Kangaroo Jumping Model

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Our Design

Kangaroo Jumping Model

Kangaroo Movement

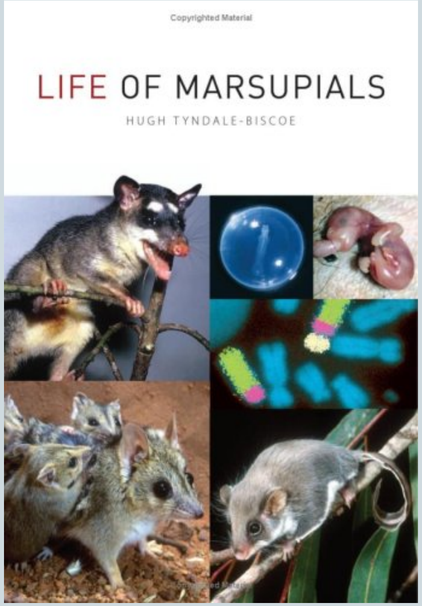
- Tendons stretched when standing
- To launch, muscles pull on the leg bones and straightening them
- Tendons relax
- Kangaroo launches
- Tendons stretched again when landing
- Can jump up to 10 feet high
- Leaps on average 12 feet long

Competing Products

Mechanical Kangaroo: ~$13 - $20

Uses Gears.
Not analogous to real motion.

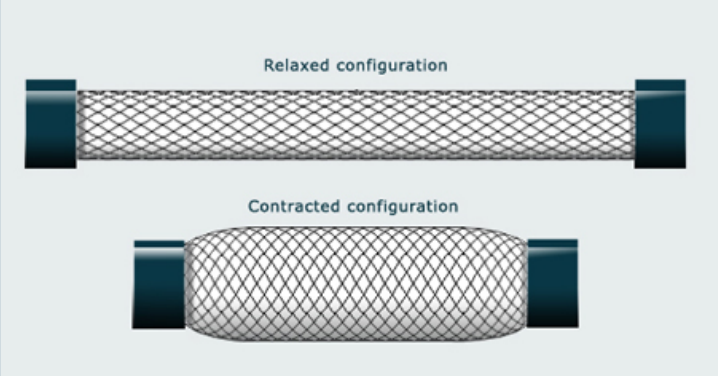
Books: ~$150



Shows
diagrams with
explanation.

Our Focus

- Purely Vertical Jumping
- Elastic Chords for Tendons
  - Different lengths and elasticity's
- Pneumatic Artificial Muscles
  - Pressurized and de-pressurized



Stakeholder Needs

Educational Value	Teachers, Students, Admin.
Safety	Teachers, Students
Design	Teachers, Manufacturers
Marketability	Investors
Distribution	Manufacturers, Developers
Power	Teachers
Aesthetics	Teachers, Students
U.I./Experience	Teachers, Students

Stakeholder Needs

- Educational Values
  - Must demonstrate biological system or phenomenon
  - Must hold attention of 14-17 yr olds for lesson
  - Accompanying documentation must be well-written and universally understood (multi-lingual, diagrams)
  - Must promote analytical and experimental skills
  - Must be versatile to accommodate multiple levels of students/teachers
  - Demonstrate a concept with underlying math and physics

Final Design - Educational Goals

- Model the mechanics of jumping by a kangaroo
- Show the interaction between the muscles and tendons
  - Muscles contract and pull on bones via tendons
  - Product jumps
  - Tendons stretch upon landing
- No "black box"
- Accurate depiction of leg structure

Final Design - Performance Goals

- Want the product to jump at least 6 inches
- Rebound height will be dependent on the elasticity of the bands/bungees
- Pneumatic system should be safe and easy to use while still providing over 60psi
- Students should be able to alter tendon elasticity and placement with measurable variations in jump height
- Students should be able to alter muscle strength (change the muscle) to exert different forces
- Students should be able to change the bone length for comparisons of multiple animals
- Should effectively promote the understanding of energy conservation and loss with different configurations with calculations to support
- Lightweight system should be able to broken down and transported by the average teacher.

Critical Functionalities

<table>
<tr><th>Inputs</th><th>Subsystem</th><th>Function</th><th>Output</th></tr>
<tr><td rowspan="9">Muscle Force (Air Pressure, Electricity)

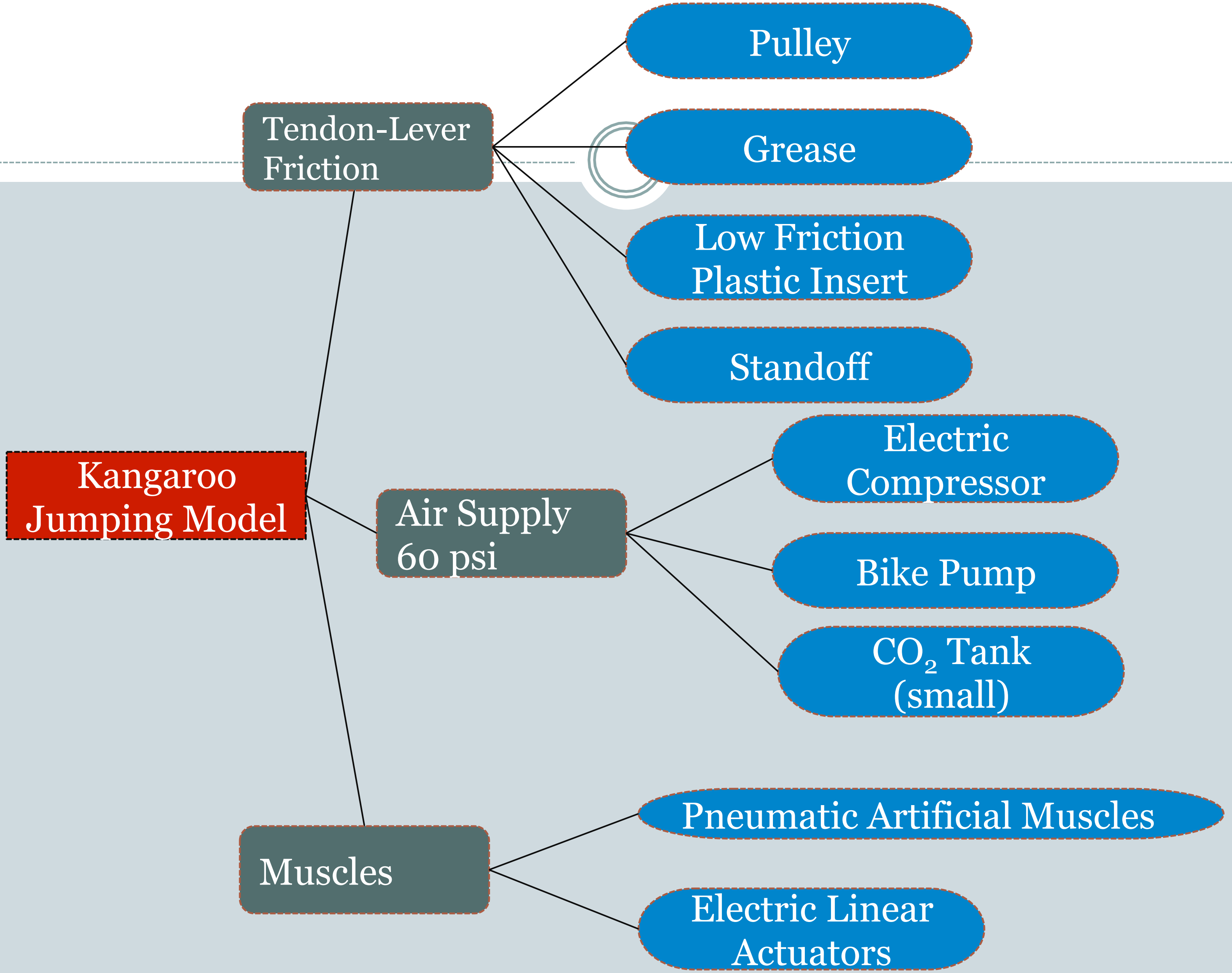
Placement on Bone

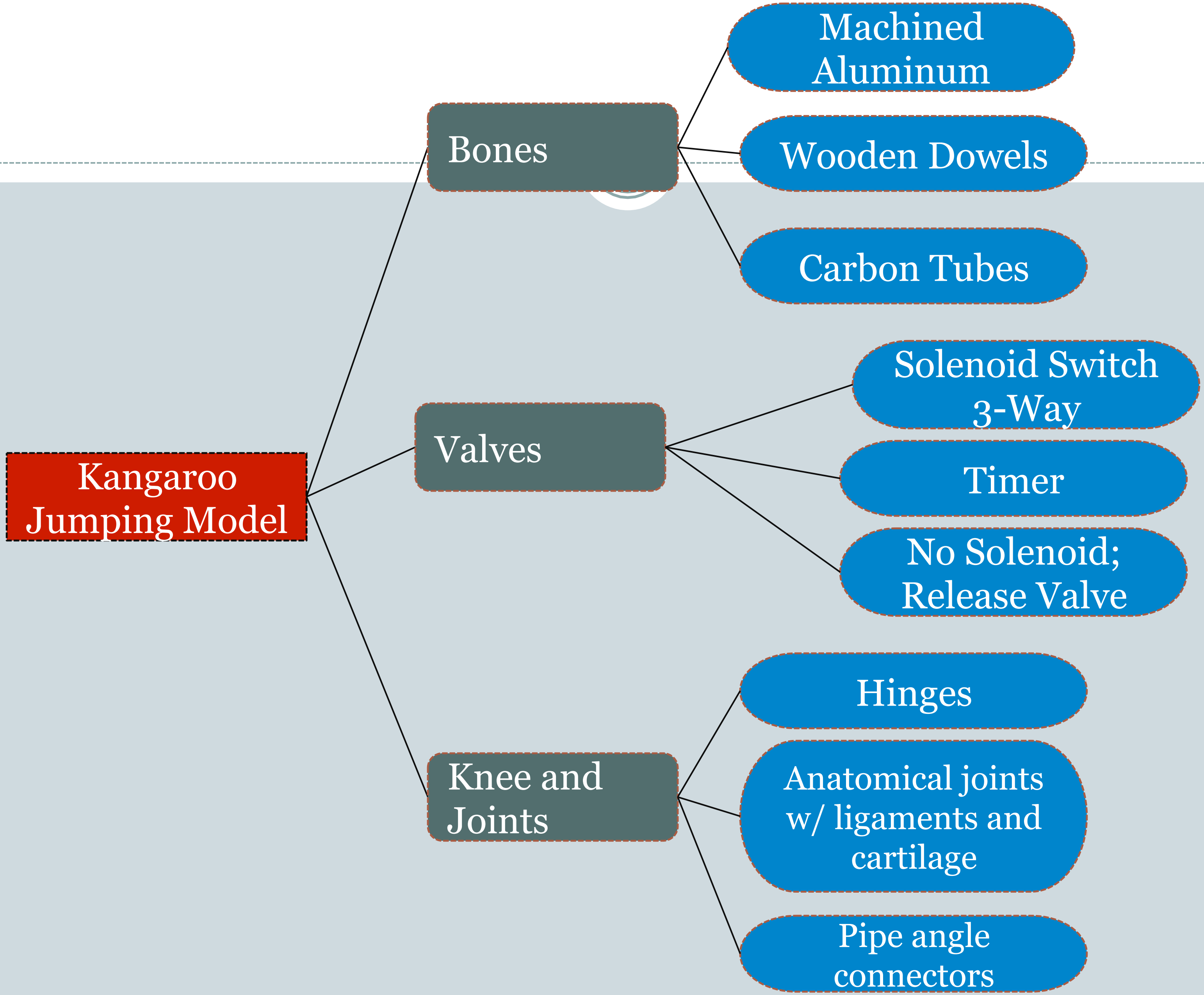
Muscle Actuation Duty Cycle

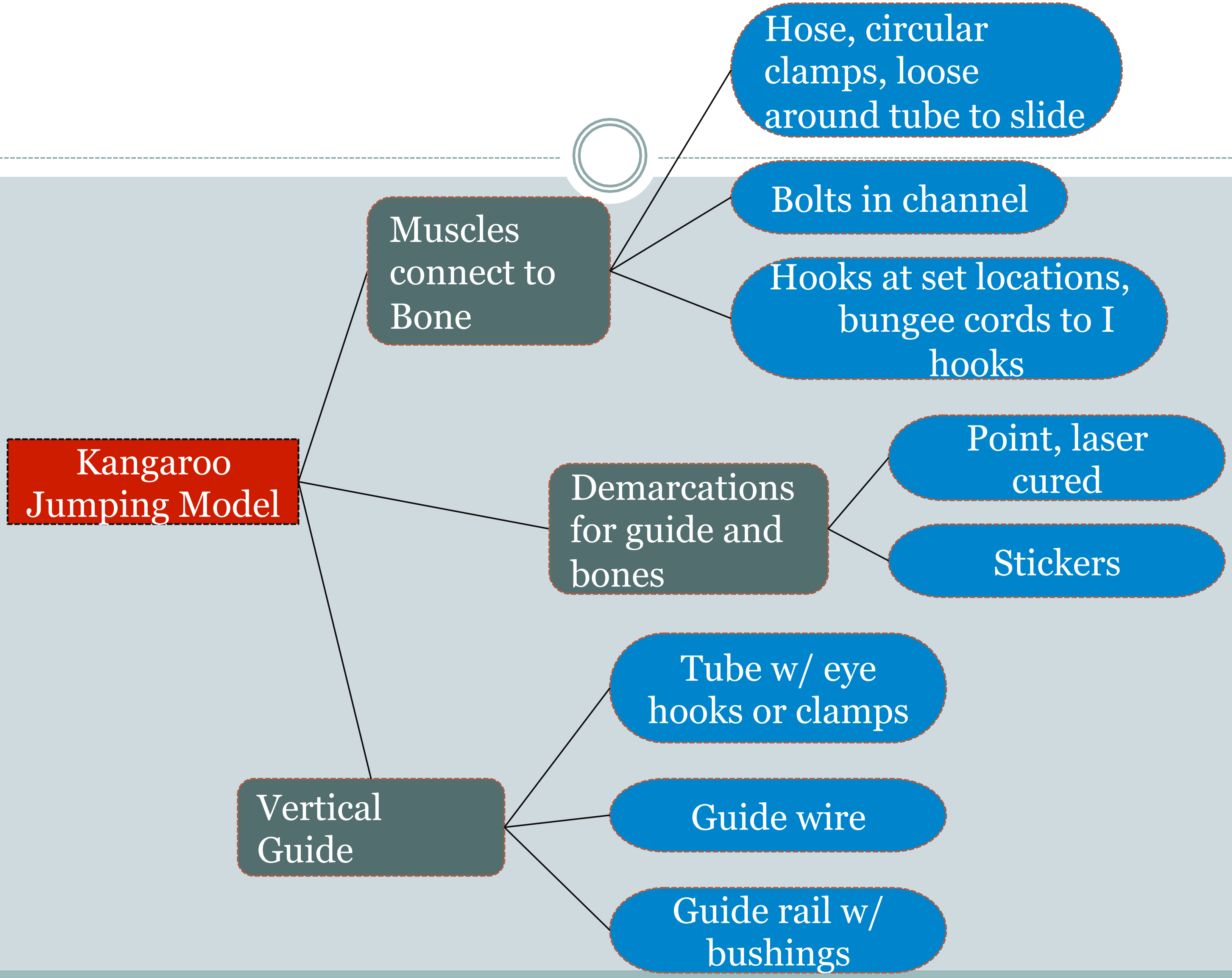
Overall cross-sectional area of tendon elastic bundles</td><td>Muscles</td><td>Provides initial force (Compression)</td><td rowspan="9">Height of jump

Height of subsequent jumps

Understanding of tendon importance, not muscle importance on jump</td></tr>
<tr><td>Bones</td><td>Structural part of system</td></tr>
<tr><td>Tendons</td><td>Stores energy for jump/converts kinetic energy for subsequent jumps</td></tr>
<tr><td>Air Supply</td><td>Applies air pressure to system</td></tr>
<tr><td>Valve</td><td>Allows muscles to hold air pressure</td></tr>
<tr><td>Knee + Joints</td><td>Allows movement within system while keeping system help together</td></tr>
<tr><td>Vertical Guide</td><td>Keeps system in line for jump</td></tr>
<tr><td>Tendon Connections to Bones</td><td>Applies force from tendons to bones</td></tr>
<tr><td>Demarketions for rulers, guide and bones</td><td>Easier to measure Height of jump</td></tr>
</table>


Kangaroo Jumping Model
Tendon-Lever Friction
Pulley
Grease
Low Friction Plastic Insert
Standoff
Air Supply 60 psi
Electric Compressor
Bike Pump
CO_2 Tank (small)
Muscles
Pneumatic Artificial Muscles
Electric Linear Actuators


Kangaroo Jumping Model
Bones
Machined Aluminum
Wooden Dowels
Carbon Tubes
Valves
Solenoid Switch 3-Way
Timer
No Solenoid; Release Valve
Knee and Joints
Hinges
Anatomical joints w/ ligaments and cartilage
Pipe angle connectors


Kangaroo Jumping Model
Muscles connect to Bone
Hose, circular clamps, loose around tube to slide
Bolts in channel
Hooks at set locations, bungee cords to I hooks
Demarcations for guide and bones
Point, laser cured
Stickers
Vertical Guide
Tube w/ eye hooks or clamps
Guide wire
Guide rail w/ bushings

Main-System	Sub-Systems	Options	Comments
Kangaroo Jumping Model	Tendon-Lever Friction	A) Pulley B) Grease C) Low Friction Plastic insert **D) Standoff**	A) Store bought B) Dirty, maintenance required C) Manufacturing step D) Easily adjustable, no moving parts
	Air Supply 60 psi	A) Electric Compressor **B) Bike Pump** C) CO_2 Tank (paintball gun)	A) $$, heavy B) Cheap, light C) Refillable or cheap to replace
	Muscles	**A) Pneumatic Artificial Muscles** B) Electric linear actuators	A) Air pressure, may avoid electricity B) Costly electronics
	Bones	A) Machined Alum B) Carbon tubes **C) Wooden Dowel**	A) Aesthetic, heavy, slot for muscles adjacent B) Costly, light flexible, durable C) Cheap, easy to cut, strong
	Valves	**A) Push button valve** B) Timer C) No solenoid, just release valve D) Switch solenoid 3-way	A) Cheap, effective B) Unnecessary unless doing constant pumping, costly C) Cheapest D) Expensive, needs electrical power

Main-System	Sub-Systems	Options	Comments
Kangaroo Jumping Model	Knee and Joints	A) Hinges B) Anatomical joints w/ ligaments and cartilage **C) Pipe Angle Connectors**	A) Easy, cheap, low friction B) Out of focus, not anatomy model, added complication
	Muscle connect to Bone	A) Hose, circular clamps, loose around tube to slide B) Bolts in channel **C) Elastic fixed with hose clamp**	A) Simple, store bought B) Not variable, more pieces, easier switching C) Easily variable
	Demarcations for rulers, guide and bones	A) Point, laser cured **B) Mounted Meterstick**	A) Material must be laser cutter safe B) Outsourced unless pound outline
	Vertical Guide	A) Tube w/ eye hooks or clamps B) Guide wire **C) Guide rail w/ bushings**	A) Rigid, allows ruling, possibly low friction B) Cheap, flexible, may allow too much oscillation

Subsystem Decisions

- Based on stakeholder needs and target specs
- Example:

Subsystem: Air Supply	Specs met (Others Don't)	Specs not met (Others Do)
Electric Compressor		-Must cost less than $200 to develop/manufacture -Quiet Operation -Portable for teachers traveling between classrooms and schools
Bike Pump	-Must be versatile to accommodate multiple levels of students/teachers -Self or human powered	
CO2 Tank (paintball gun)		-Durable to misuse -Not to be stolen by students -Should not depend on consumables

Design of Final Product

- Subsystems
  - Kangaroo Leg Model
    - Bones (lightweight wood)
    - Joints
    - Ability to change mass above hip (post and weights with holes)
    - Variable positioning of tendons on bone (quick release clamps)
    - Variable tendon elasticity (larger/smaller bundles with known K)
  - Pneumatic System
    - Air source (bike pump - no reliance on electric)
    - Pressure tank and regulator (low cost PVC)
    - Pneumatic Muscles (can be made for <$5 each with raw materials)
    - Push button valves for pressurization and blow-off (easy to use and learn efficient jump timing)

Critical Elements

- Muscles
- Bones & Joints
- Tendons/Tendon placement
- Pneumatic system
- Ruled vertical guide
- Lab manual

Critical Elements

- Challenges
  - Simplifying Kangaroo leg to allow for only vertical motion
  - Balancing the prototype before and after the jump
  - Maintaining some biological accuracy
  - Correct depiction of muscle and tendon interaction
  - Creating lab experiments
  - Muscle performance

- Trade-offs
  - Restricted to only vertical movement
  - Limited depiction of muscles in the leg
  - Overall ability to jump high

Concerns

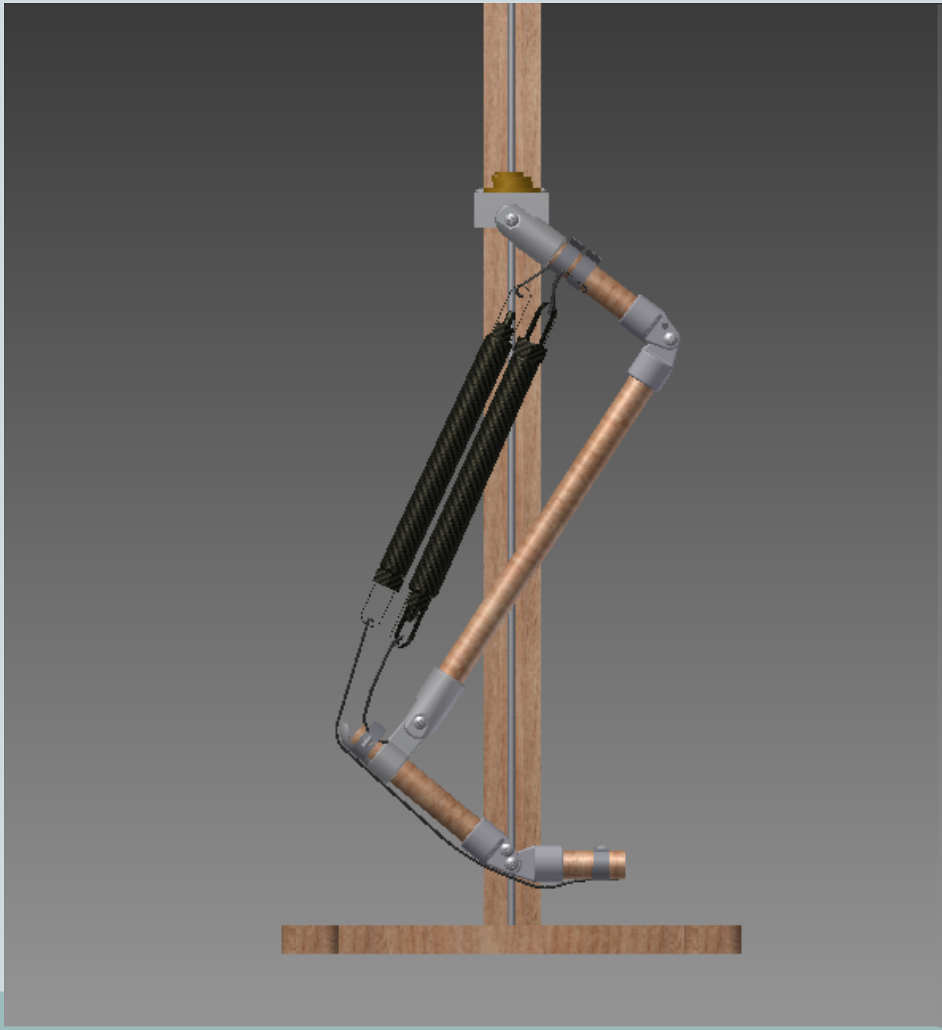
We Pay For Performance!

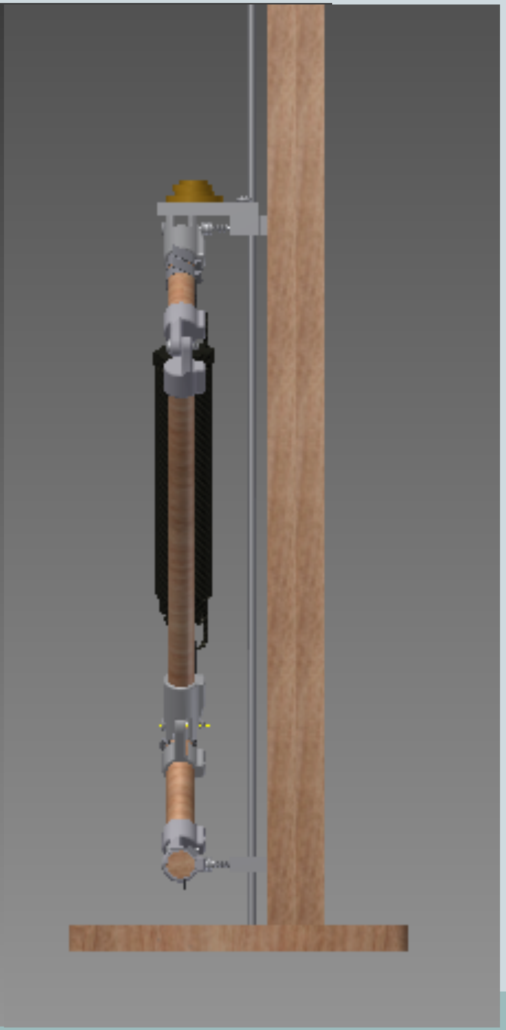
- Performance
  - Not enough force to jump
  - Friction on vertical guide
  - Part durability
  - Air pressure regulation
  - Joint and tendon friction
  - Force absorption due to bending bones or non-rigid structure
- Educational
  - Effectiveness of energy conservation concepts
  - Biological inspiration
- Design must meet needs and target specs

Prototype - Performance Goals

- Prototype should jump at least 3 inches high
- Rebound height will be dependent on the elasticity of the bands/bungees
- Pneumatic system should be safe and easy to use while still providing over 60psi
- Students should be able to alter tendon elasticity and placement with measurable variations in jump height
- Should effectively promote the understanding of energy conservation and loss with different configurations

Detailed Design of Prototype





How it Works

The important muscles of the lower leg used by kangaroos in jumping are the calf muscles, gastrocnemius and plantaris. The first of these is the larger and the main agent responsible for extending the foot and so lifting the body off the ground. It begins on the underside of the femur (or thigh bone) and swells into two large muscle masses, which then narrow at the ankle into a powerful tendon that is attached to the heel. The second smaller plantaris muscle is also attached to the thigh bone but its tendon passes round the heel and attaches to the sole of the foot, especially to the large 4th digit, the great toe of the kangaroo with which it drives off from the ground (Fig. 9.11). At the end of a stride, while the kangaroo is in the air, the two hind feet are fully extended forward; then as the feet strike the ground they are quickly flexed, so that the two muscles and their tendons are stretched to their full extent. The muscles themselves change only slightly in length, because the muscle fibres are arranged in a pennate manner, but in a large kangaroo the 200 mm long tendons are stretched by 11 mm. The elastic energy stored in the stretched tendons is rapidly released in the next jump as the tendons shorten.

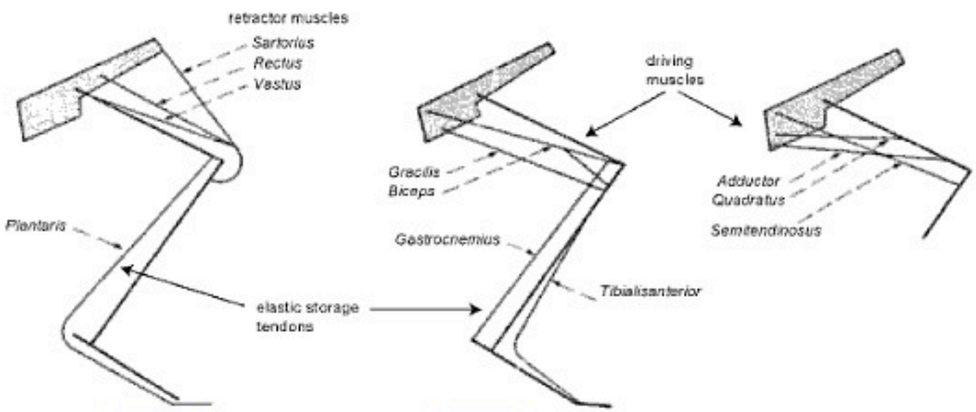


Figure 9.11: Diagram of the hind limb of a kangaroo to show the disposition of the main muscles involved in hopping: the muscles that deliver the main driving force and those involved in retraction are grouped around the hip, while the muscles of the lower limb store the elastic energy when the kangaroo first lands at the end of a hop. After Alexander and Vernon (1975).

JUMPING

Gastrocnemius

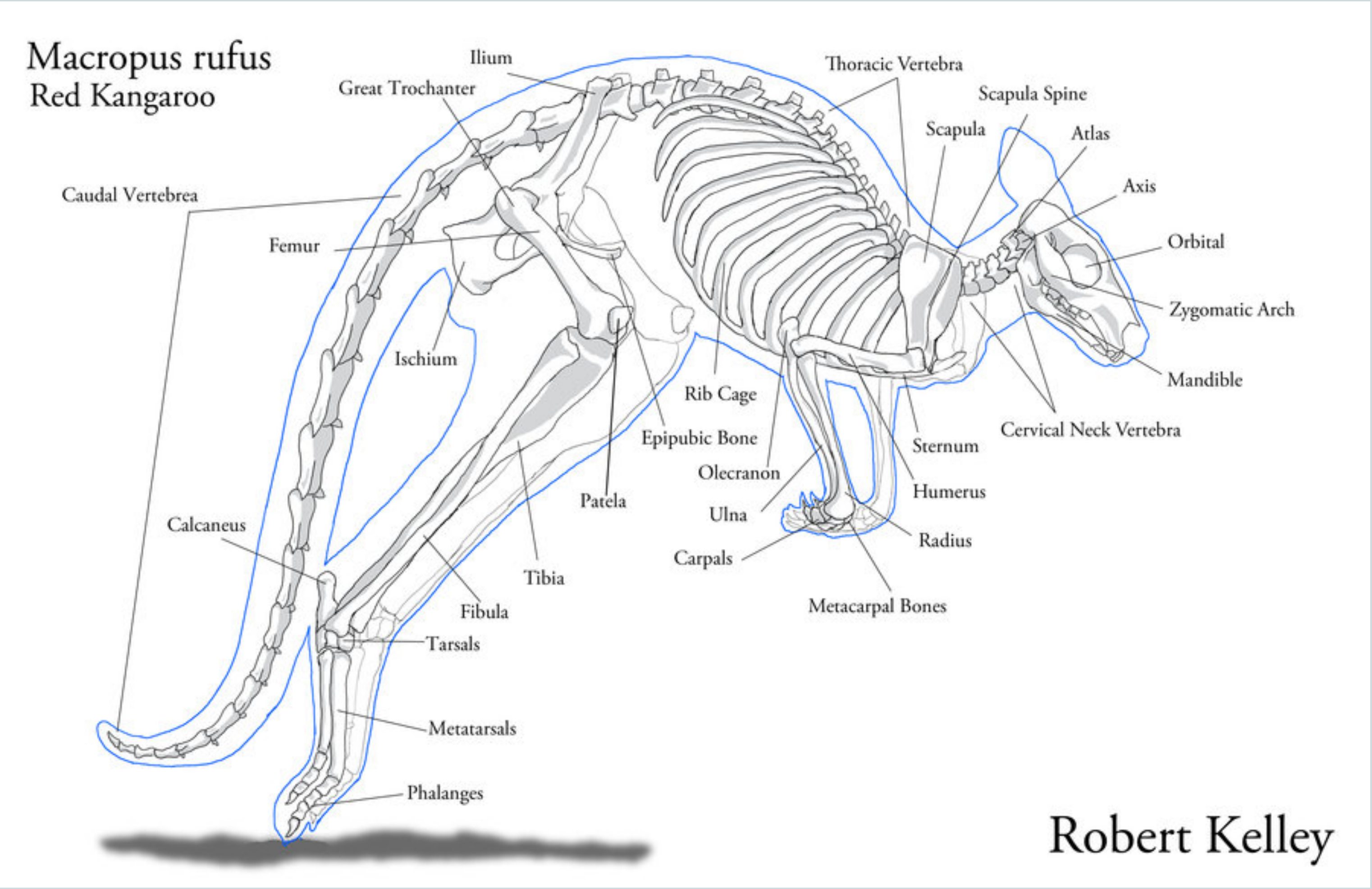
- Larger of the two main jumping muscles.
- Connects femur (thigh) to heel via tendon

Plantaris

- Connects femur to large toe
- Wraps around heel of foot and connects at the sole via tendon

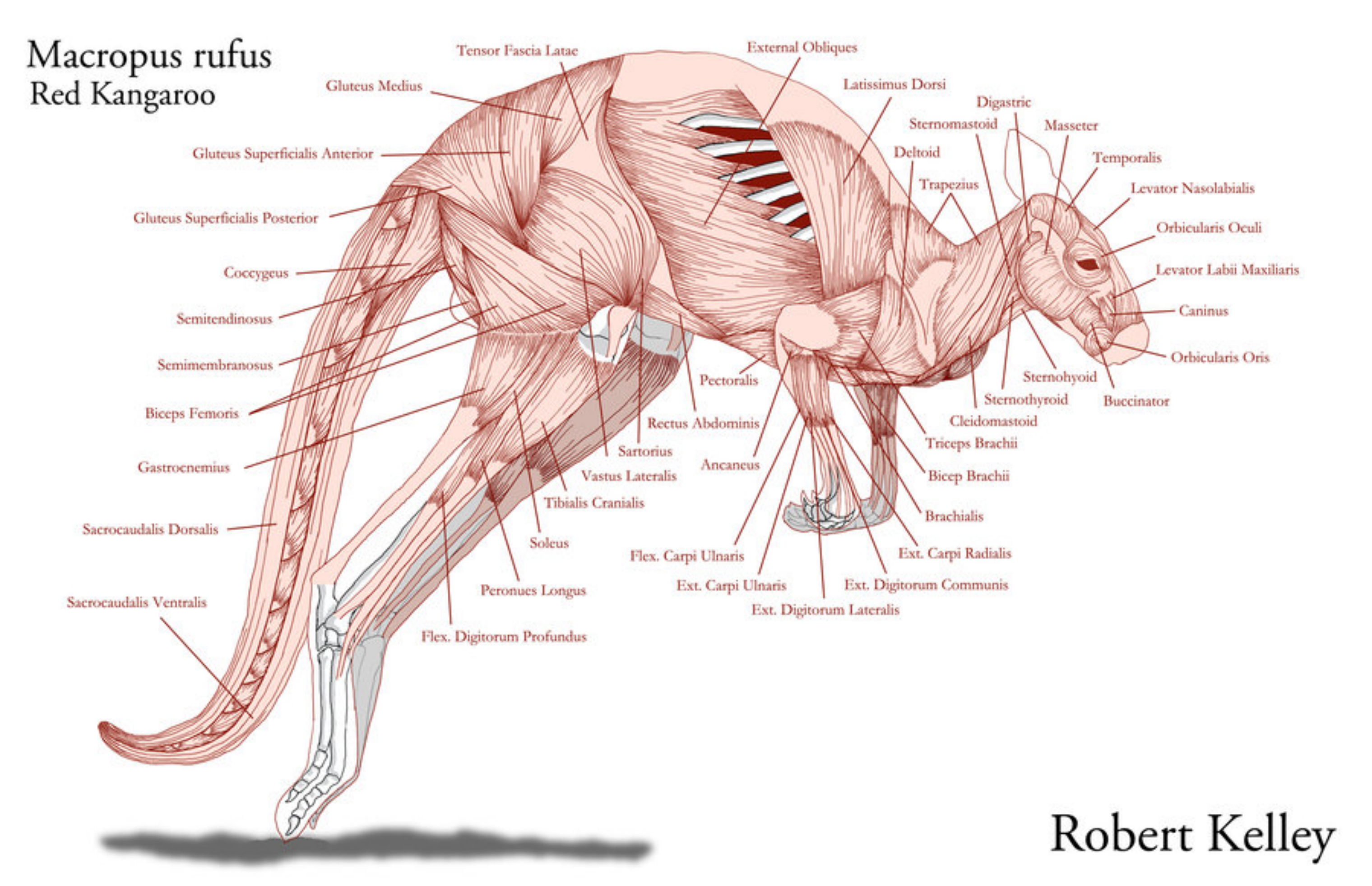
Landing stretches tendons and stores energy for next bound

How it Works



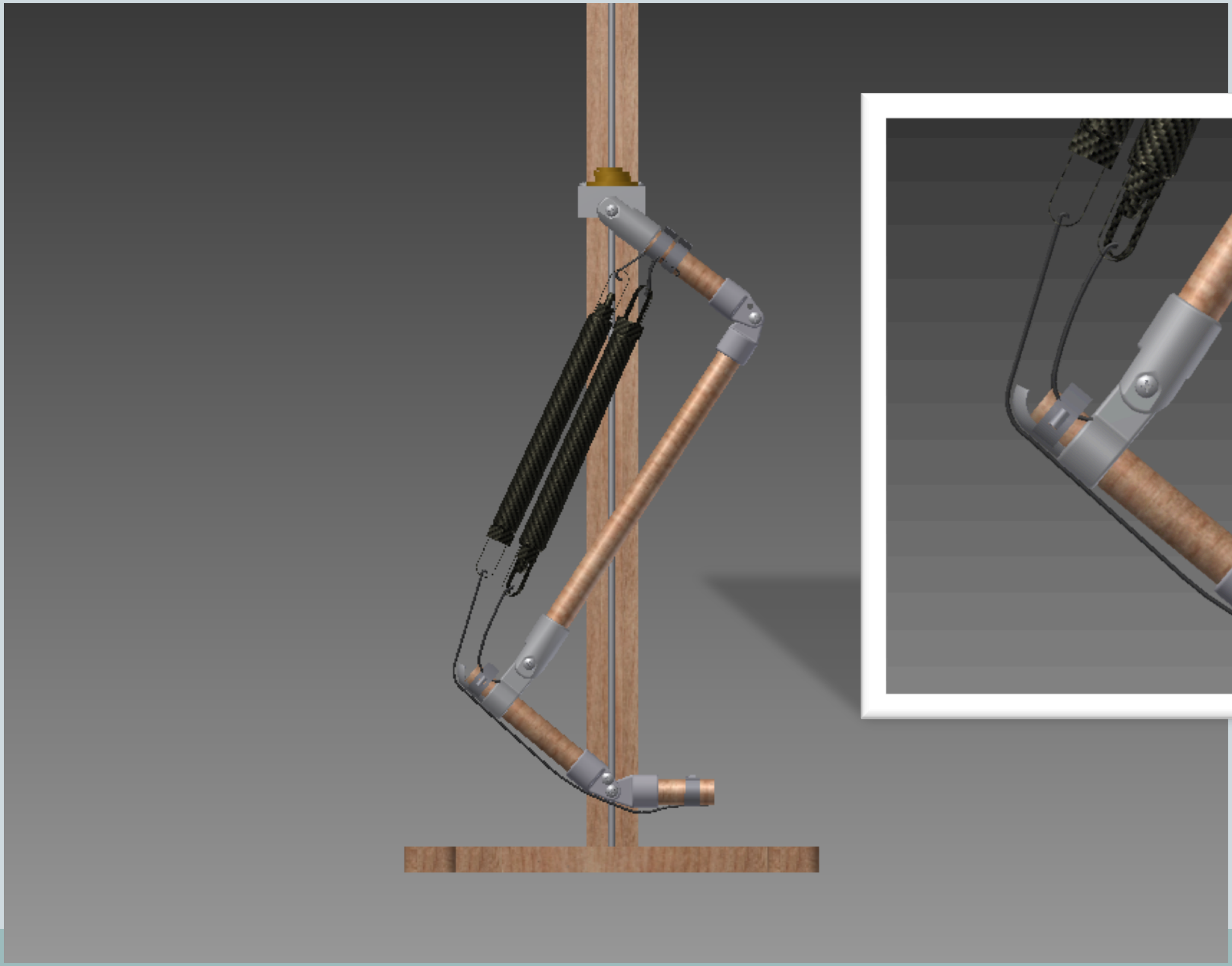
Macropus rufus
Red Kangaroo
Ilium
Great Trochanter
Thoracic Vertebra
Scapula Spine
Scapula
Atlas
Axis
Orbital
Zygomatic Arch
Mandible
Cervical Neck Vertebra
Caudal Vertebrea
Femur
Ischium
Rib Cage
Epipubic Bone
Olecranon
Sternum
Humerus
Ulna
Radius
Carpals
Metacarpal Bones
Patela
Tibia
Fibula
Calcaneus
Tarsals
Metatarsals
Phalanges
Robert Kelley

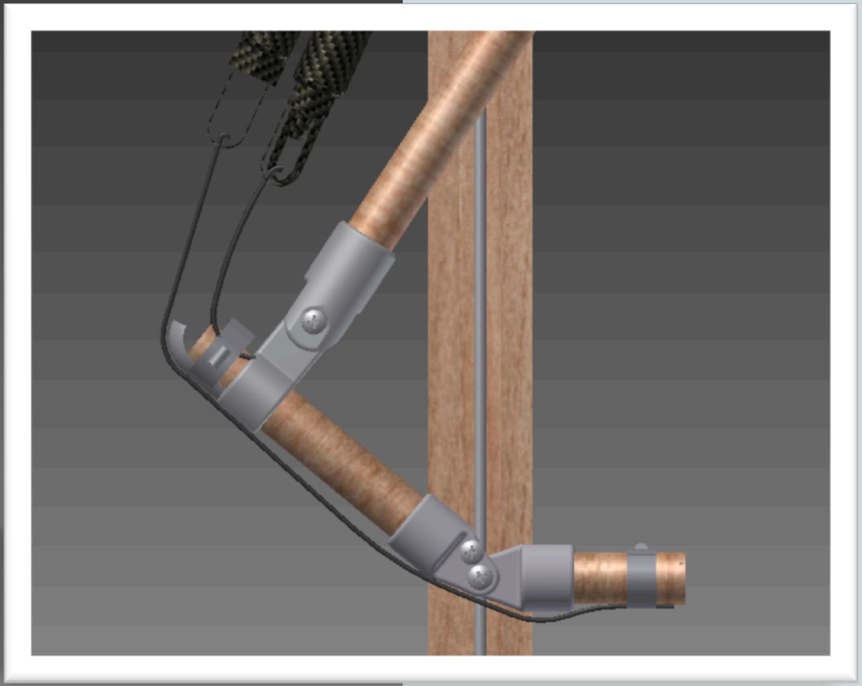
How it Works



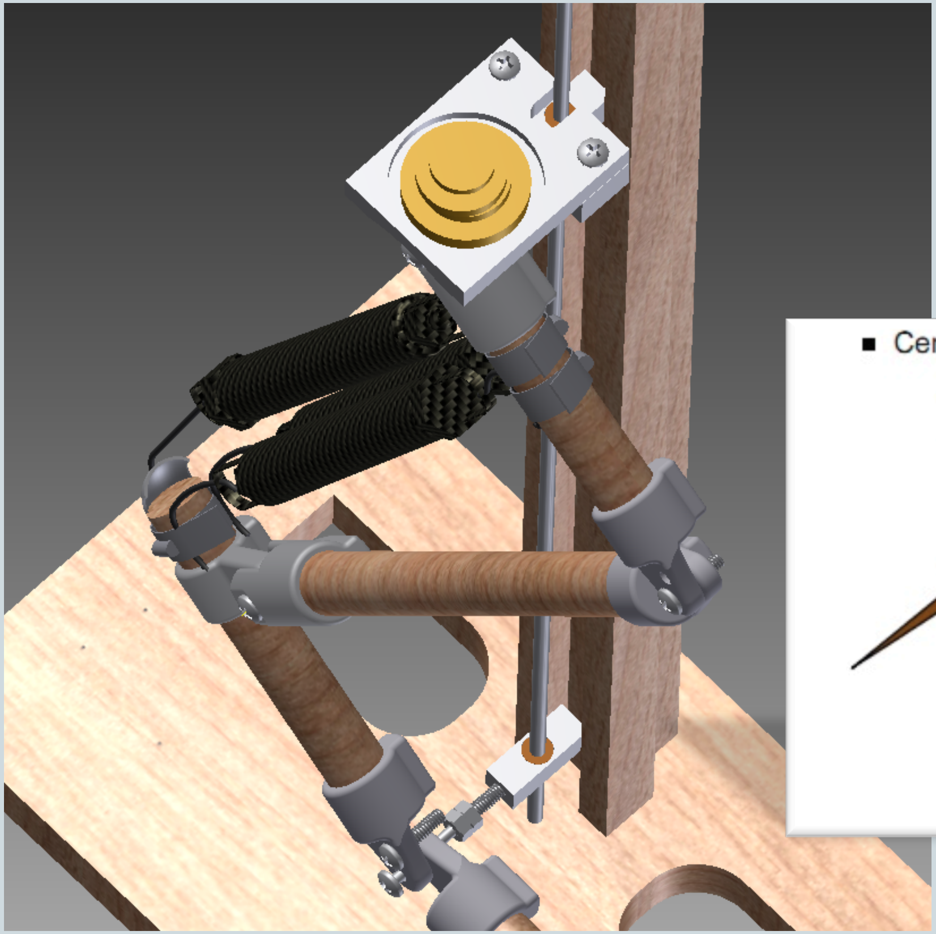
Macropus rufus
Red Kangaroo
Tensor Fascia Latae
External Obliques
Gluteus Medius
Latissimus Dorsi
Digastric
Sternomastoid
Masseter
Gluteus Superficialis Anterior
Deltoid
Temporalis
Trapezius
Levator Nasolabialis
Gluteus Superficialis Posterior
Orbicularis Oculi
Coccygeus
Levator Labii Maxiliaris
Semitendinosus
Caninus
Semimembranosus
Orbicularis Oris
Pectoralis
Sternohyoid
Sternothyroid
Buccinator
Biceps Femoris
Rectus Abdominis
Cleidomastoid
Sartorius
Triceps Brachii
Gastrocnemius
Ancaneus
Vastus Lateralis
Bicep Brachii
Tibialis Cranialis
Sacrocaudalis Dorsalis
Brachialis
Soleus
Flex. Carpi Ulnaris
Ext. Carpi Radialis
Peronues Longus
Ext. Carpi Ulnaris
Ext. Digitorum Communis
Sacrocaudalis Ventralis
Ext. Digitorum Lateralis
Flex. Digitorum Profundus
Robert Kelley

How it Works

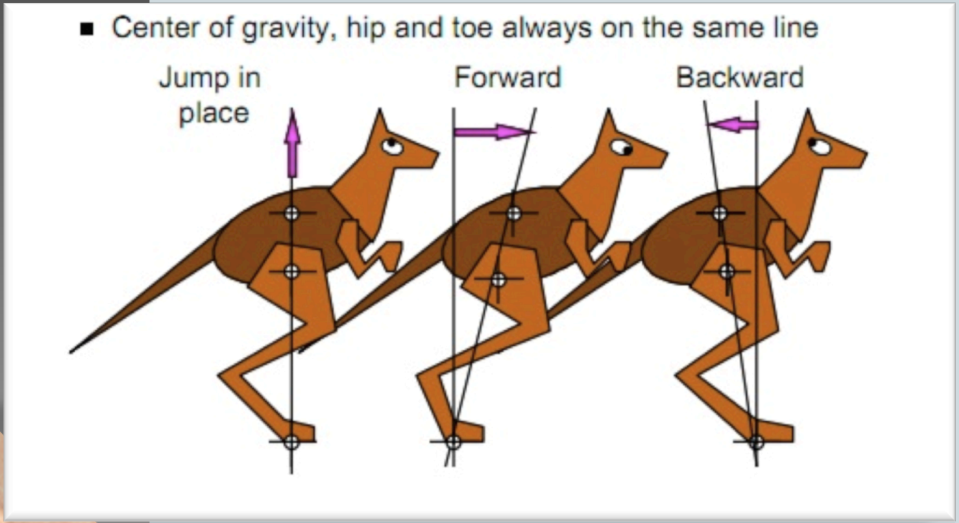




How it Works

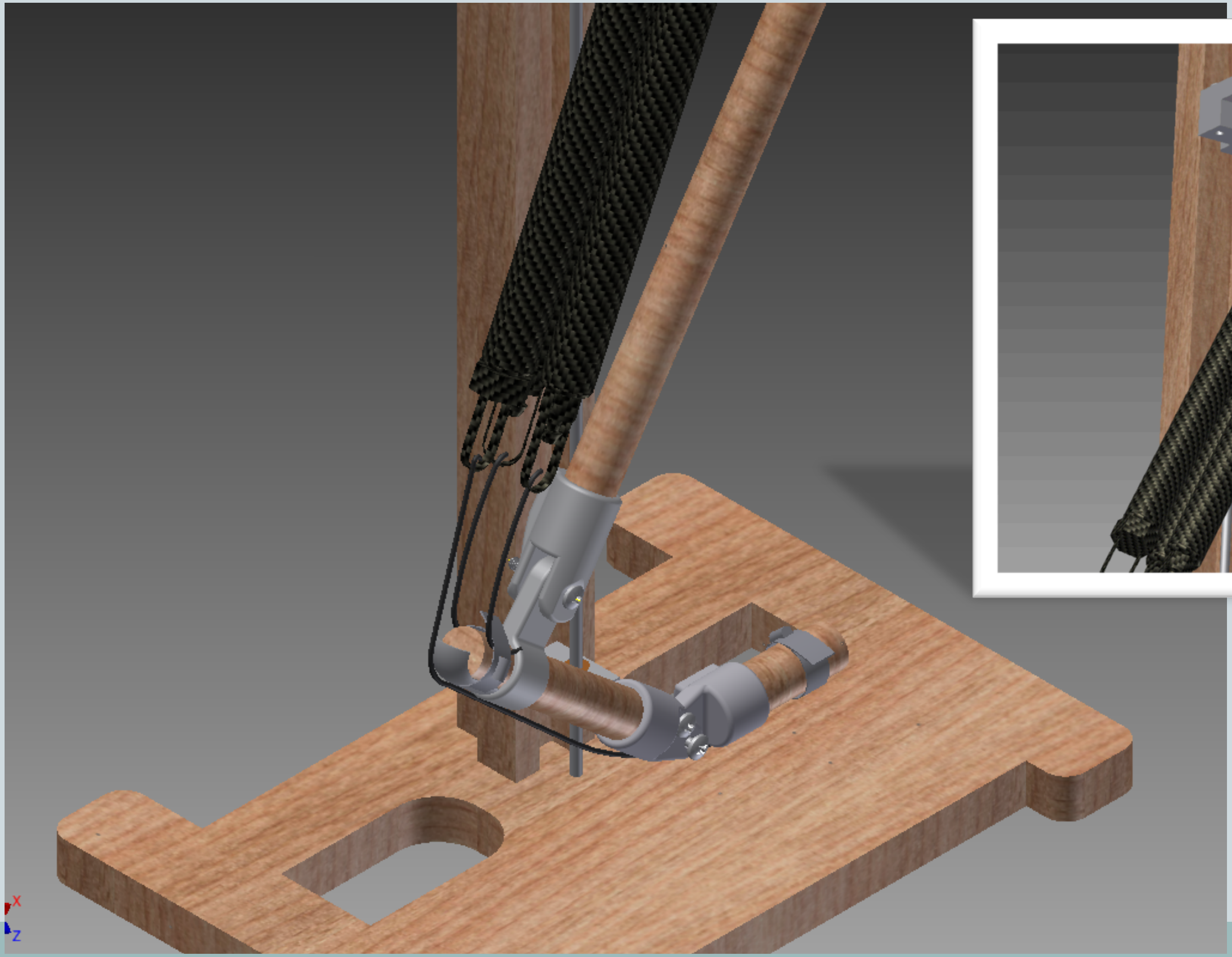


Bushings keep the center of mass (mass is variable), hip and toe joint aligned vertically



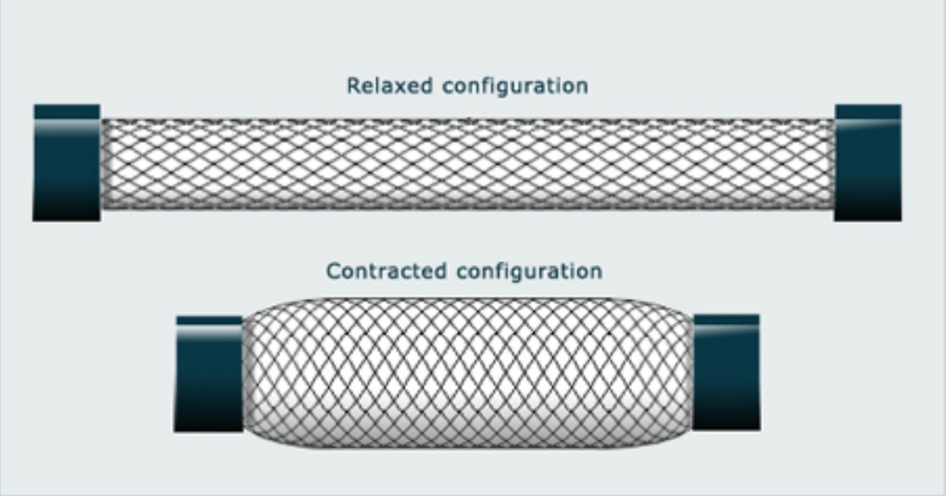
Umberto Costanzini & Young Cho

How it Works



Entire structure is 12” x 16” x 48”

How it Works



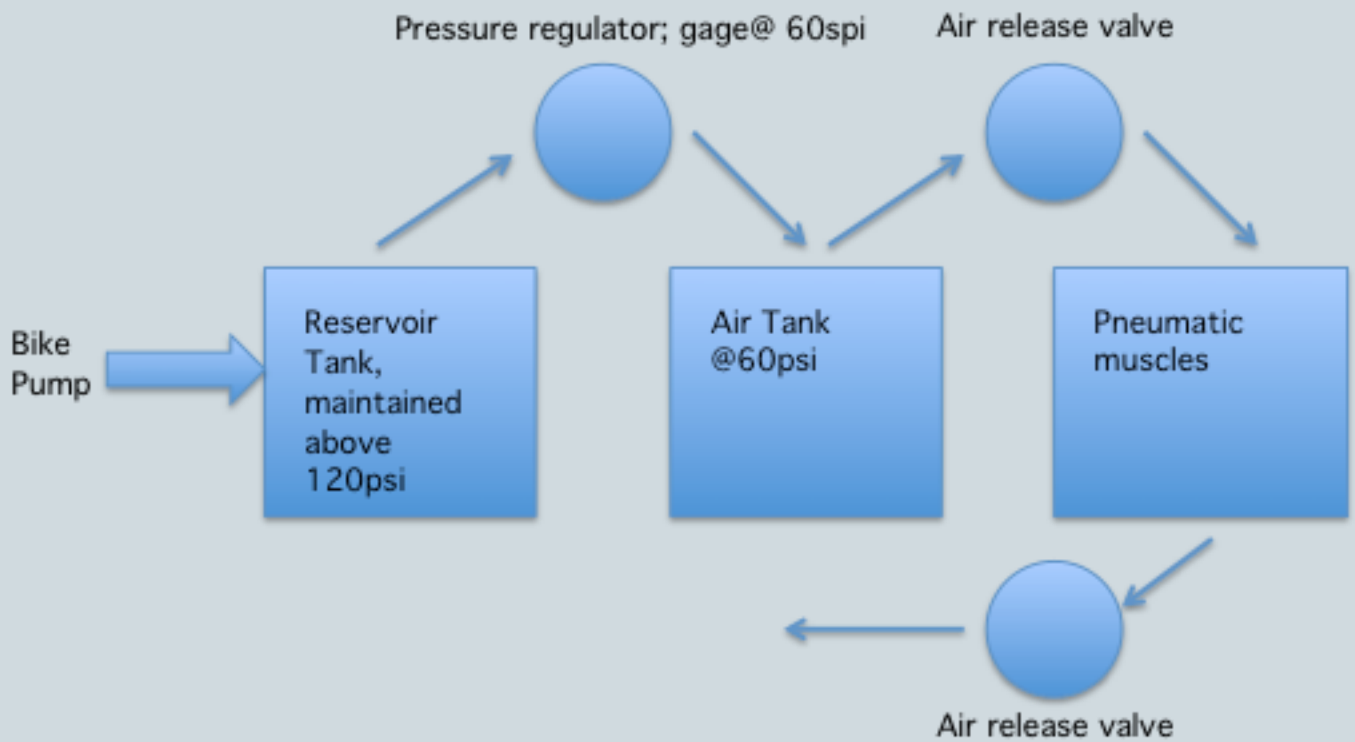
McKibben Muscles

- Pressurized to above 60psi
- Can lift about 6lbs by 1.5” (8” muscle)

- Pressure swells inner bladder, causing cross sectional area to increase. This nylon mesh (think Chinese finger trap) shrinks in length as its diameter expands.

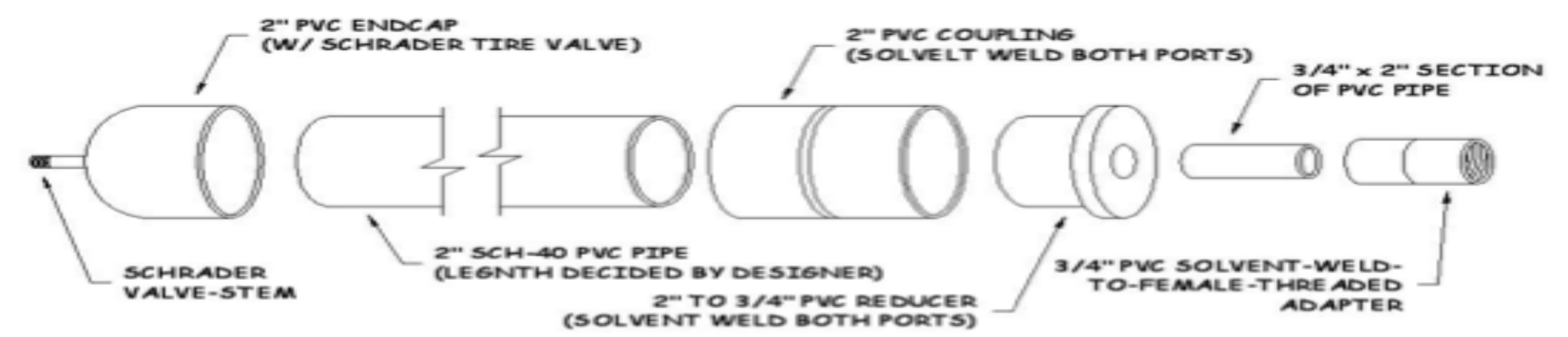
Manufacturing and Part Acquisition

Compressed Air System



Schematic Diagram of compressed air system

Manufacturing and Part Acquisition



Design concept for Reservoir Tanks

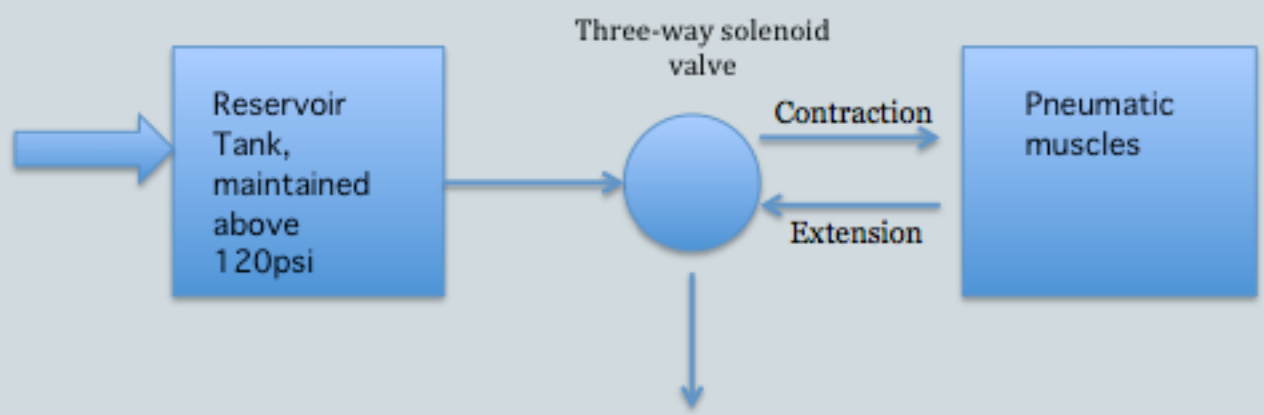
Pressure Regulator with gage

Push button valve

Bike pump with gage

Detailed Design of Prototype

- Air System Components
  - Two tank air reservoir
  - Three way solenoid air control valve
  - Electricity powered



Manufacturing and Part Acquisition

- Almost all parts are standard from McMaster-Carr
- Pneumatic Muscles can be made from silicon tubing, nylon wire conduit, crimp clamps (or wire) and appropriate valves
- Majority of Air System components already owned

Parts List [McMaster-Carr]

Part Number/ASIN	Description	Form	Shipping Time	Qty	Unit Price ($)	Cost ($)
4698T82	Aluminum Slip-on Rail Fittings Adjustable-Angle Elbow, Fits 3/4" Pipe Size	each	next day	2	12.01	24.02
4698T96	Aluminum Slip-on Rail Fittings Adjustable-Angle Tee, Fits 3/4" Pipe Size	each	next day	2	11.24	22.48
9683K21	1''x36" Birch Dowel	pack of 2	next day	1	9.71	9.71
1031K68	Precision Ceramic-Coated Aluminum Shaft 1/4" Diameter, 48" Length	each	within 2 weeks	1	24.48	24.48
9440T13	1/4" Flange Bearing	each	next day	4	0.99	3.96
5362K13	Worm-Drive Hose & Tube Clamp with Thumb Screw	pack of 5	next day	1	7.73	7.73
8858T82	1/8" RED Latex Rubber with Polypropylene Cover			50	0.11	5.5
8975K417	3"x12"x3/4" Aluminum Stock	each	next day	1	20.15	20.15
5486K112	M6x1x22 Hex-Head Bolt	individual	next day	2	6.71	13.42
5111K667	Aluminum (6061) 5mm OD Rod	individial	next day	2	4.43	8.86
5392K11	1/4" rigid white polypropylene tubing	form of 25 ft	next day	1	10.5	10.5

Parts List [Miscellaneous]

- 1/4-20 phillips-head machine screws
  - 1”   1.5”   2.75”
- ¼-20 bolts
- About 300in² of 1” thick birch

These parts can be bought from Home Depot in quantities necessary

Bibliography

- http://yang-thesis.blogspot.com/2007/10/kangaroos.html
- http://www.google.com/imgres?imgurl=http://curiousanimals.net/wp-content/uploads/2007/09/red-2d20kangaroo-2d2c-2d20australia-2dsmall.jpg&imgrefurl=http://petsphotos.blogspot.com/&usg=__1lT-VSvIFXJ0xvJnHCAfUFKuRd0=&h=435&w=580&sz=49&hl=en&start=0&sig2=TBL9ztyZ4A9lyZ-rrzC67A&zoom=1&tbnid=Wdb7aL8Qn9mDdM:&tbnh=157&tbnw=209&ei=h3vITeS8F7PViAL2-ISABQ&prev=/search%3Fq%3Dbuff%2Bkangaroo%26um%3D1%26hl%3Den%26sa%3DN%26rlz%3D1R2ACAW_enUS351%26biw%3D1286%26bih%3D667%26tbm%3Disch0%2C194&um=1&itbs=1&iact=hc&vpx=263&vpy=94&dur=95&hovh=194&hovw=259&tx=170&ty=100&page=1&ndsp=18&ved=1t:429,r:7,s:0&biw=1286&bih=667
- http://www.pump-zone.com/seals/expansion-joints/optimizing-fiber-reinforcement-of-expansion-joints.html
- http://www.twenga.com/dir-Sports,Nautical-equipment,Bungee-cord
- http://healthylifecarenews.com/material-rubber-latex-can-cause-allergic/rubber-band/
- http://www.eportfolio.lagcc.cuny.edu/scholars/doc_fa07/Natalia.Kolganova/goals.html
- http://www.thunderchaser.com/TSR_timeline.html
- http://www.boncherwales.com/Accounts.html
- http://www.bio.davidson.edu/people/midorcas/animalphysiology/websites/2005/Shelton/Muscles.htm
- http://www.watblog.com/2009/01/14/pay-for-performance-marketing-a-curse-or-a-boon-for-digital-media/