Components of an OpenSim Model

What is a musculoskeletal model?

1. <u>Skeleton</u>:
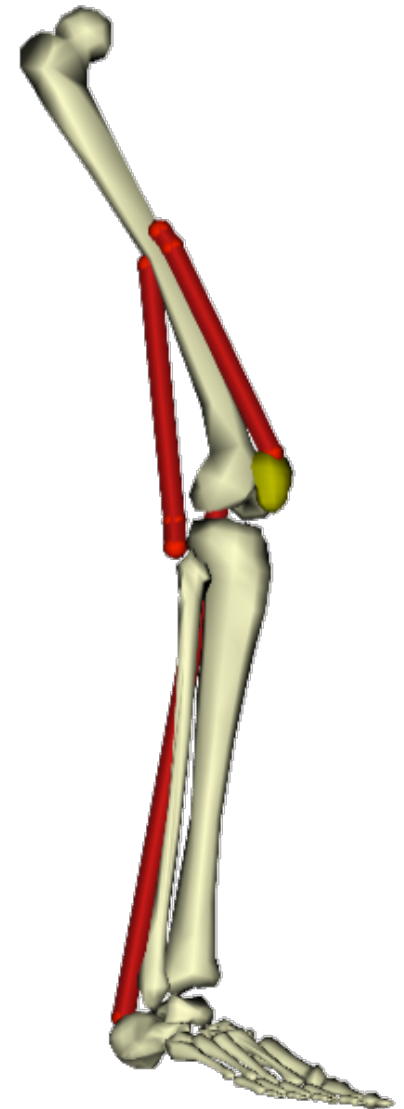   - Bones are rigid bodies
    - Joints permit motion between bodies
    - Constraints limit motion
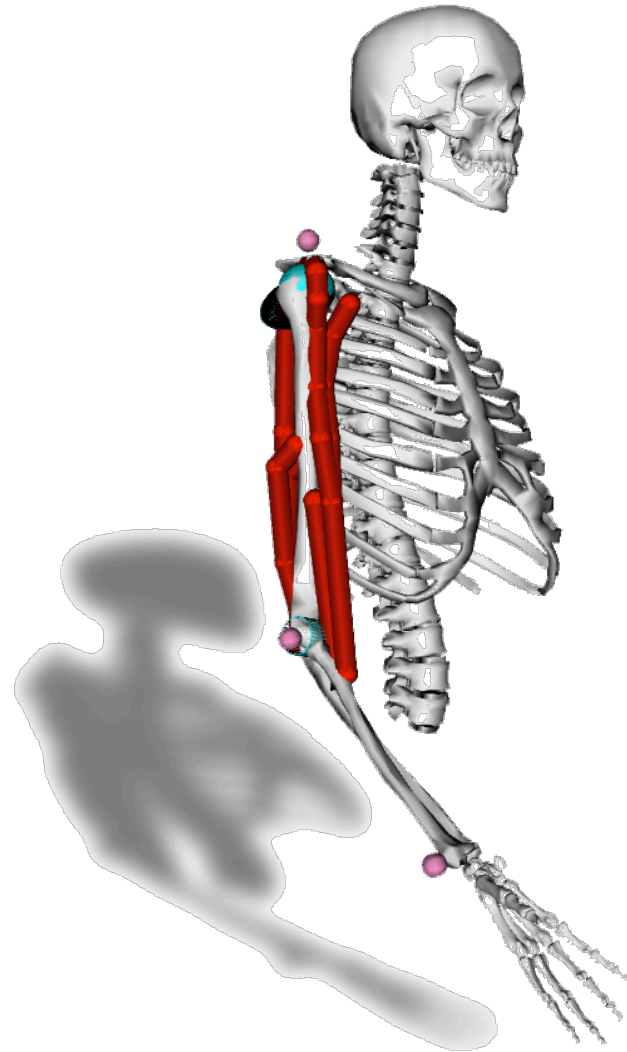
2. <u>Muscles</u> :
    - Specialized forces

3. <u>Other forces</u>:
    - PrescribedForce
    - BushingForce
    - CoordinateActuator
    - Contact

OpenSim Model

OpenSim Model File


```
<Model name="A
    <!—Default                          are not specified.-->
    <defaults>
    <credits> M
    <publicatio
    <length_uni
    <force_unit
    <!--Acceler
    <gravity> 0                   0.00000000 </gravity>
    <!--Bodies
    <BodySet na
    <!--Constra
    <Constraint
    <!—All the                          -->
    <ForceSet n
    <!—Kinemati
    <MarkerSet
    <!—Surface                   e elements in the model.-->
    <ContactGeo
</Model>
```
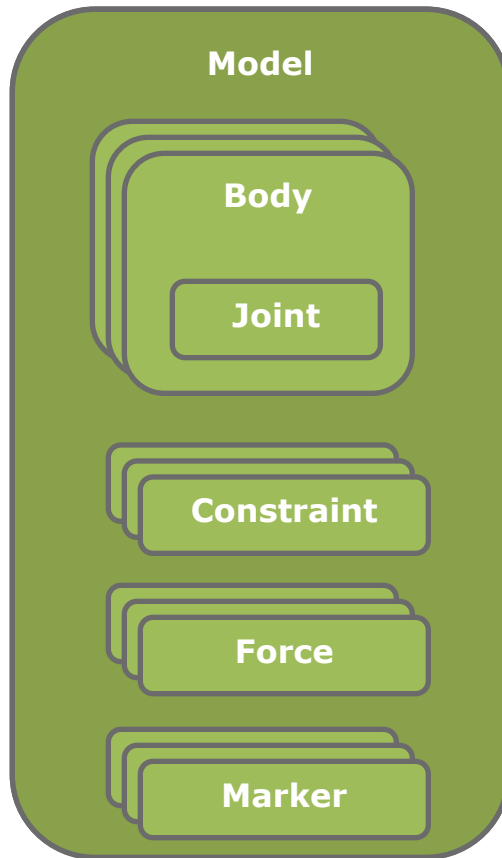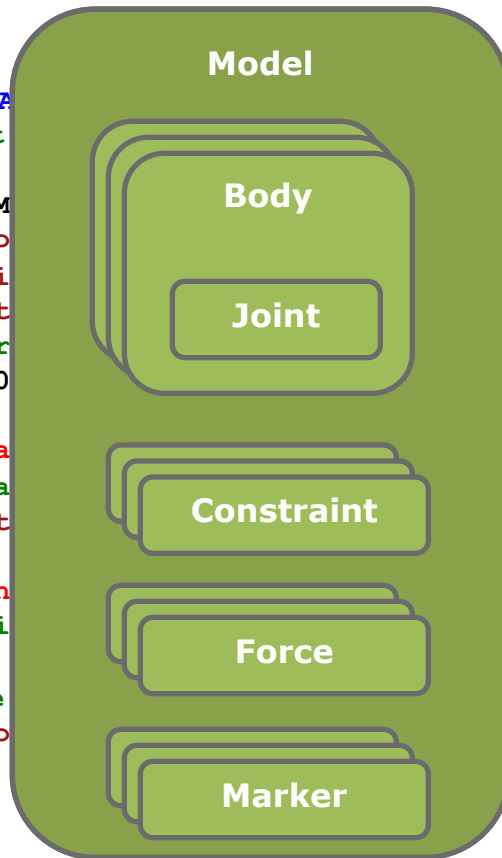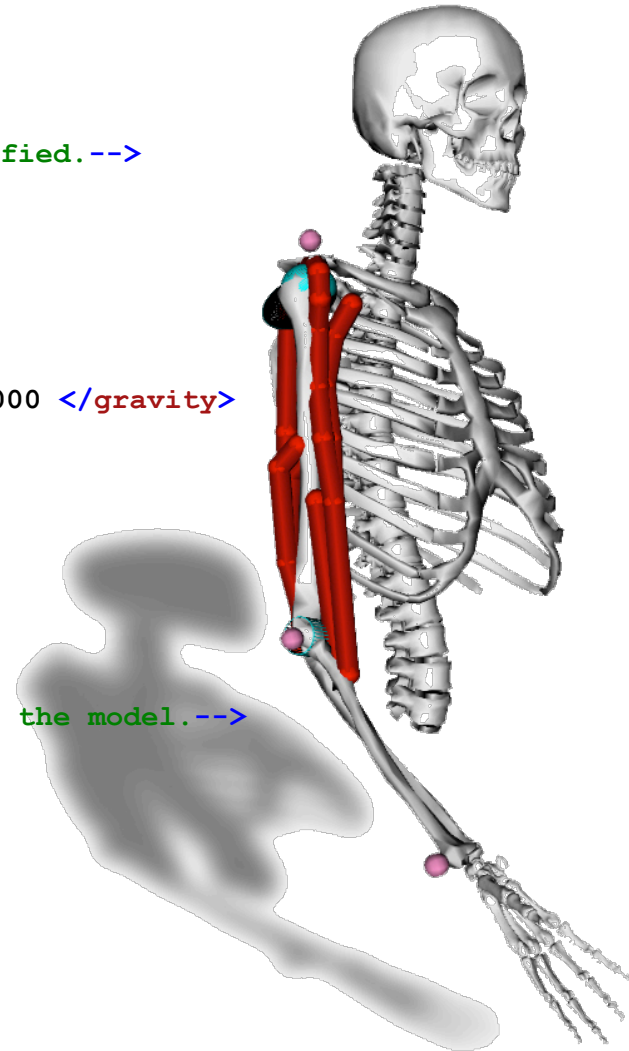
Model

Body

Joint

Constraint

Force

Marker
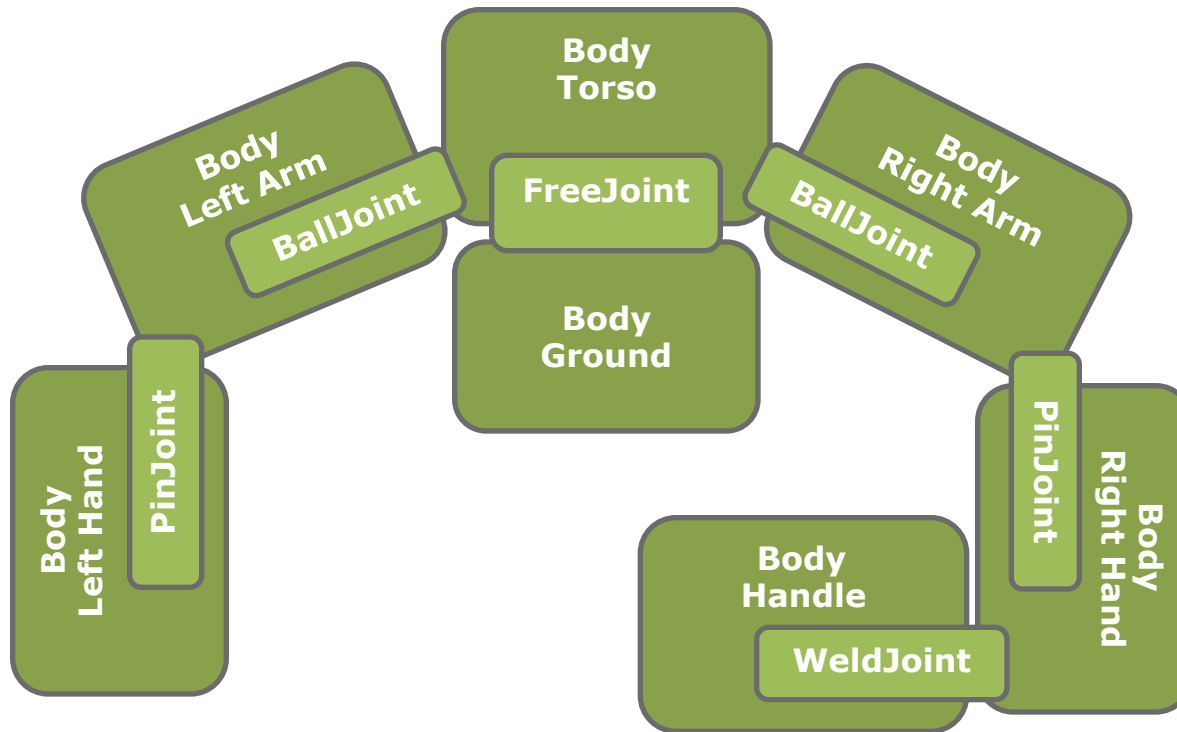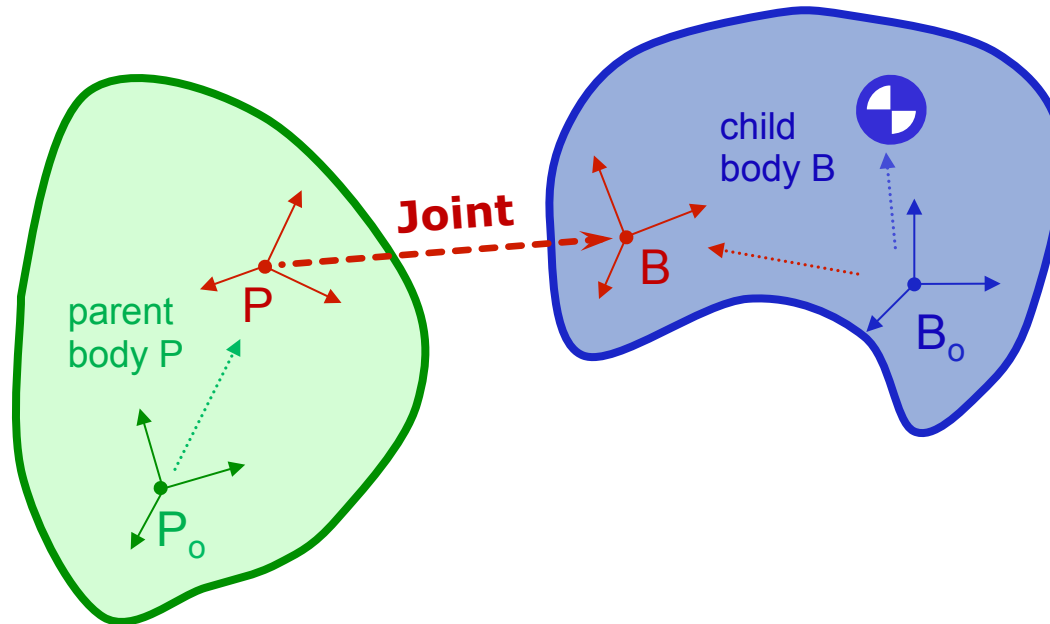
Tree Topology of Multibody Models

Each body is connected by ONE joint to create a chain or open tree structure.

Body and Joint Reference Frames

B specified by joint `location` and `orientation`

P specified by joint `locationInParent` and `orientationInParent`

Joint coordinates specify the kinematics of B relative to P

Defining a Body and its Joint

```xml
<Body name="block">
    <mass>  5.00 </mass>
    <mass_center> 0.0  0.0  0.0 </mass_center>
    <inertia_xx>  0.1 </inertia_xx>
    ...
    <inertia_yz>  0.0 </inertia_yz>
    <!—Joint connects the block to ground. -->
    <Joint>
```

Defining a Body and its Joint

```xml
<Joint>
    <SliderJoint name="">
        <parent_body> ground </parent_body>
        <location_in_parent>     0.0   0.0 0.0 </location_in_parent>
        <!-- 45 degrees in the horizontal plane -->
        <orientation_in_parent>  0.0   0.7853981633974483    0.0 </orientation_in_parent>
        <location>         0.0     -0.1     0.0 </location>
        <orientation>      0.0       0.7853981633974483      0.0 </orientation>
        <!--Generalized coordinates parameterizing this joint.-->
        <CoordinateSet name="">
            <objects>
                <Coordinate name="block_trans">
                <!--Coordinate can describe rotational, translational, or coupled.-->
                    <motion_type> translational </motion_type>
                    <default_value>           0.00000000 </default_value>
                    <range> -10   10 </range>
                    <locked> false </locked>
                </Coordinate>
            </objects>
        </CoordinateSet>
    </SliderJoint>
</Joint>
<VisibleObject name=""> ...
</Body>
```
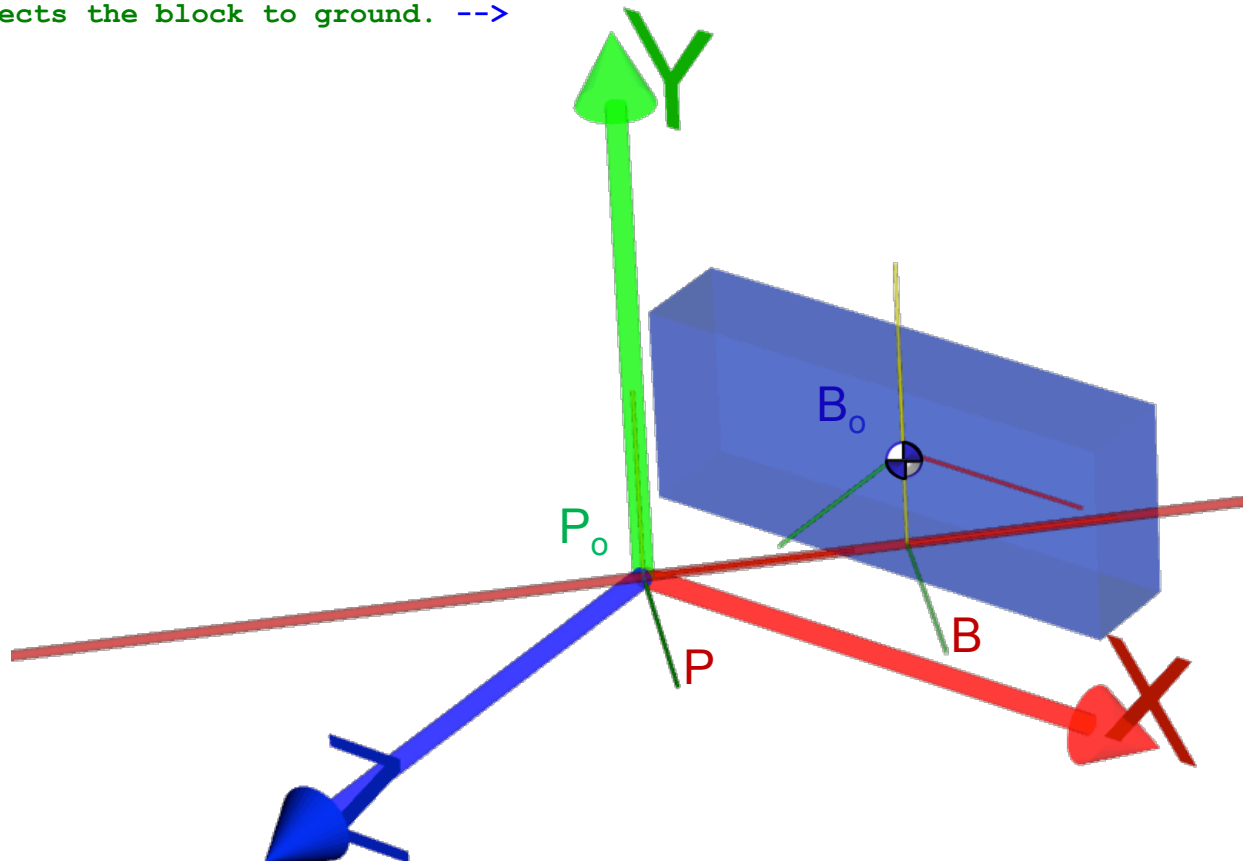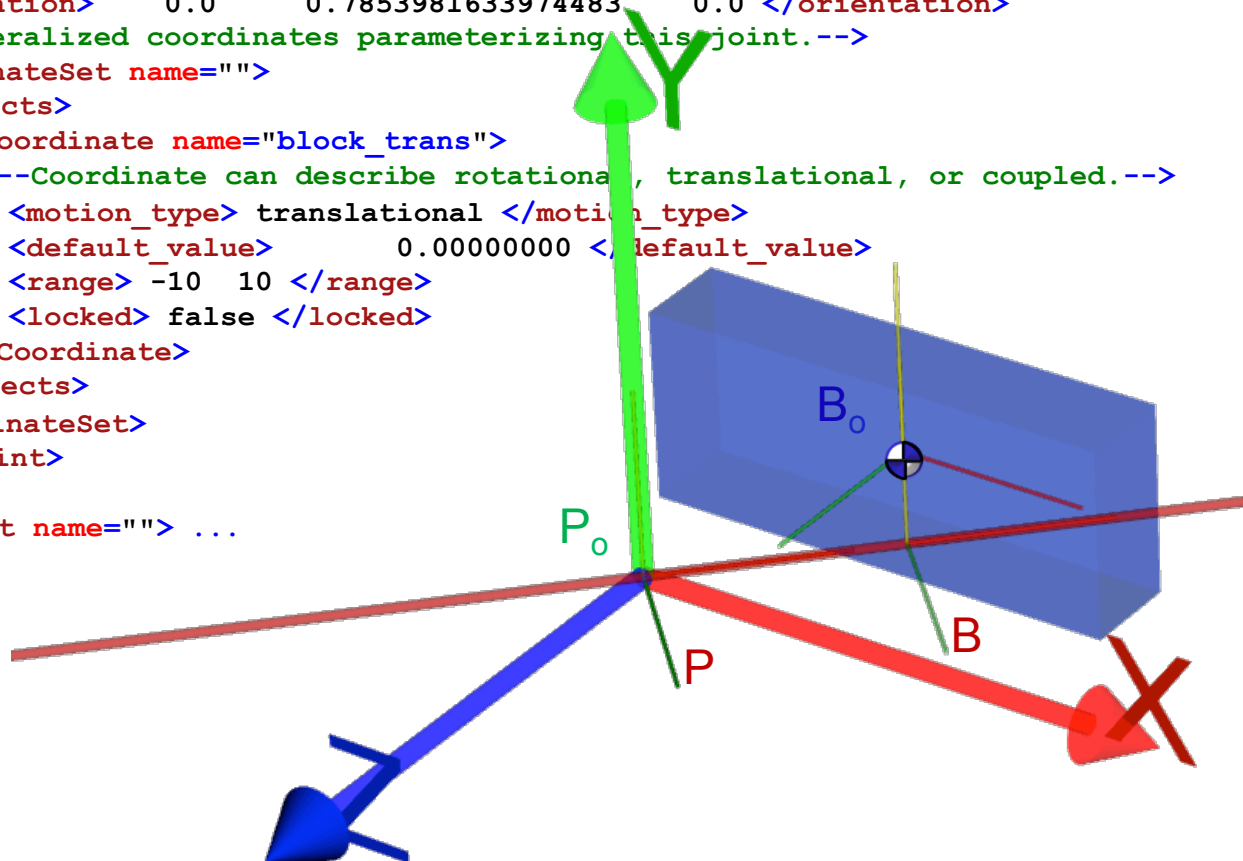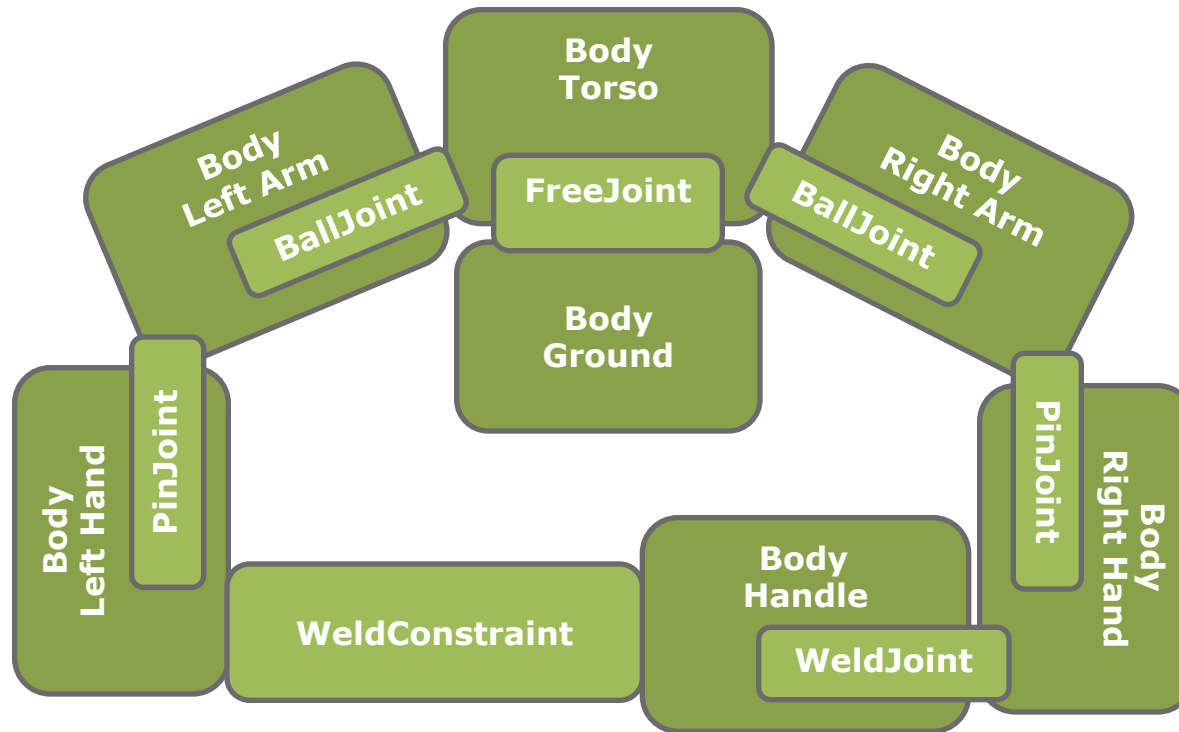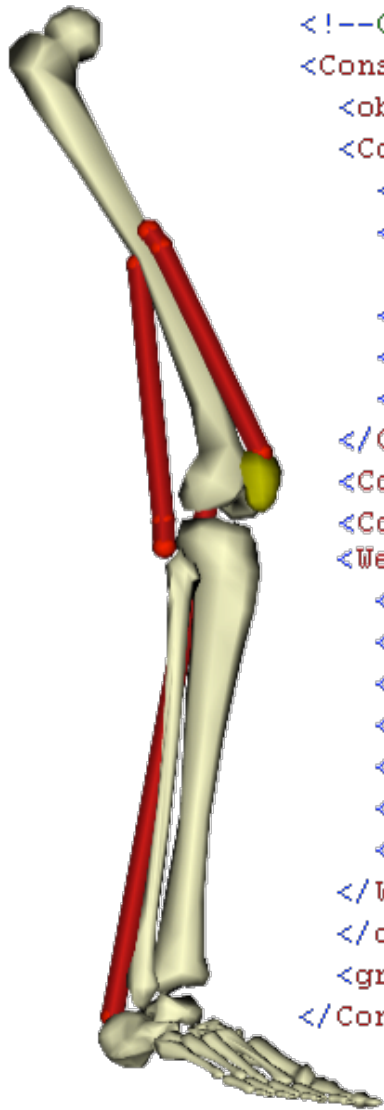
Tree Topology of Multibody Models

Each body is connected by ONE joint to create a chain or open tree structure.

Constraint is required to form a closed loop

Kinematic Constriants

```xml
<!--Constraints in the model.-->
<ConstraintSet name="">
  <objects>
  <CoordinateCouplerConstraint name="pat_tx_r">
    <isDisabled> false </isDisabled>
    <coupled_coordinates_function>
      <natCubicSpline name="">...</natCubicSpline>
    </coupled_coordinates_function>
    <independent_coordinate_names> knee_angle_r </independent_coordinate_names>
    <dependent_coordinate_name> pat_tx_r </dependent_coordinate_name>
  </CoordinateCouplerConstraint>
  <CoordinateCouplerConstraint name="pat_ty_r">...</CoordinateCouplerConstraint>
  <CoordinateCouplerConstraint name="pat_angle_r">...</CoordinateCouplerConstraint>
  <WeldConstraint name="">
    <isDisabled> false </isDisabled>
    <body_1> ground </body_1>
    <body_2> calcn_r </body_2>
    <location_body_1>      0.0000000000        0.0000000000        0.0840000000
    <orientation_body_1>    0.0000000000         0.0000000000         0.00000000
    <location_body_2>      0.0000000000        0.0000000000        0.0000000000
    <orientation_body_2>    0.0000000000         0.0000000000         0.00000000
  </WeldConstraint>
  </objects>
  <groups/>
</ConstraintSet>
```

Available Joints and Constriants
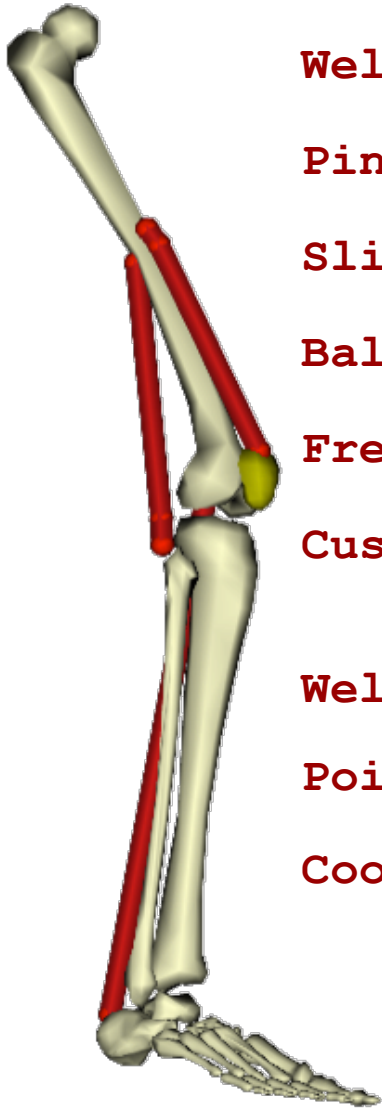
WeldJoint: No q's, adds body frame to parent

PinJoint: One q, rotation about common Z

SliderJoint: One q, translation along common X

BallJoint: Three q's, rotation about body-fixed X, Y, Z

FreeJoint: Six q's, rotations like Ball and 3 translations
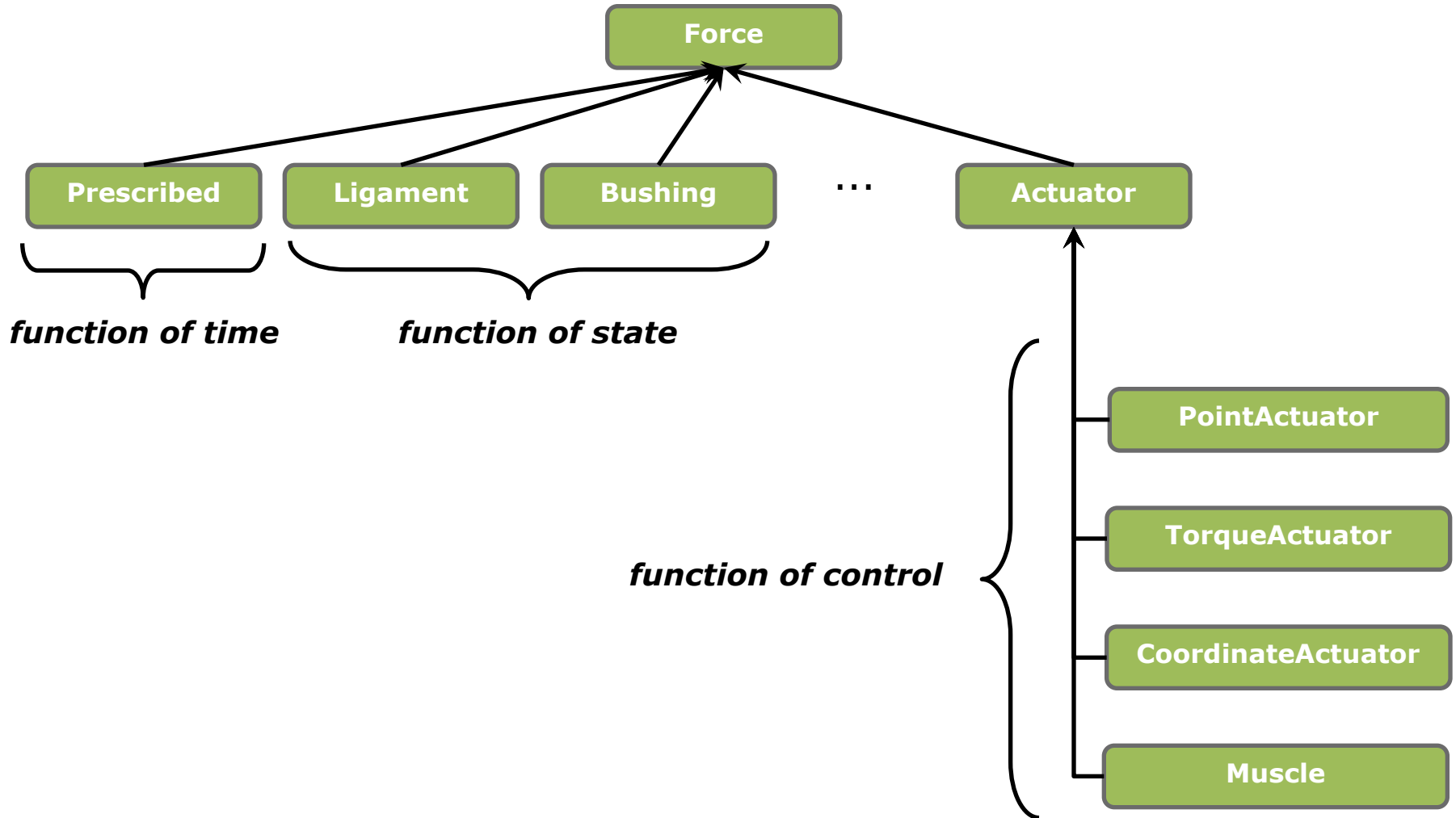
CustomJoint: User-defined SpatialTransform,1 to 6 q's
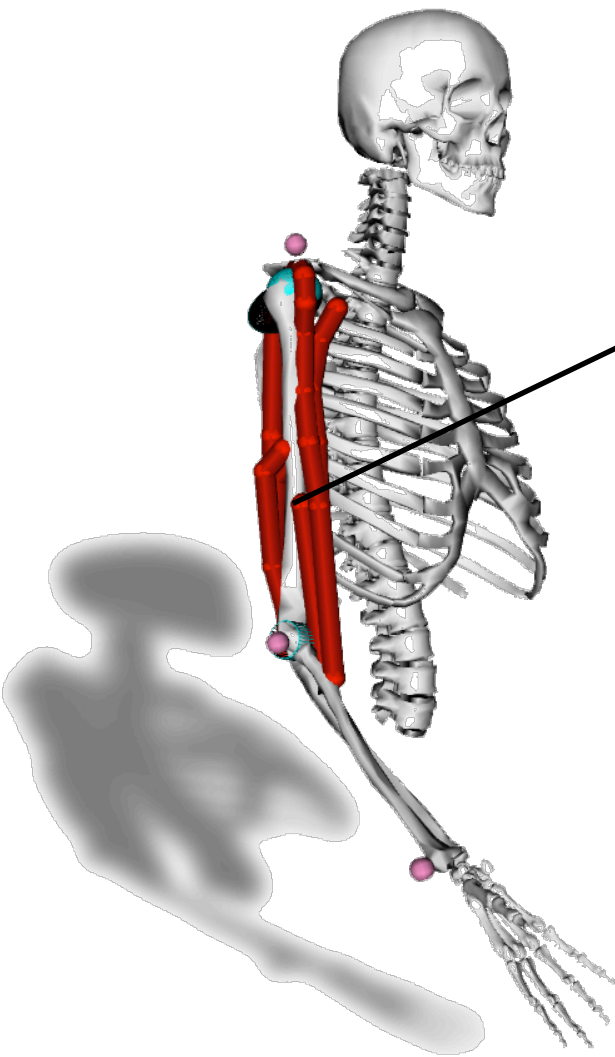
WeldConstraint: frames on two bodies are fixed

PointConstraint: points on two bodies are fixed

CoordinateCouplerConstraint: $q_{dep} = F(q_{ind})$

Types of Forces in OpenSim

Force

Prescribed   Ligament   Bushing   ...   Actuator

function of time   *function of state*

function of control

PointActuator

TorqueActuator

CoordinateActuator

Muscle

Muscle Actuator Example


```xml
<Thelen2003Muscle name="brachialis_r">
  <GeometryPath name="">
    <!—- points on bodies that define the path of the muscle -->
    <PathPointSet name="">
      <objects>
        <PathPoint name="brachialis_r-P1">
          <location> -0.00240000 -0.15330000 0.00710000 </location>
          <body> humerus_r </body>
        </PathPoint>
        <PathPoint name="brachialis_r-P2">
          <location> 0.00000000  0.03100000 -0.00530000 </location>
          <body> r_ulna_radius_hand </body>
        </PathPoint>
      </objects>
      <groups/>
    </PathPointSet>
    <PathWrapSet name=""> ...
  </GeometryPath>
  <!--maximum isometric force of the muscle fibers-->
  <max_isometric_force> 972.00000000 </max_isometric_force>
  <!--optimal length of the muscle fibers-->
  <optimal_fiber_length> 0.08580000 </optimal_fiber_length>
  <!--resting length of the tendon-->
  <tendon_slack_length> 0.05300000 </tendon_slack_length>
  <!--angle between tendon and fibers at optimal fiber length-->
  <pennation_angle> 0.00000 </pennation_angle>
  <!--time constant for ramping up of muscle activation-->
  <activation_time_constant> 0.01000000 </activation_time_constant>
  <!--time constant for ramping down of muscle activation-->
  <deactivation_time_constant> 0.04000000 </deactivation_time_constant>
  <!--maximum contraction velocity at full activation (fiber length/s)-->
  <Vmax> 10.00000000 </Vmax>

  ...
</Thelen2003Muscle>
```

Hands On Example:
Manipulate and modify a model in the gui!

- Adding a joint to the model increases/ decreases the number of degrees of freedom.

- Adding a constraint increases/decreases the number of system equations.

- How are actuators different from other types of OpenSim forces?