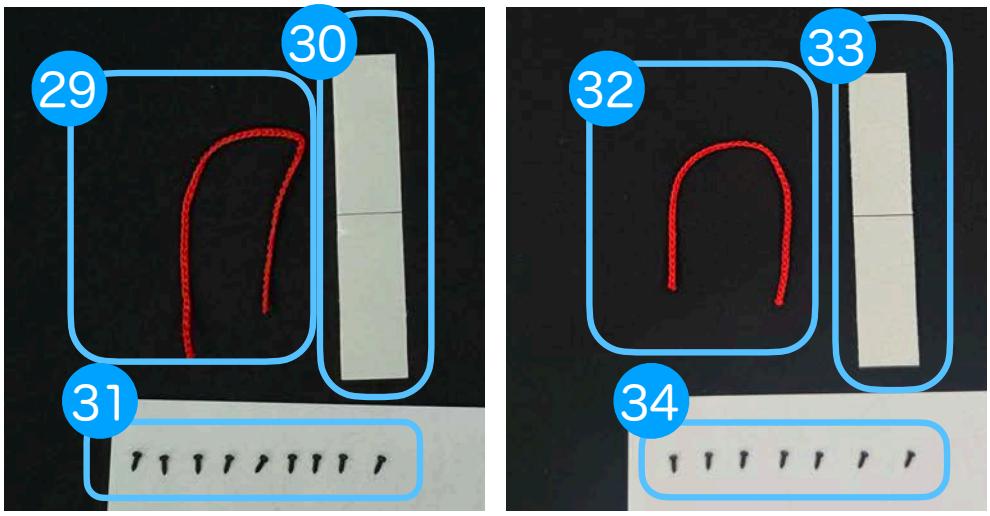
(27) Tapping Screw [M2.5 × 6 mm]

(28) Tapping Screws [M1 × 3 mm, 8 pcs + 1 spare]

About the kit

(E) Finger and base parts

Contents of the human-like PIP joint pouch	Contents of the human-like DIP joint pouch



(29) Ligament (approx. 94 mm)

[Made by chain-stitching braided PE fishing line (8-strand braid, 5#)]

(30) Joint capsule sheet (12 × 610 mm)

(31) Tapping Screws [M1 × 3 mm, 8 pcs + 1 spare]

(32) Ligament (approx. 78 mm)

[Made by chain-stitching braided PE fishing line (8-strand braid, 5#)]

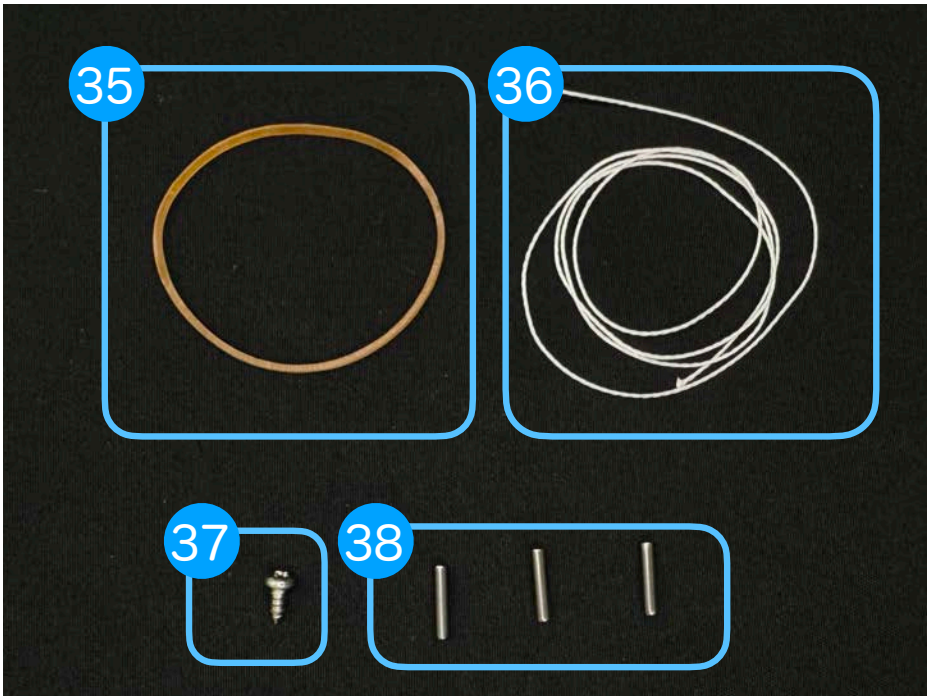
(33) Joint capsule sheet (12 × 610 mm)

(34) Tapping Screws [M1 × 3 mm, 6 pcs + 1 spare]

About the kit

(E) Finger and base parts

Contents of the revolute-joint pouch



(35) Rubber Band [Folded length: 60 mm]

(36) Muscle Wire [Braided PE fishing line (8-strand, 5#)]

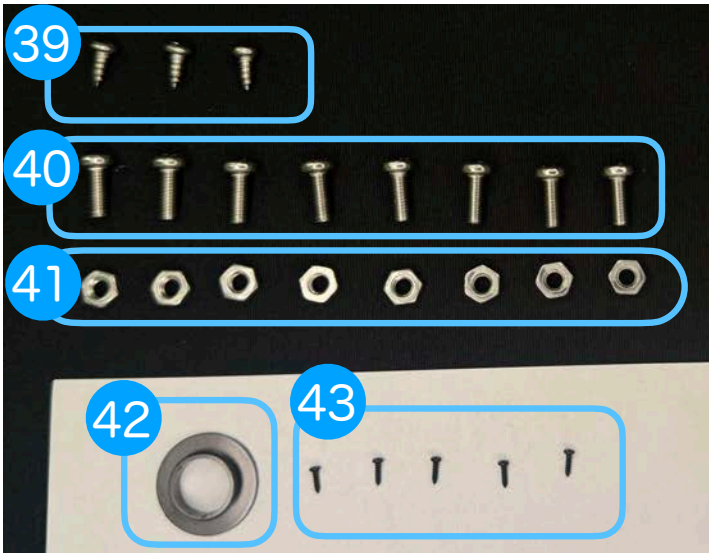
(37) Tapping Screw [M2.5 × 6 mm]

(38) Shafts [M2 × 10 mm, 3 pcs]

About the kit

(E) Finger and base parts

Contents of the base pouch



(39) Tapping Screws [M2.5 × 6 mm, 2 pcs + 1 spare]

(40) Bolts [M3 × 8 mm, 8 pcs]

(41) Nuts [M3, 8 pcs]

(42) Flanged Bush [80F-0803]

(43) Tapping Screws [M1 × 3.5 mm, 4 pcs + 1 spare]

Required tools

Tools

(a) Scissors
(b) Mini needle-nose pliers
(c) Wire cutters
(d) Precision screwdriver
(e) Darning needle
(f) Curved-tip tweezers
(g) Diamond file
(h) Cloth tape
(i) Pincushion
(j) Magnetizer
(k) Stainless steel tray
(l) Magnetic sheet
(m) Cutting mat

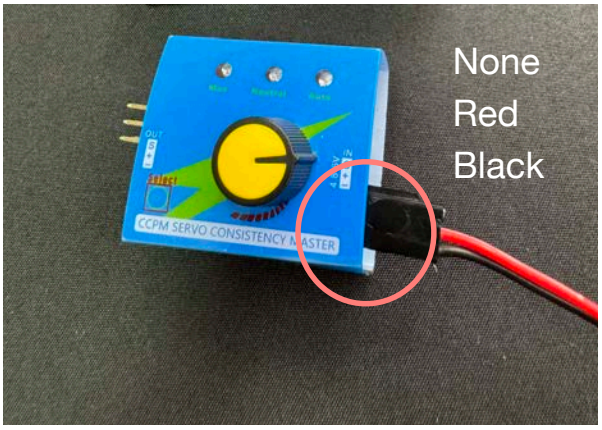
Assembly procedure

Controller assembly

1 Inserting the batteries

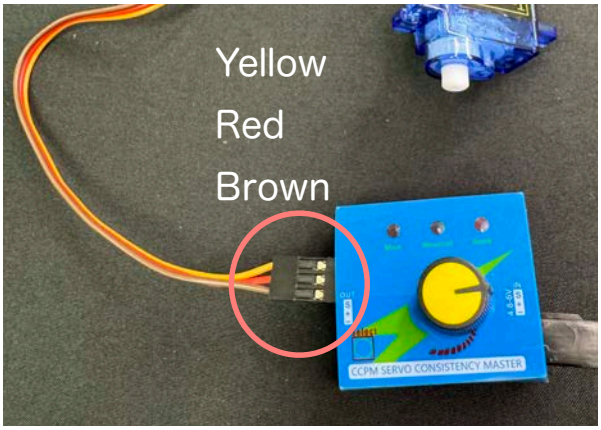
Insert the (1) batteries into the (7) battery box.

2 Connecting the servo cable



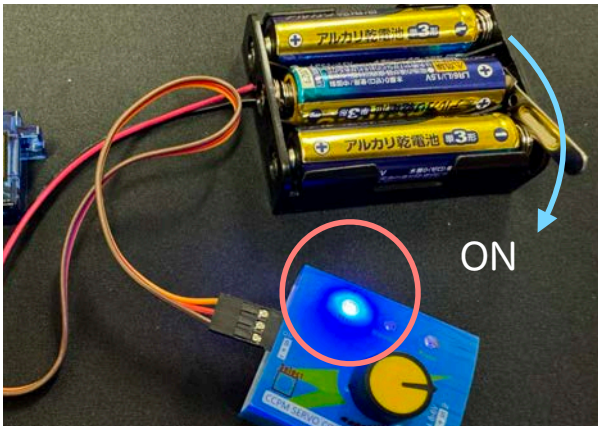
Connect the (1) servo cable to the (2) controller.

3 Connecting the controller cable



Connect the (3) servo motor to the (2) controller.

4 Function check



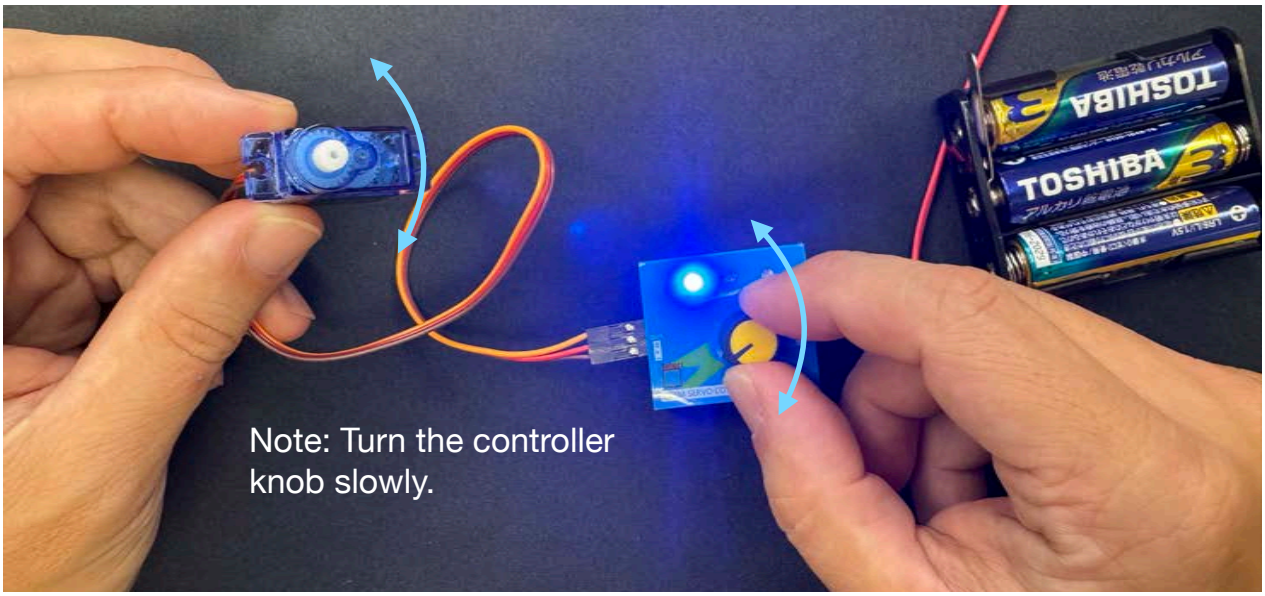
Turn on the switch and confirm that the LED lights up.

Assembly procedure

Controller assembly

5

Function check



Rotate the knob on the (2) controller and confirm that the (3) servo motor rotates accordingly.

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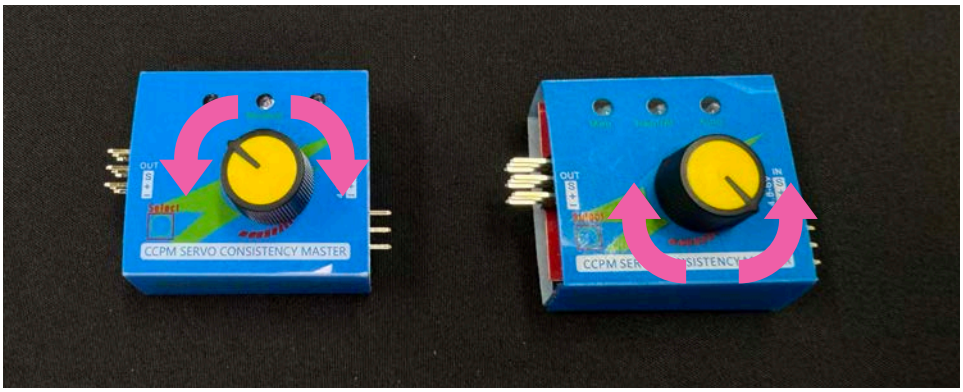


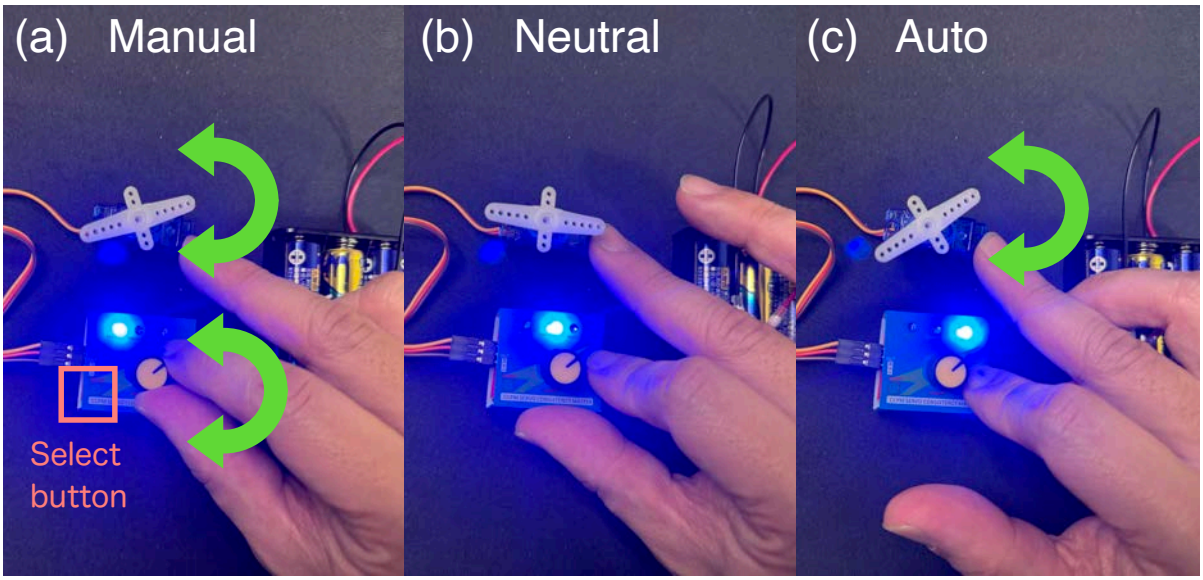
Note: Depending on the manufacturing batch of the controller, the mounting orientation of the knob may be reversed. This does not affect the function of the controller.

Assembly procedure

Controller assembly

6

Operating modes check



Press the Select button to switch between the following three modes:

(a) Manual Mode: The motor rotates as you turn the knob.

(b) Neutral Mode: The motor stops at the 0-degree position.

(c) Auto Mode: The motor automatically moves back and forth between ± the maximum angle.

Press the button and observe how the behavior changes in each mode.

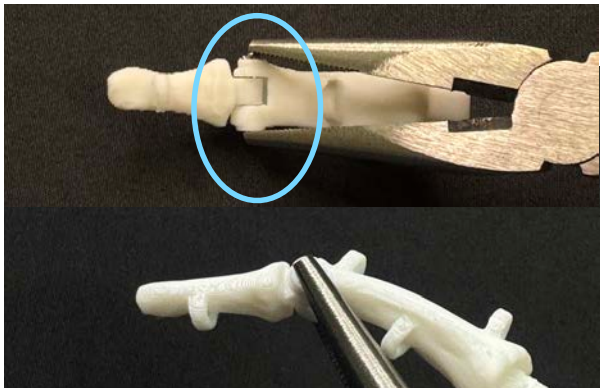
After checking the operation, turn off the power switch.

Note: If the motor does not move smoothly,
try replacing the batteries with new ones.

Assembly procedure

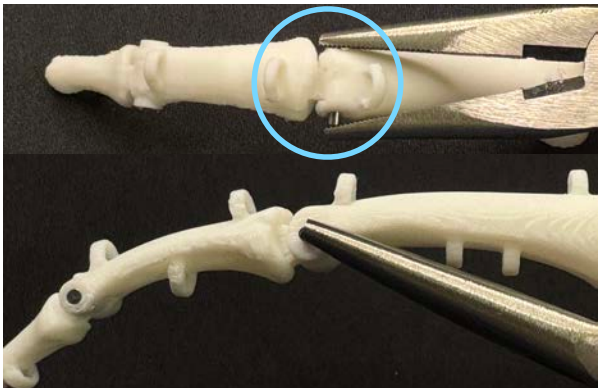
Assembly of the revolute-joint middle finger

1 Assembling the DIP joint



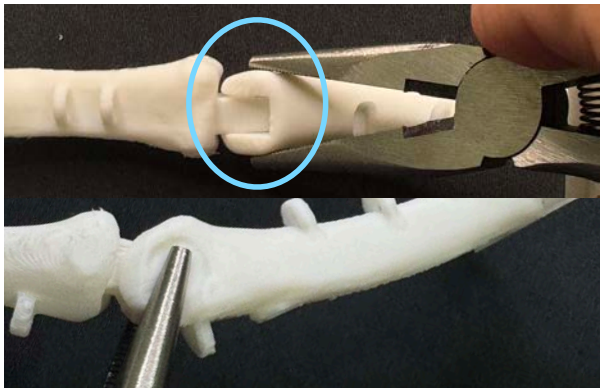
Form the DIP joint using the (18) distal phalanx (R) and the (17) middle phalanx (R), then insert the (38) shaft.

2 Assembling the PIP joint



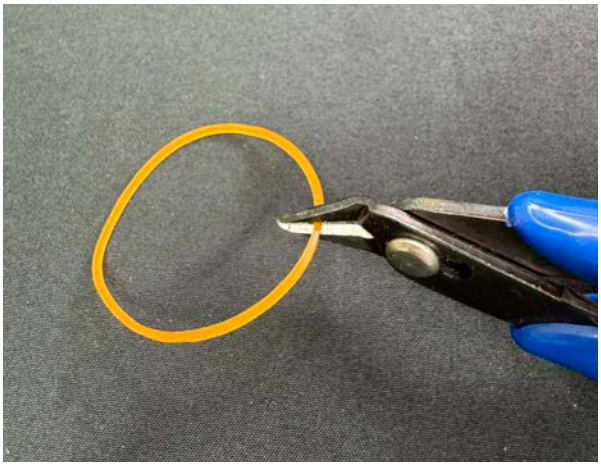
Form the PIP joint using the (17) middle phalanx (R) and the (16) proximal phalanx (R), then insert the (38) shaft.

3 Assembling the MP joint



Form the MP joint using the (16) proximal phalanx (R) and the (15) metacarpal (R), then insert the (38) shaft.

4 Assembling the extensor mechanism



Cut the (35) rubber band using the (c) wire cutters.

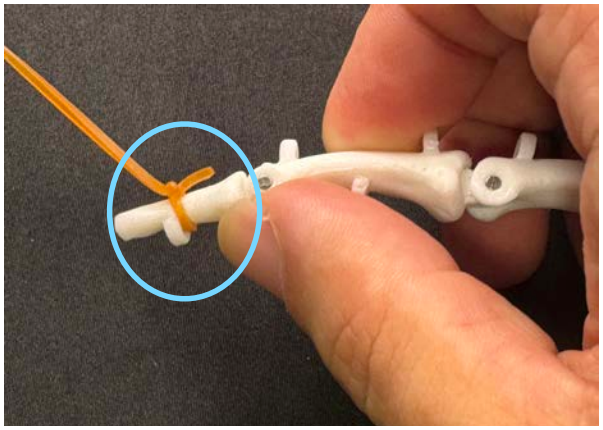
TIPS

DIP joint: Distal Interphalangeal Joint
PIP joint: Proximal Interphalangeal Joint
MP joint: Metacarpophalangeal Joint

Assembly procedure

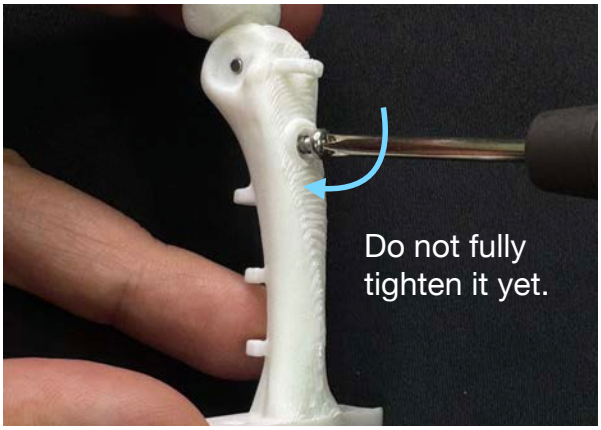
Assembly of the revolute-joint middle finger

5 Assembling the extensor mechanism



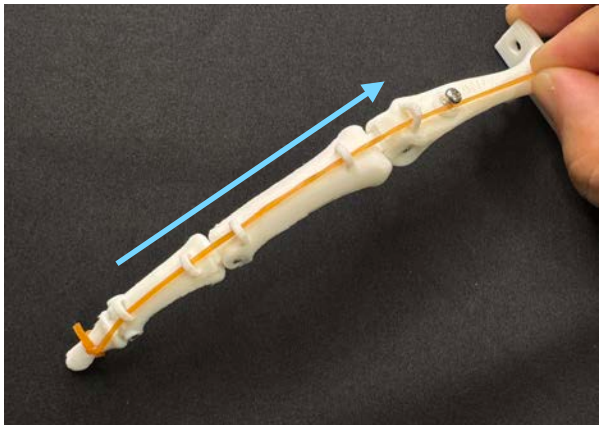
Tie one end of the cut (35) rubber band to the recessed area of the (18) distal phalanx (R).

6 Assembling the extensor mechanism



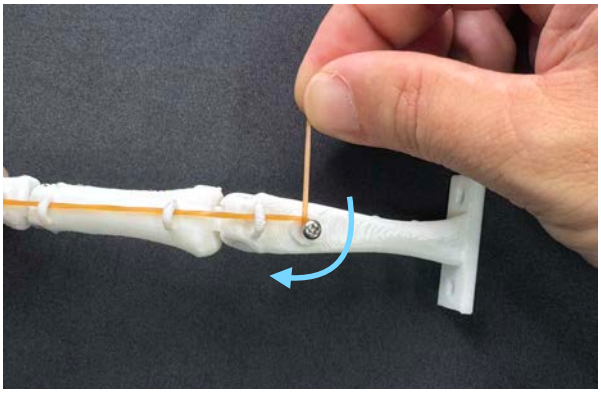
Lightly fasten the (37) tapping screw into the hole on the dorsal side of the (15) metacarpal (R).

7 Assembling the extensor mechanism



Thread the (35) rubber band through all of the dorsal loops.

8 Assembling the extensor mechanism



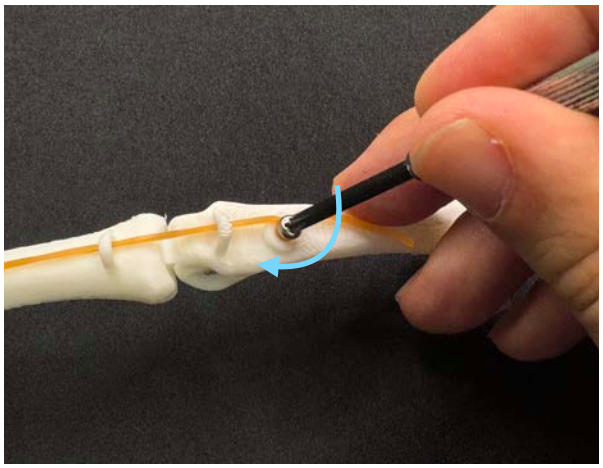
Wrap the (35) rubber band once around the loosely fastened (37) tapping screw in the tightening direction.

TIPS The force that extends the finger changes depending on how much of the rubber band is wrapped around the screw.

Assembly procedure

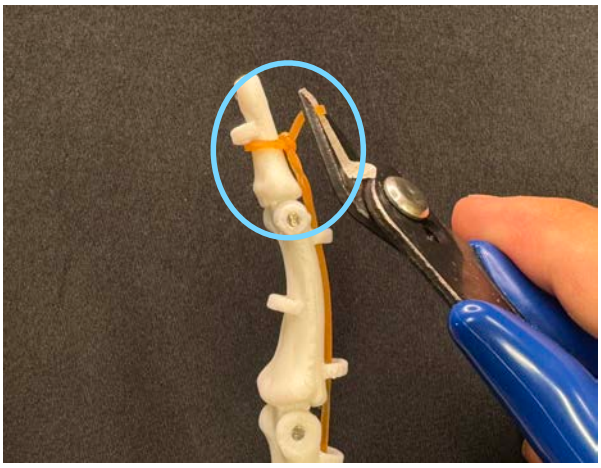
Assembly of the revolute-joint middle finger

9 Assembling the extensor mechanism



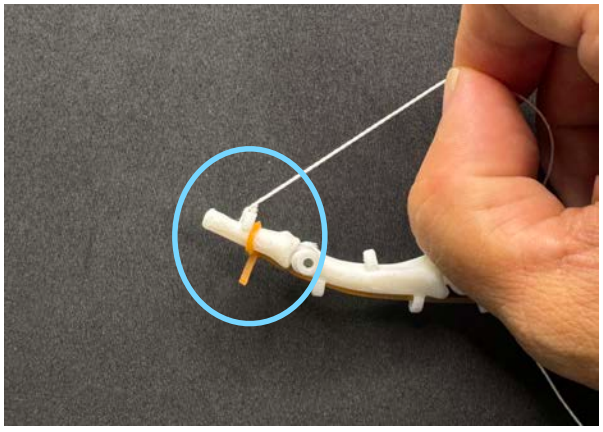
Fully tighten the temporarily fastened (37) tapping screw.

10 Assembling the extensor mechanism



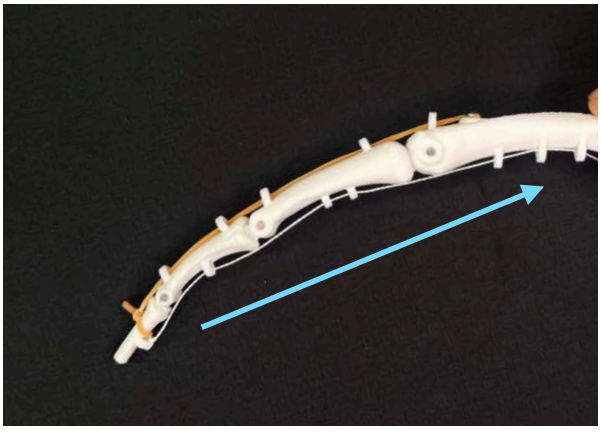
Trim off any excess (35) rubber band.

11 Assembling the flexor mechanism



Tie one end of the (36) muscle wire to the palmar-side loop of the (18) distal phalanx (R).

12 Assembling the flexor mechanism



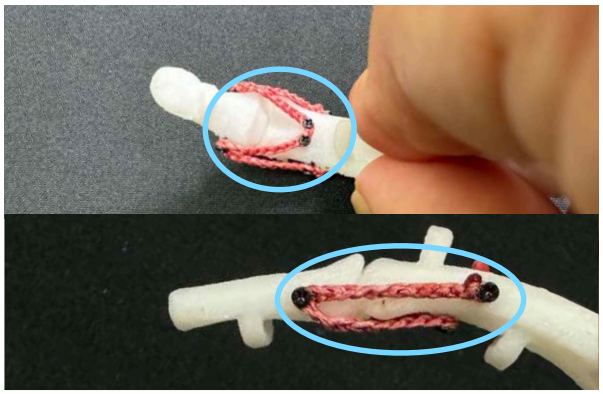
Thread the (36) muscle wire through all of the palmar-side loops.

TIPS Pull the muscle wire by hand and check that each joint flexes as expected. This type of mechanism is called a wire-driven mechanism or a tendon-driven mechanism.

Assembly procedure

Assembly of the human-like joint middle finger (Part 1)

1 Assembling the DIP joint



Form the DIP joint using the (22) distal phalanx (H) and the (21) middle phalanx (H). Attach the corresponding (32) ligament by referring to the next page.

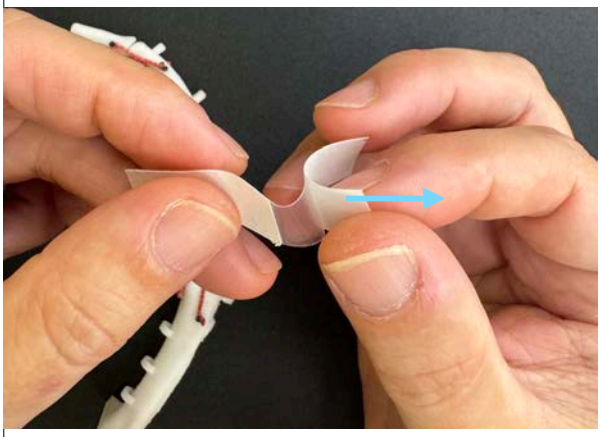
2 Assembling the PIP joint

Form the PIP joint using the (21) middle phalanx (H) and the (20) proximal phalanx (H). Attach the corresponding (29) ligament by referring to the next page.

3 Assembling the MP joint

Form the MP joint using the (20) proximal phalanx (H) and the (19) metacarpal (H). Attach the corresponding (23) ligament by referring to the next page.

4 Assembling the joint capsule (DIP)



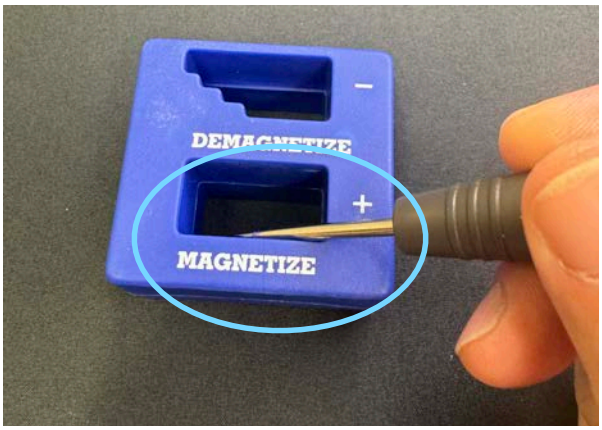
Peel off the white backing sheet from the (33) joint capsule sheet in preparation for attaching it.

Assembly procedure

Ligament fixation method

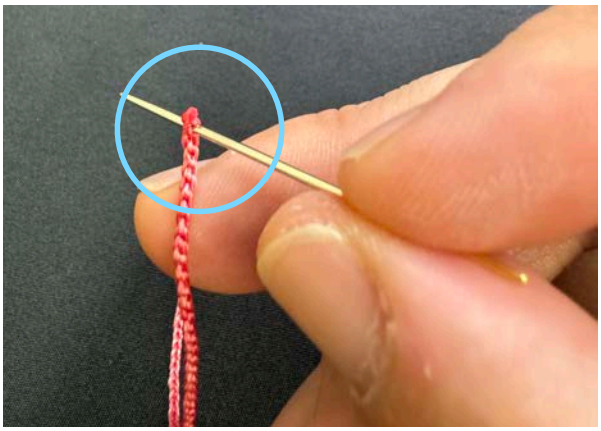
Using the MP Joint as an Example

1 Magnetizing the precision screwdriver



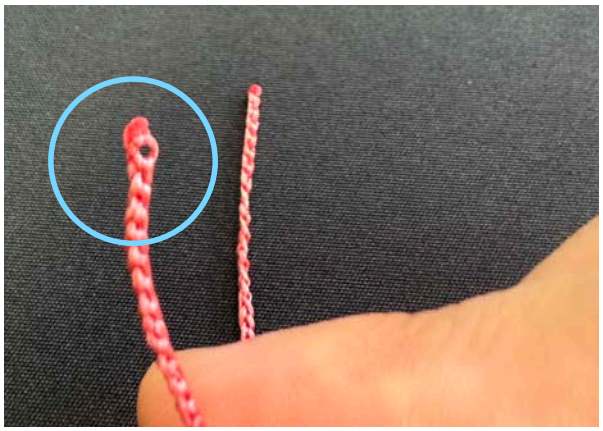
If the magnetic force of the (d) precision screwdriver is weak, touch it to the (j) magnetizer to magnetize the tip.

2 Attaching the screw to the ligament



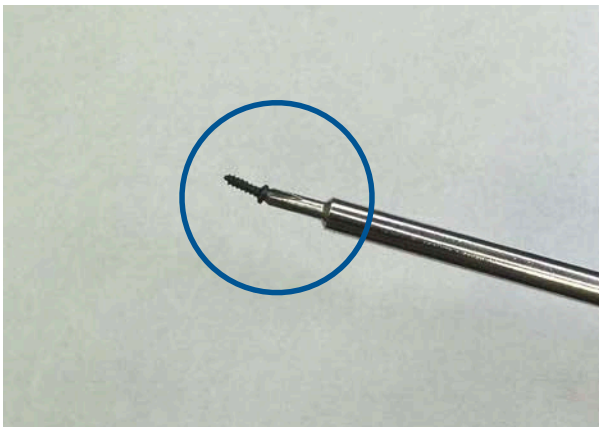
Insert the (e) darning needle into the gap of the chain at the end of the (23) ligament.

3 Attaching the screw to the ligament



Remove the (e) darning needle and confirm that a hole has been made at the end of the (23) ligament.

4 Attaching the screw to the ligament



Place the (28) tapping screw on the tip of the (d) precision screwdriver (thin tip).

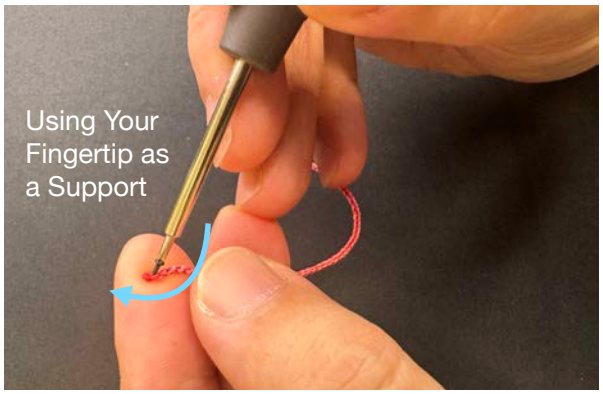
TIPS The ends of the ligament have been heat-sealed with a lighter to prevent fraying.

Assembly procedure

Using the MP Joint as an Example

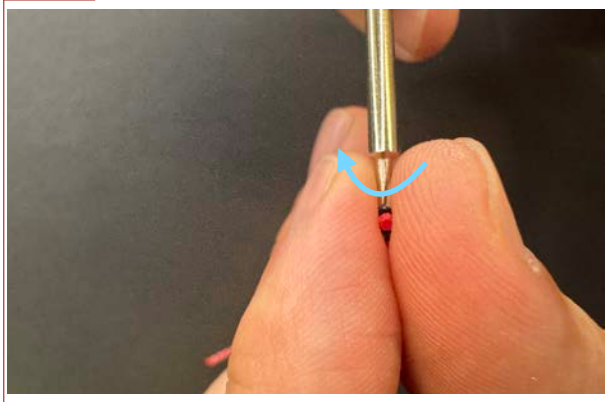
Ligament fixation method

5 Attaching the screw to the ligament



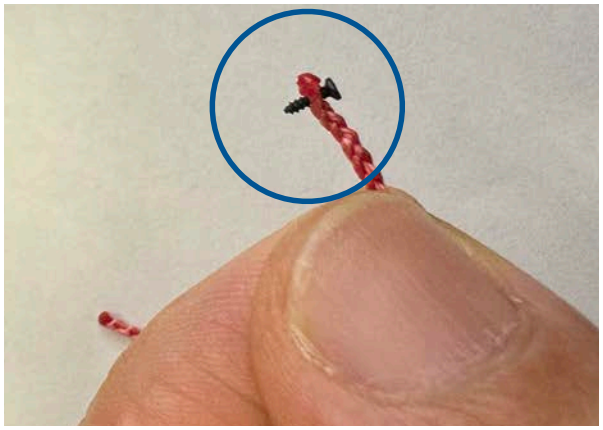
Insert the (28) tapping screw into the hole of the (23) ligament. Turning the screwdriver while inserting the screw makes this easier.

6 Attaching the screw to the ligament



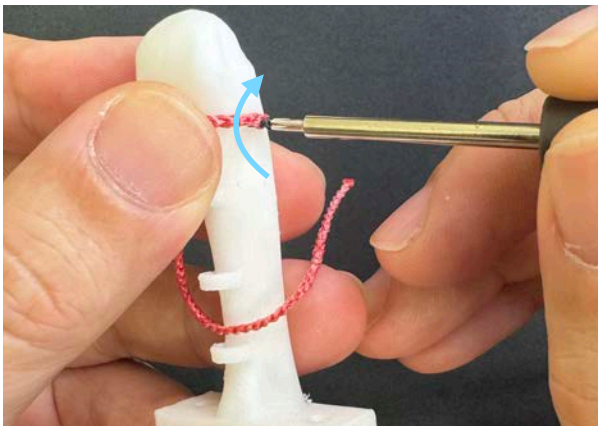
Once the (28) screw has started to enter the (23) ligament, rotate the (d) precision screwdriver between your fingertips to drive the tapping screw deeper into the ligament.

7 Attaching the screw to the ligament



Confirm that the (28) tapping screw is securely inserted into the (23) ligament.

8 Attaching the ligament to the phalanx



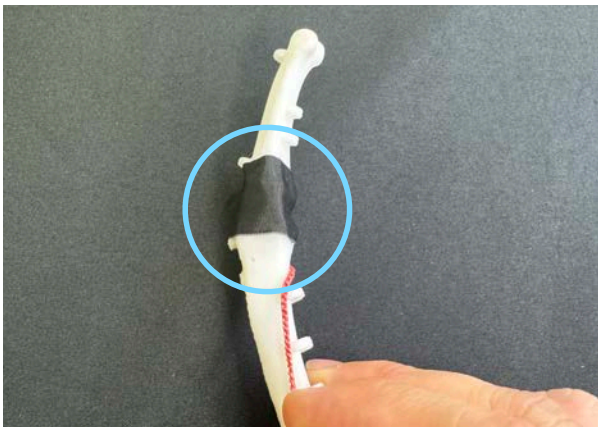
Referring to steps 15–17, fasten the (28) tapping screw to the location marked as attachment point (1).

Assembly procedure

Ligament fixation method

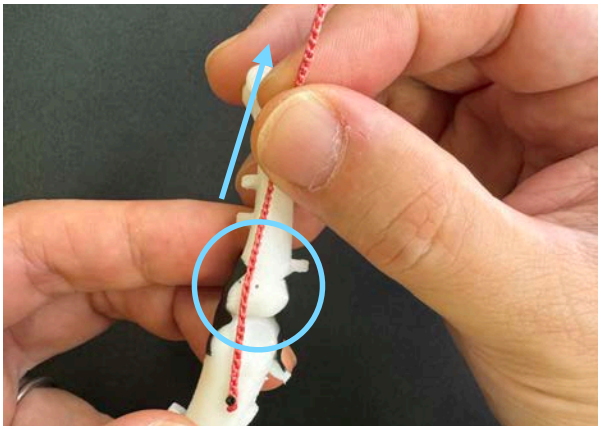
Using the MP Joint as an Example

9 Attaching the ligament to the phalanx



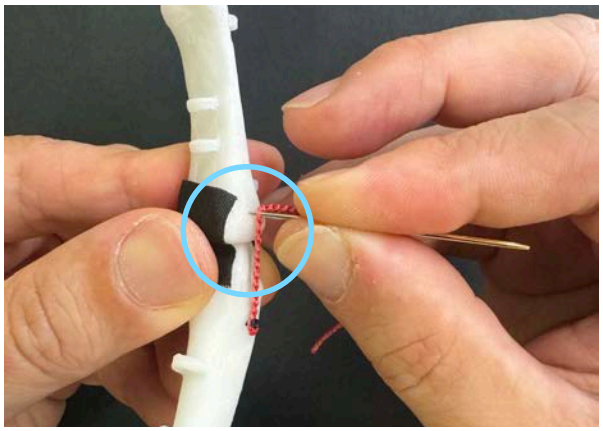
Temporarily hold the two bones in place using the (h) cloth tape for provisional joint fixation.

10 Attaching the ligament to the phalanx



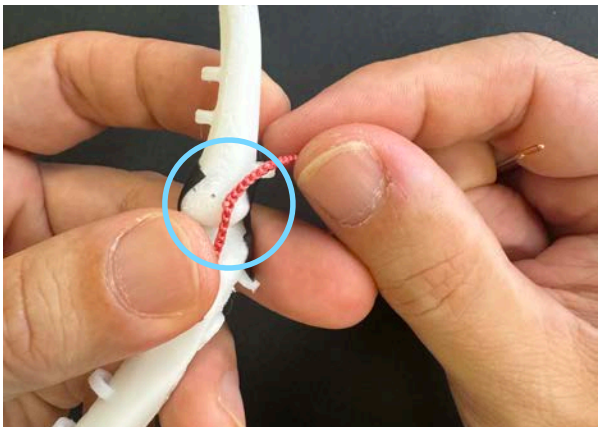
Pull the (23) ligament and extend it to the next attachment point.

11 Attaching the ligament to the phalanx



Insert the (e) darning needle into the (23) ligament so that it aligns with the hole at the next attachment point.

12 Attaching the ligament to the phalanx



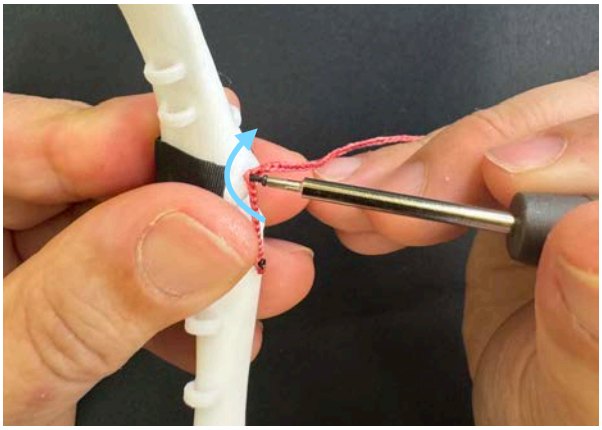
Confirm that a hole has been created at the position of the next attachment point.

Assembly procedure

Using the MP Joint as an Example

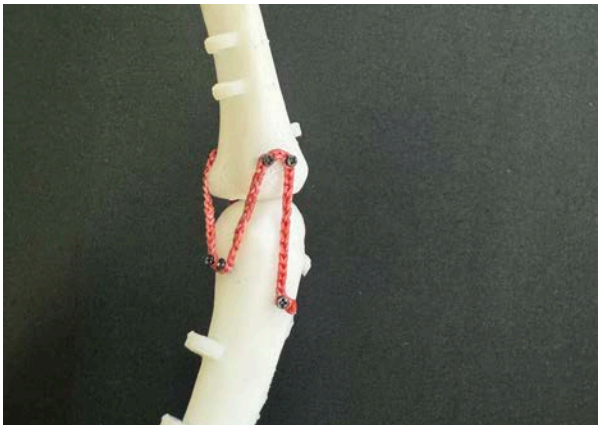
Ligament fixation method

13 Attaching the ligament to the phalanx



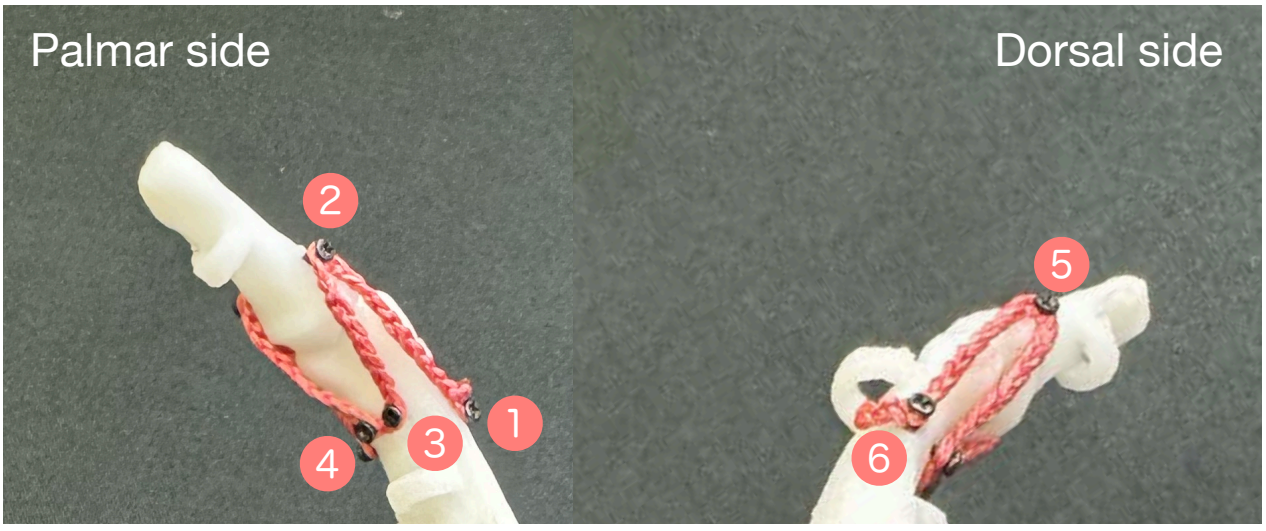
Using the (28) tapping screw, fasten the (23) ligament to the phalanx.

14 Attaching the ligament to the phalanx



Return to Step 10 and, using the same procedure, fix (29)(32) ligaments to the phalanges one by one.

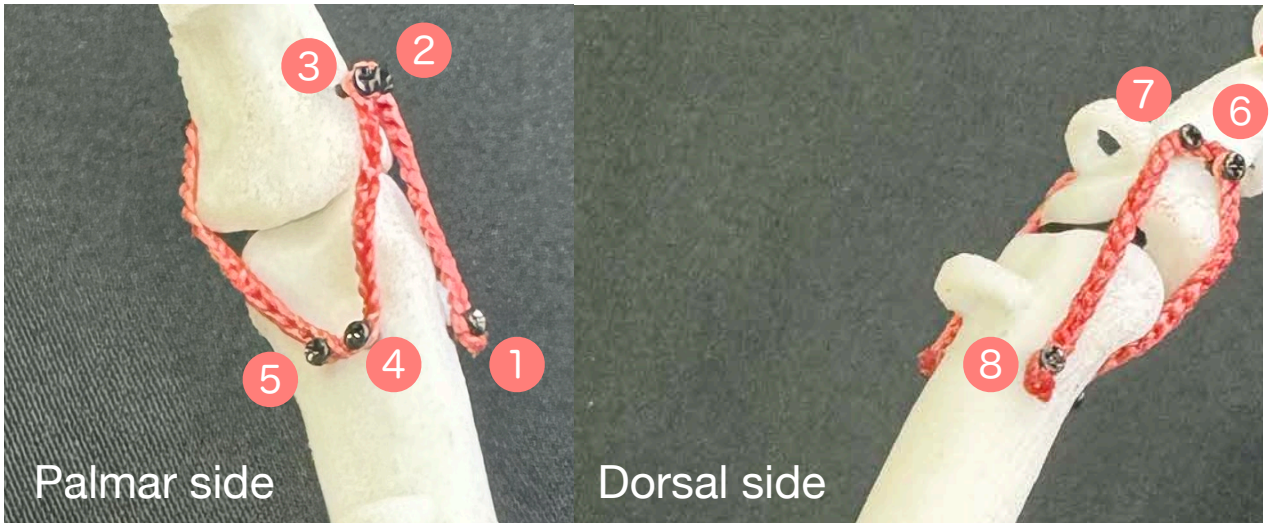
15 Ligament attachment points for the DIP joint



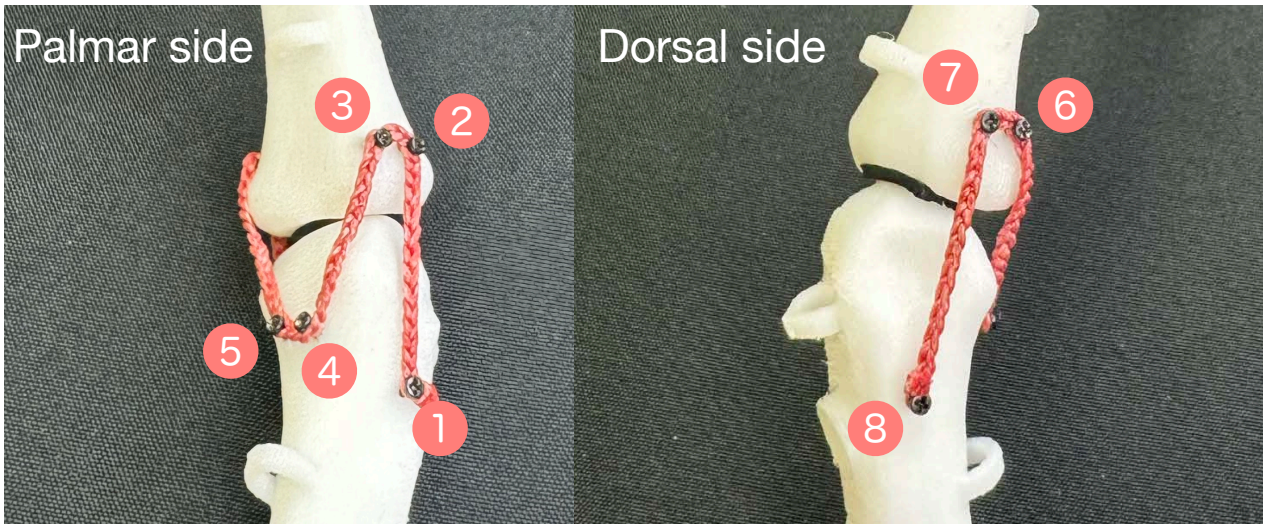
Assembly procedure

Ligament fixation method

16 Ligament attachment points for the PIP joint



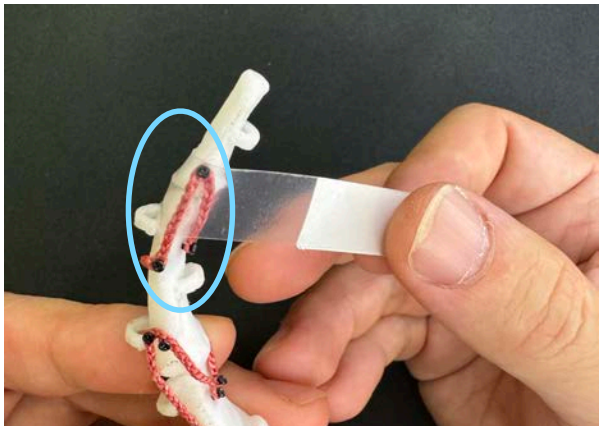
17 Ligament attachment points for the MP joint



Assembly procedure

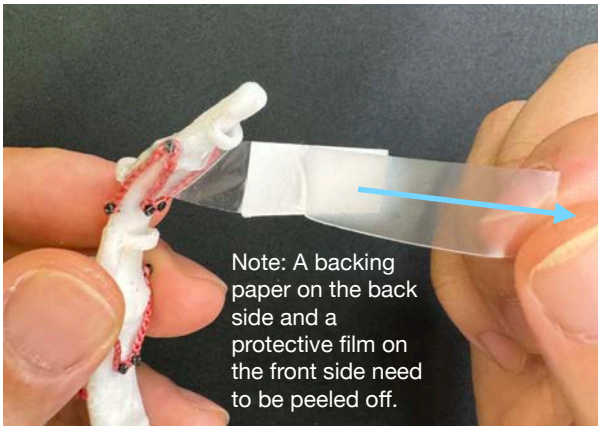
Assembly of the human-like joint middle finger (Part 2)

5 Assembling the joint capsule (DIP)



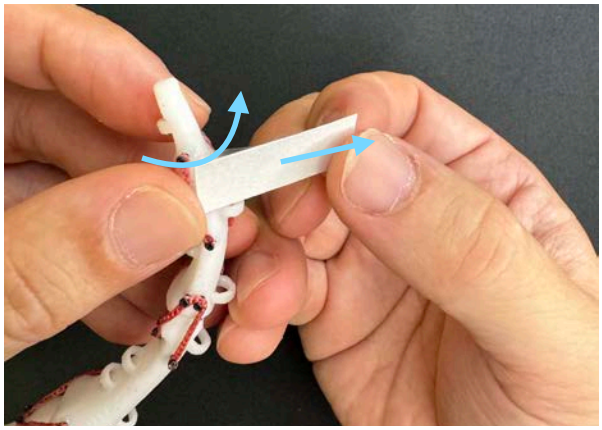
Attach the adhesive side of the (33) joint capsule sheet (with the backing removed) to the DIP joint.

6 Assembling the joint capsule (DIP)



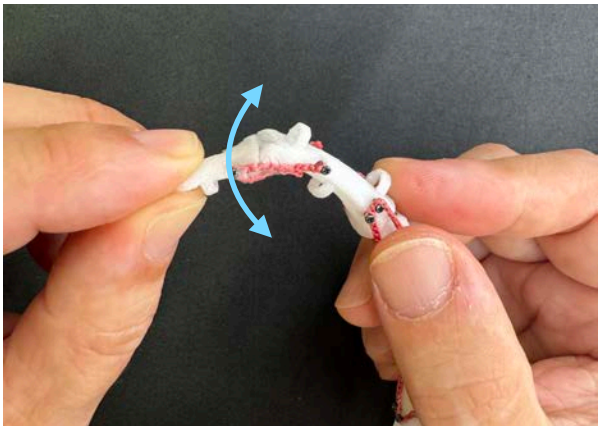
Starting from one end of the (33) joint capsule sheet, peel off the transparent protective film and the backing paper.

7 Assembling the joint capsule (DIP)



While gradually peeling off the remaining backing paper, wrap the (33) joint capsule sheet around the joint.

8 Assembling the joint capsule (DIP)

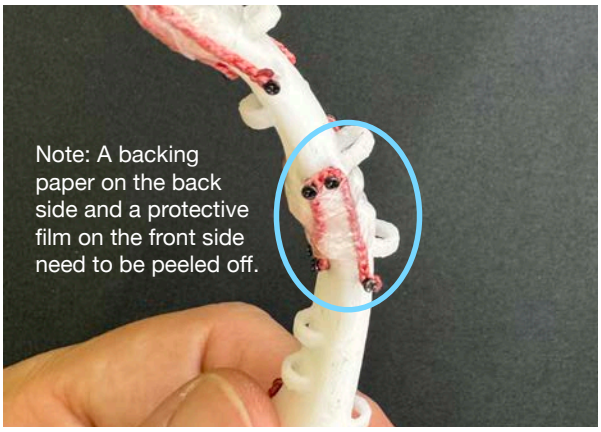


Manually flex and extend the DIP joint several times to slightly reduce the adhesive strength.

Assembly procedure

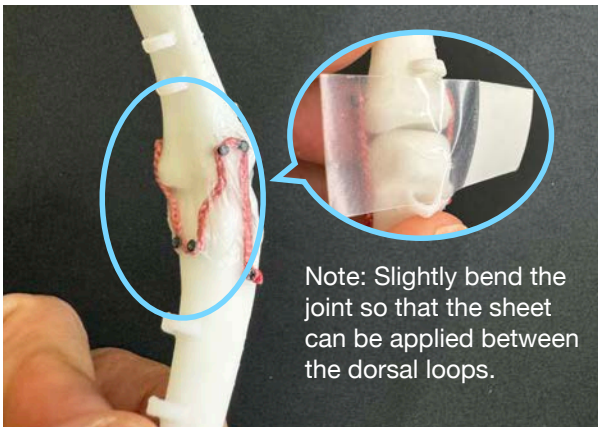
Assembly of the human-like joint middle finger (Part 2)

9 Assembling the joint capsule (PIP)



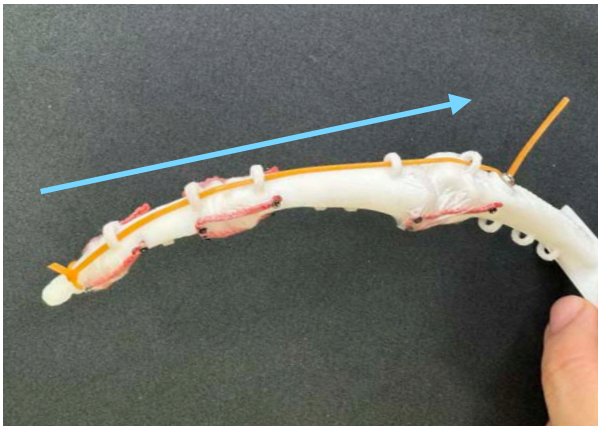
Return to Step 4 and, using the same method, wrap the (30) joint capsule sheet around the PIP joint.

10 Assembling the joint capsule (MP)



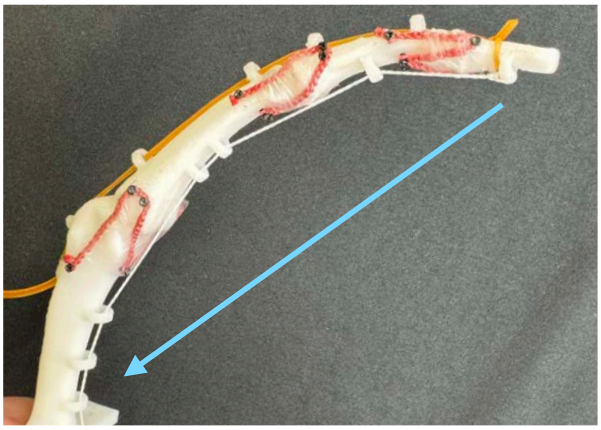
Return to Step 4 and, using the same method, wrap the (24) joint capsule sheet around the MP joint.

11 Assembling the extensor mechanism



Attach the (25) rubber band in the same way as for the revolute-joint middle finger.

12 Assembling the flexor mechanism



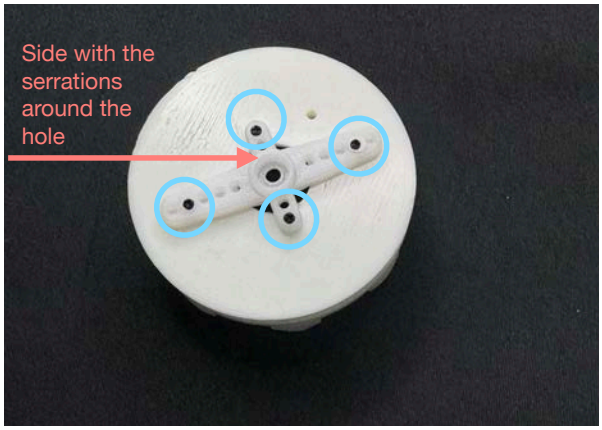
Attach the (26) muscle wire in the same way as for the revolute-joint middle finger.

TIPS Pull the muscle wire by hand and check that each joint flexes. Can you feel the difference compared to the revolute-joint middle finger?

Assembly procedure

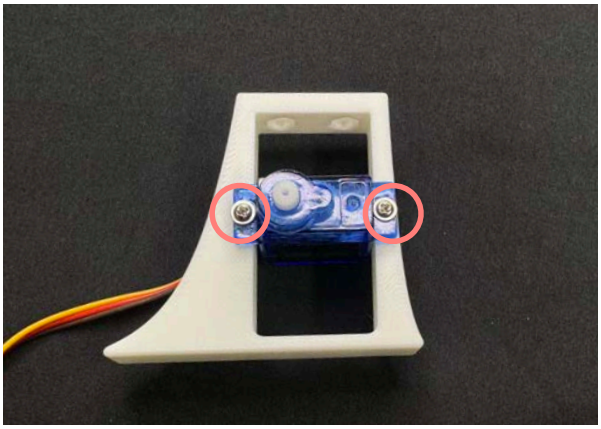
Base assembly

1 Assembling the pulley



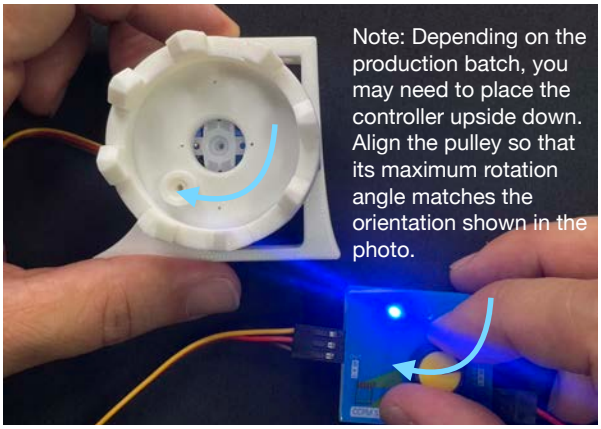
Using the (43) tapping screws, fix the (4) servo horn to (11) pulley 1.

2 Assembling the base



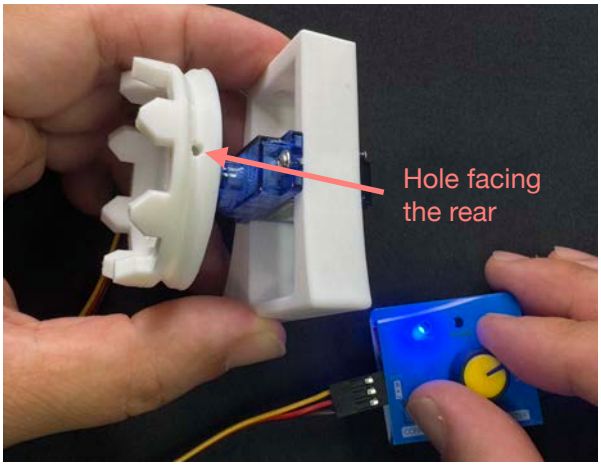
Using the (5) mounting screws, fix the (3) servo motor to the (8) base (left).

3 Assembling the pulley



Using the controller, rotate the (3) servo motor clockwise to its maximum angle, then attach the (4) servo horn.

4 Assembling the pulley

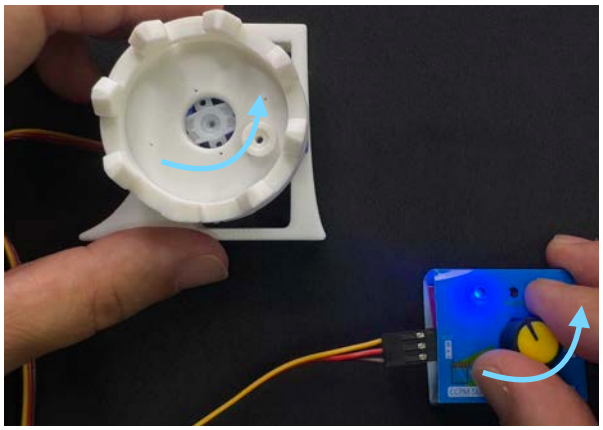


View from the rear in Step 3.

Assembly procedure

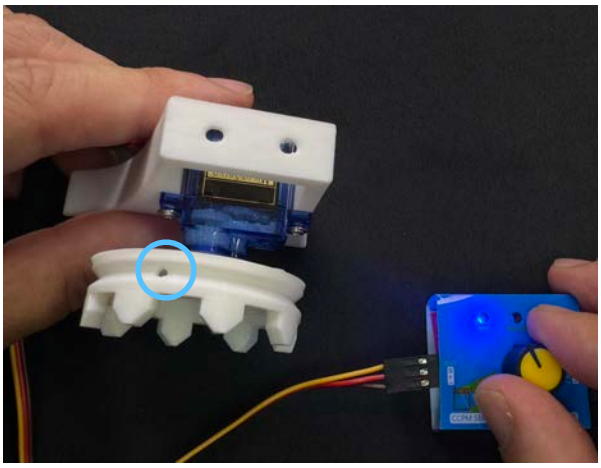
Base assembly

5 Assembling the pulley



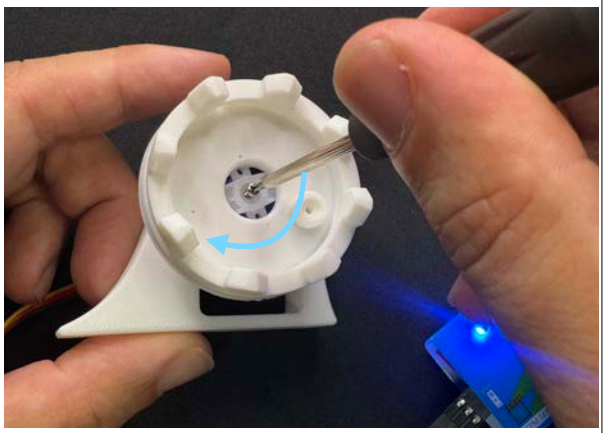
Rotate the controller in the opposite direction and confirm that the (3) servo motor rotates counterclockwise.

6 Assembling the pulley



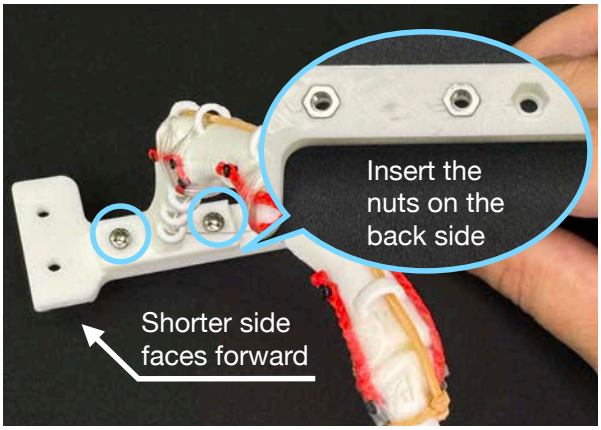
View from above in Step 5.

7 Assembling the pulley



Using the (5) horn fixing screw, secure the (4) servo horn to the (3) servo motor.

8 Assembling the base



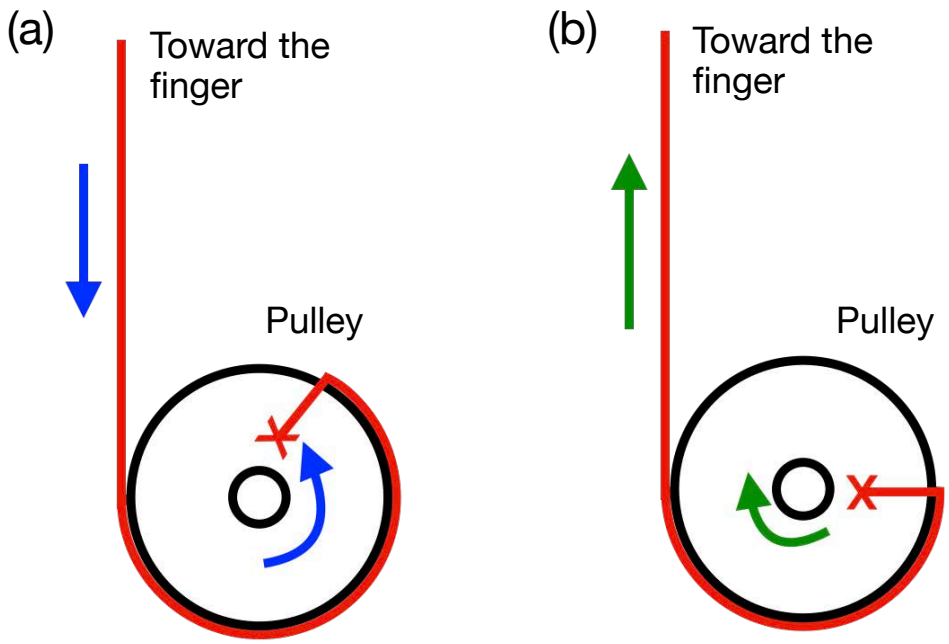
Using the (40) bolt and (41) nut, fix the human-like joint middle finger to the (9) base (center).

Assembly procedure

Base assembly

!

How the wire-driven mechanism works



Side view with the servo motor positioned toward the back

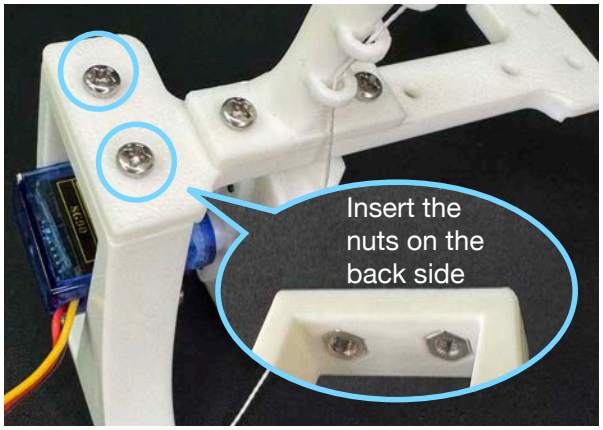
(a) When the servo motor rotates counterclockwise, it winds up the wire. Because the wire is connected to the finger, winding the wire causes the finger to flex.

(b) When the servo motor rotates clockwise, the wire is released. The loosened wire is then pulled back by the finger, which is extended by the rubber band.

Assembly procedure

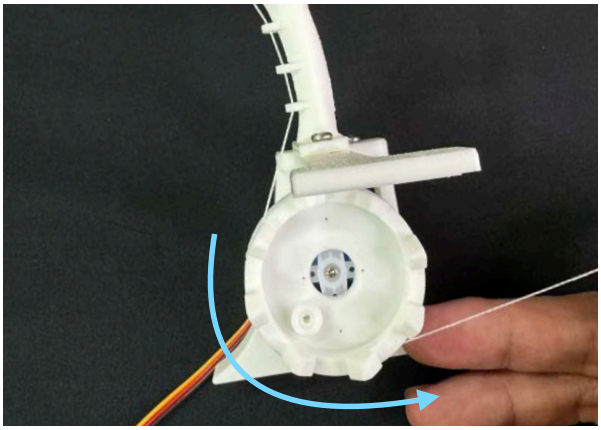
Base assembly

9 Assembling the base



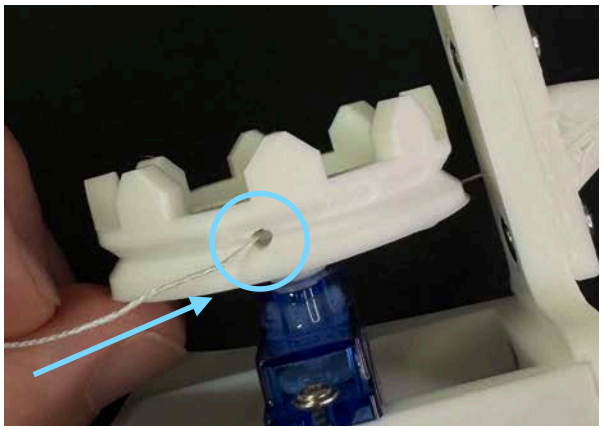
Using the (40) bolt and (41) nut, fix the (8) base (left) to the (9) base (center).

10 Assembling the pulley



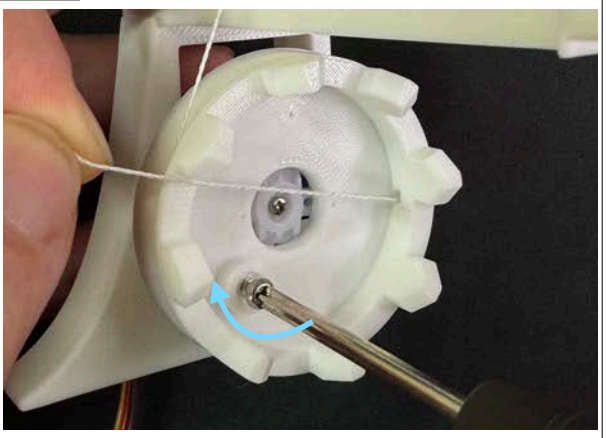
Wrap the (26) muscle wire halfway around (11) pulley 1.

11 Assembling the pulley



Thread the (26) muscle wire through the hole in (11) pulley 1.

12 Assembling the pulley

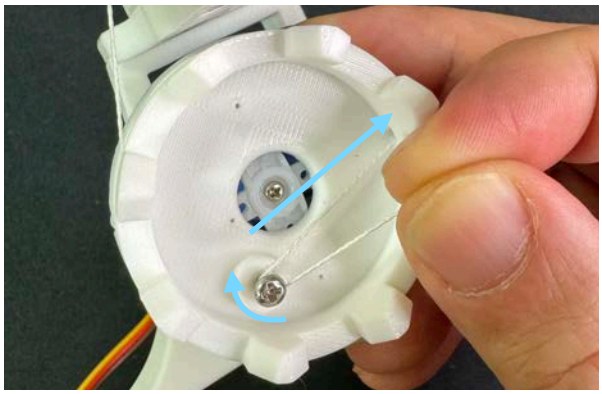


Lightly fasten the (39) tapping screw to (11) pulley 1.

Assembly procedure

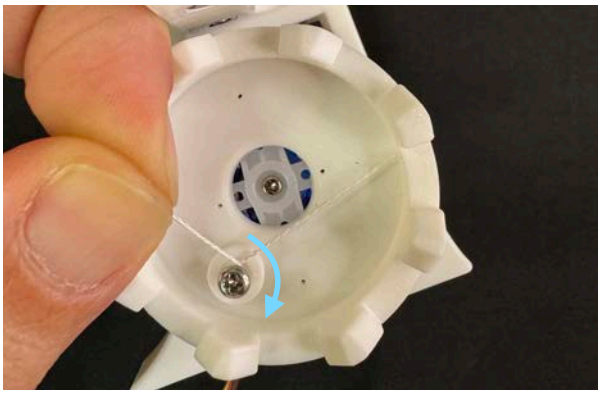
Base assembly

13 Assembling the pulley



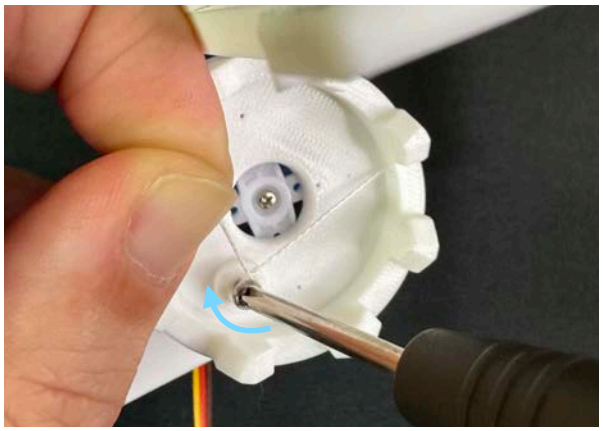
With (11) pulley 1 rotated fully clockwise, hook and pull the (26) muscle wire until just before the finger starts to flex.

14 Assembling the pulley



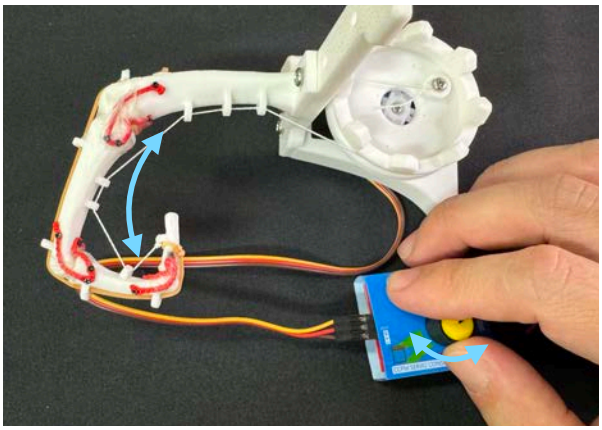
Wrap the (26) muscle wire around the temporarily fastened (39) tapping screw about two turns, following the tightening direction of the screw.

15 Assembling the pulley



Tighten the (39) tapping screw until the wire is firmly secured and cannot slip out.

16 Function check



Rotate the controller and confirm that the finger flexes in sync with the motion.

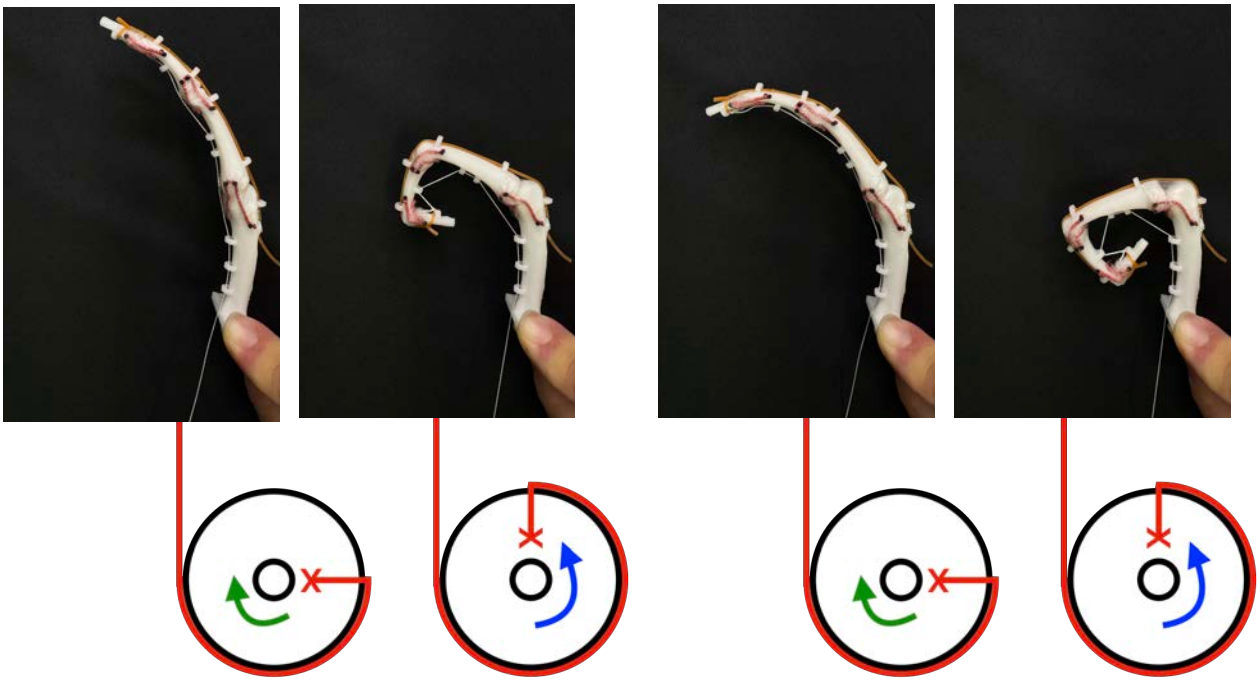
TIPS The range of finger flexing changes depending on the wire tension set in Step 14.

Assembly procedure

Base assembly

! **How to adjust the wire tension**

(a) (b)



(a) If the wire is attached while the pulley is at its maximum clockwise position (left) and the finger is fully extended, the finger will not flex fully when the pulley reaches its maximum counterclockwise position (right).

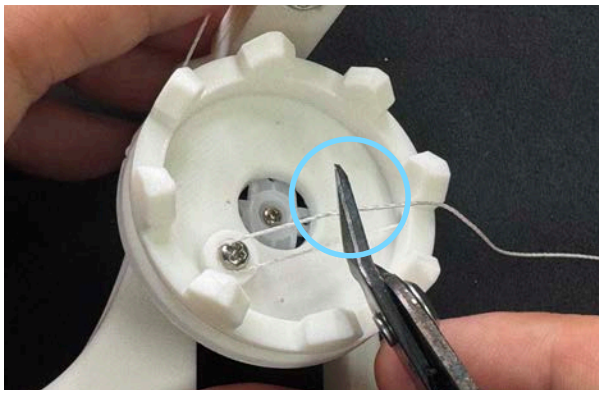
(b) To ensure that the finger flexes fully when the pulley is at its maximum counterclockwise position (right), attach the wire while the pulley is at its maximum clockwise position (left) and the finger is slightly flex.

TIPS Increasing the diameter of the winding pulley increases the amount of wire taken up, but it also reduces the pulling force.

Assembly procedure

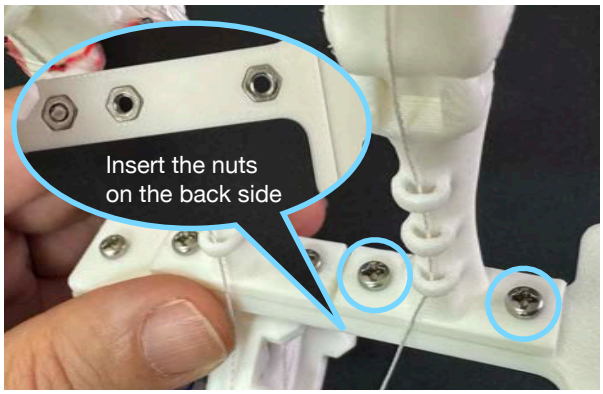
Base assembly

17 Assembling the pulley



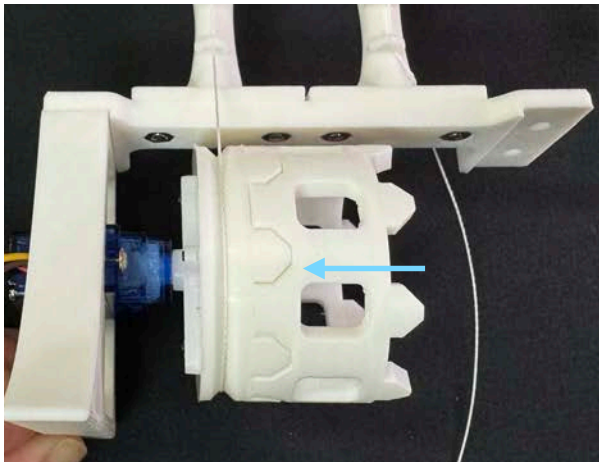
Trim any excess (26) muscle wire using the (c) wire cutters. (If you want to keep adjusting and experimenting, leave the wire uncut.)

18 Assembling the base



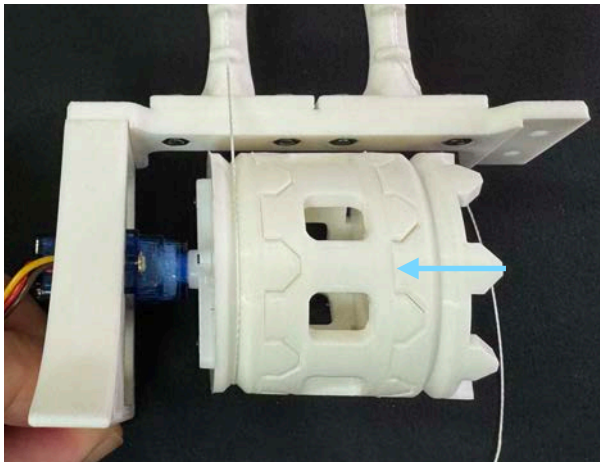
Using the (40) bolt and (41) nut as in Step 8, attach the revolute-joint middle finger to the (9) base (center).

19 Assembling the pulley



Insert (12) pulley 2 into (11) pulley 1.

20 Assembling the pulley

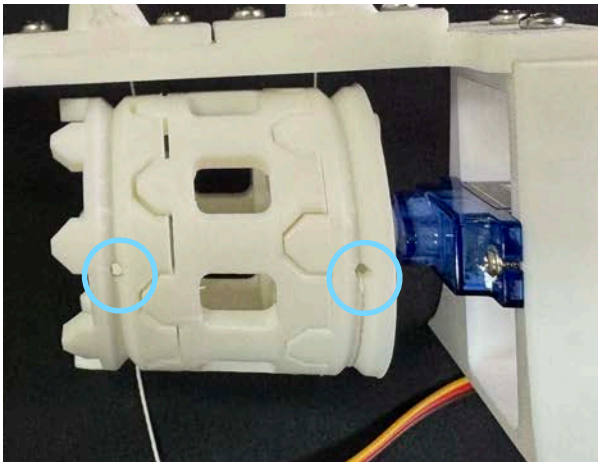


Insert (13) pulley 3 into (12) pulley 2.

Assembly procedure

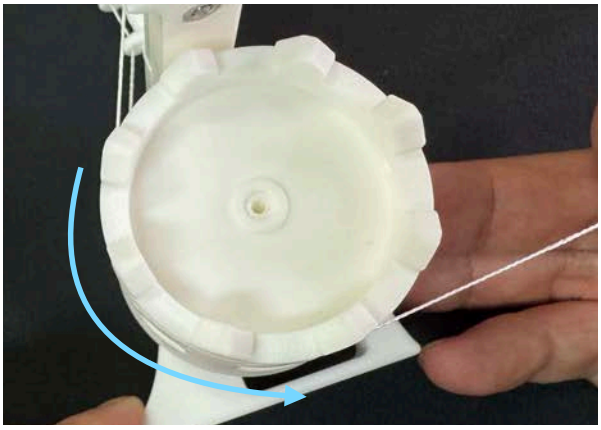
Base assembly

21 Assembling the pulley



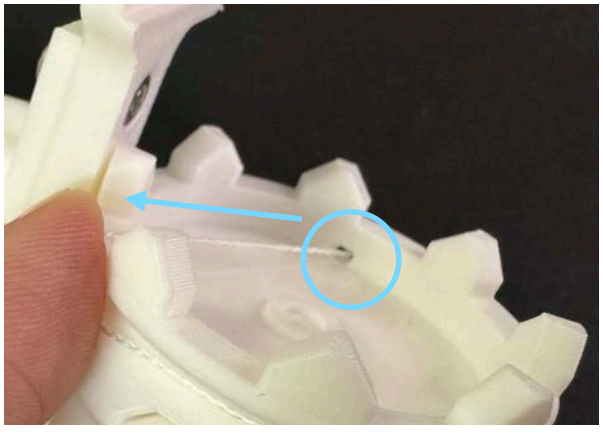
View from the rear in Step 20.

22 Assembling the pulley



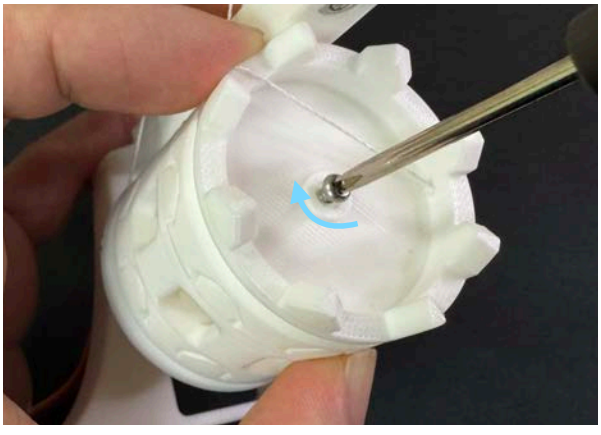
Wrap the (36) muscle wire halfway around (13) pulley 3.

23 Assembling the pulley



Thread the (36) muscle wire through the hole in (13) pulley 3.

24 Assembling the pulley

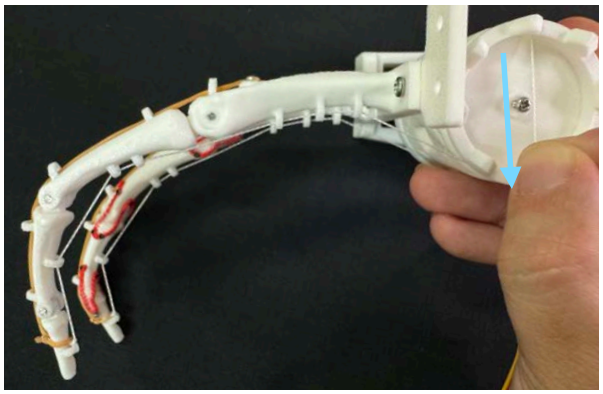


Lightly fasten the (39) tapping screw to (13) pulley 3, with the pulley rotated fully clockwise.

Assembly procedure

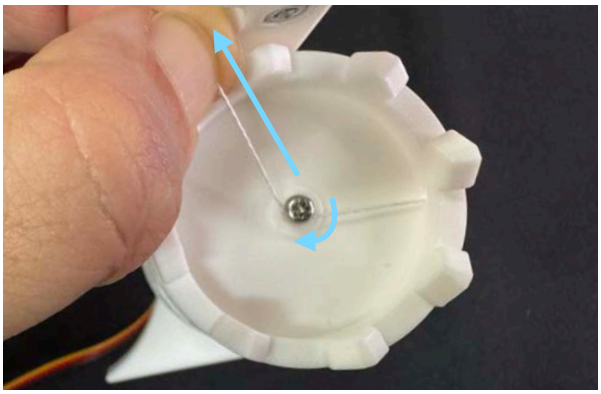
Base assembly

25 Assembling the pulley



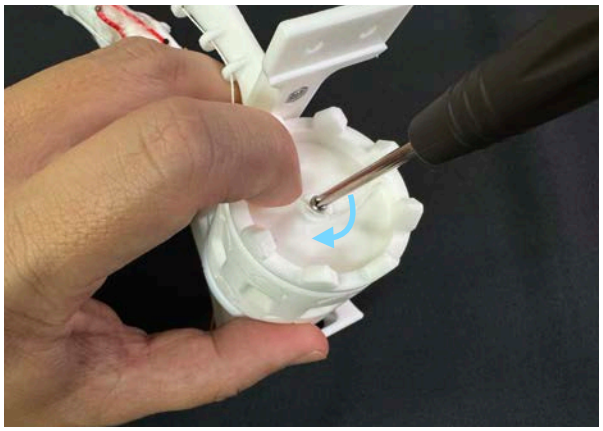
Pull the (36) muscle wire until the flexion motion of the revolute-joint middle finger becomes similar to that of the human-like joint middle finger.

26 Assembling the pulley



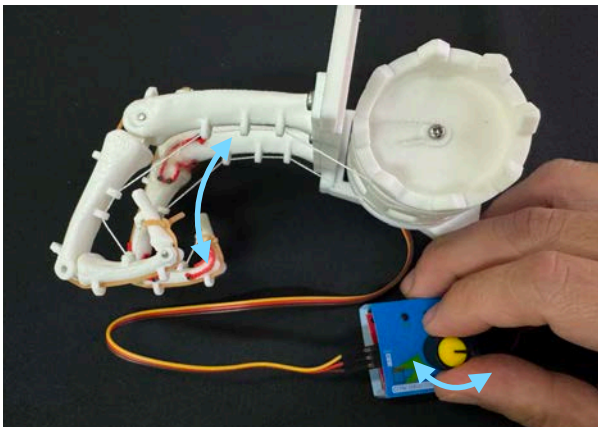
Wrap the (36) muscle wire around the temporarily fastened (39) tapping screw about two turns, following the tightening direction of the screw.

27 Assembling the pulley



Tighten the (39) tapping screw until the wire is firmly secured and cannot slip out.

28 Function check



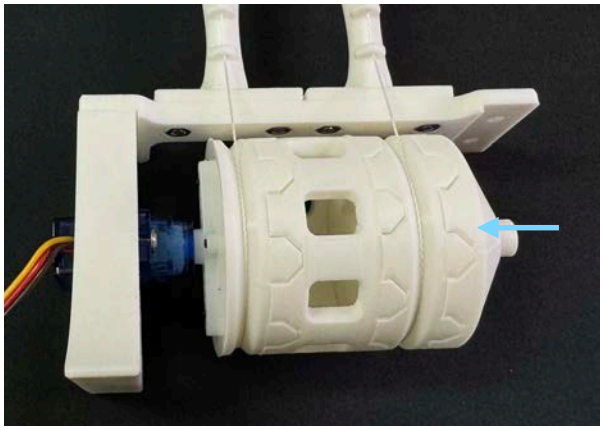
Rotate the controller and confirm that the finger flexes in sync with the motion.

TIPS In Step 25, adjust the revolute-joint middle finger by directly flexing the joints by your hand. This type of mechanism is called an underactuated mechanism.

Assembly procedure

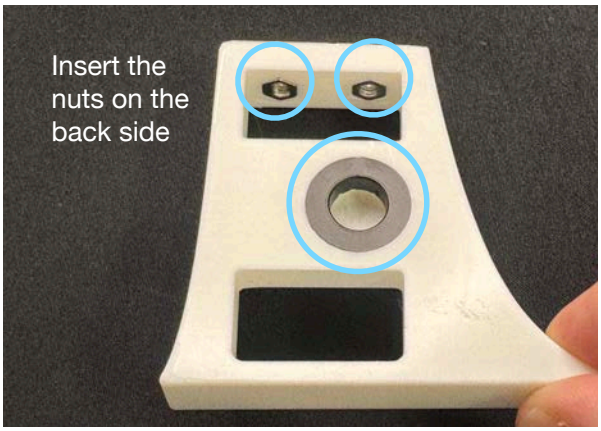
Base assembly

29 Assembling the pulley



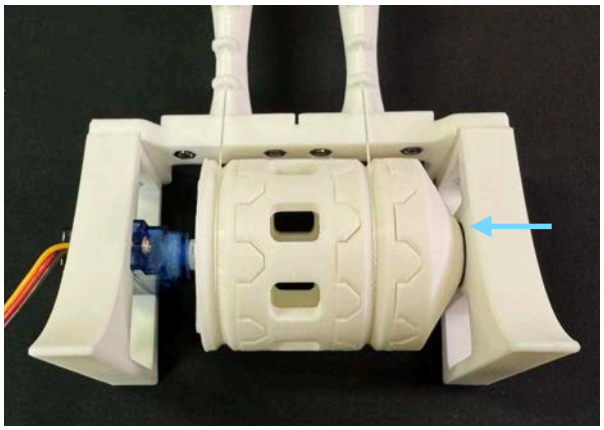
Cut off any unnecessary (36) muscle wire and insert (14) pulley 4 into (13) pulley 3.

30 Assembling the base



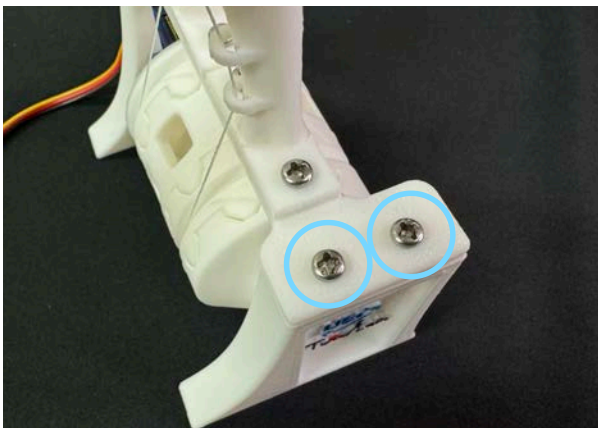
Insert the (42) flanged bush and (41) nut into the (10) base (right).

31 Assembling the base



Attach the (42) flanged bush to (14) pulley 4.

32 Assembling the base



Referring to Step 9, use the (40) bolt and (41) nut to attach the (10) base (right) to the (9) base (center).

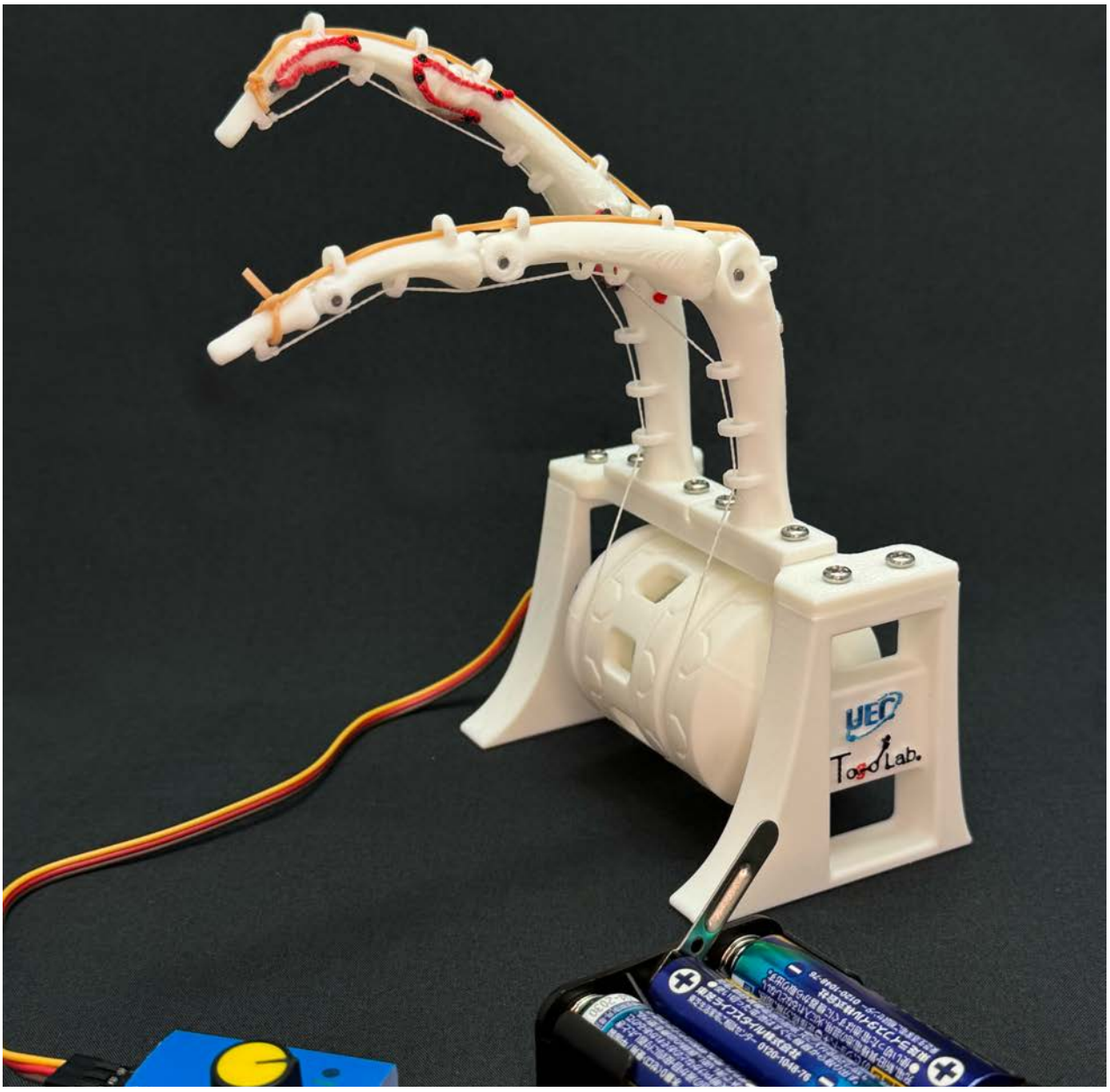
TIPS The logo on the (10) base (right) is colored with an oil-based marker.

Assembly procedure

Base assembly

33

Finished!



The anthropomimetic middle finger robot is now complete. Great work, and thank you for building it!

Let's explore!

About Robots

- What is a microcontroller that controls motor motion?
- What kinds of sensors exist in the world?
- What kinds of robot hands exist in the world?

About Making Things

- Besides 3D printers, how can resin parts be manufactured?
- What kinds of 3D printers exist in the world?
- What kinds of screws exist in the world?

About the Human Body

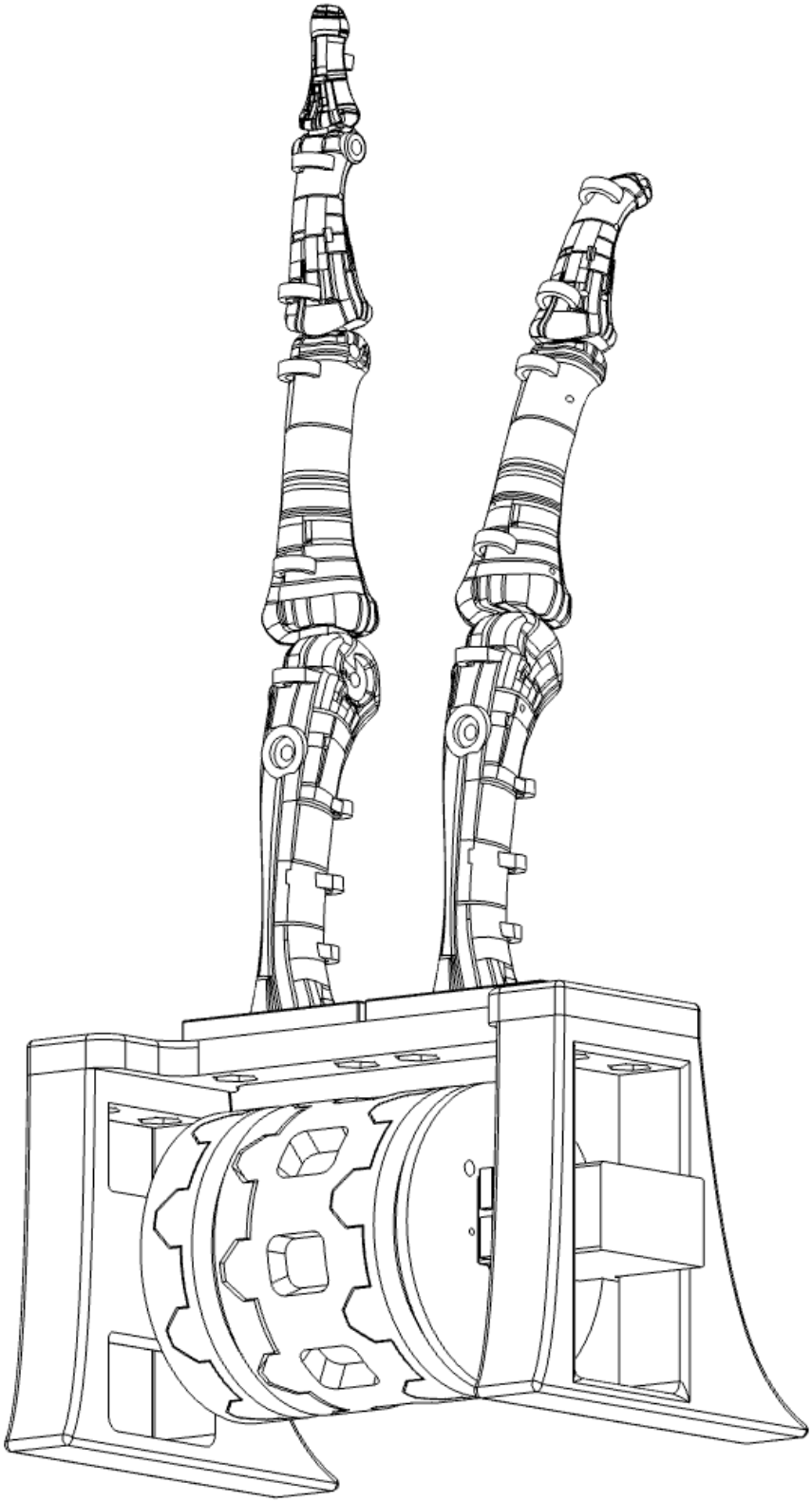
- How many bones and muscles are there in the human body?
- Which human body structures are omitted in this kit?
- How are other body parts structured?

Independent Research Topics

- What is the difference between revolute and sliding–rolling joints?
- How could the omitted human body structures be reproduced?
- How could the entire hand be reproduced?
- Is there an easy way to make ligaments? (Let us know if you come up with one!)

Let's Modify It!

- Try changing the motor (MG90S, MG90D, etc.)
- Try controlling it with a microcontroller (Arduino, Raspberry Pi, etc.)
- Try adding sensors (bend sensors, FSRs, etc.)



Anthropomimetic Middle Finger Robot Assembly Manual

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