Metals as Implantable Materials

Tom Duerig, Ph.D

President, NDC

tom.duerig@nitinol.com

www.nitinol.com

Disclosures

- The author is employed by Nitinol Devices & Components, Inc. (“NDC”),
- a supplier and development partner to many companies developing Nitinol medical devices.

Common Metallic Materials for Medical Implants

- Stainless Steel (316L)
- Cobalt–Chrome (MP35N, L-605, and Elgiloy)
- Titanium (Ti-6Al-4V and CP titanium)
- Nickel-Titanium (Nitinol)

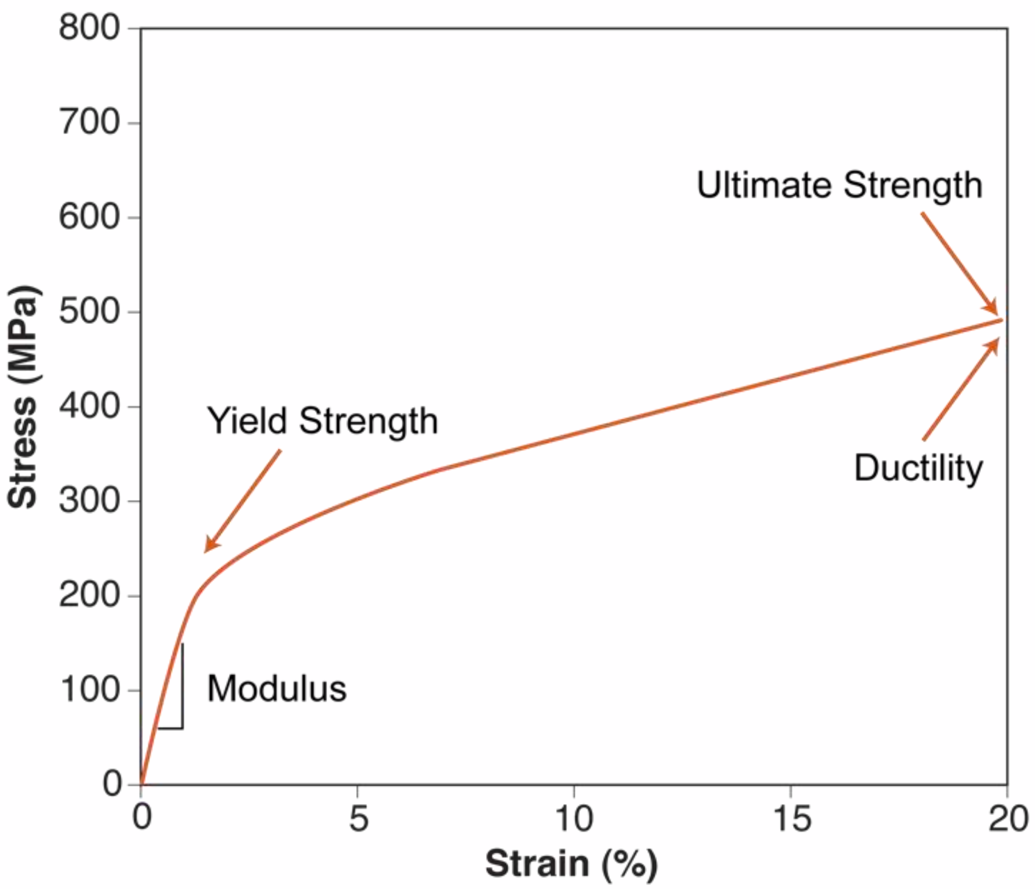
Compositions (in weight percent)

Key Element	Stainless Steel (316L)	Cobalt-Chrome (Elgiloy, MP35N, L-605)	Titanium (CP, Ti-6-4)	Nitinol
Iron	63%	1-15%		
Titanium			90-100%	45%
Nickel	14%	15-35%		55%
Chromium	18%	20%		
Cobalt		40-50%		
Other	Mo, Mn	Mo, Mn, W	Al, V	

Physical Properties of Implanted Metals

Attribute	Stainless Steel	Cobalt-Chrome	Titanium	Nitinol
Strength				
Stiffness				
Fatigue				
Corrosion				
Other				

Strength: What is it?

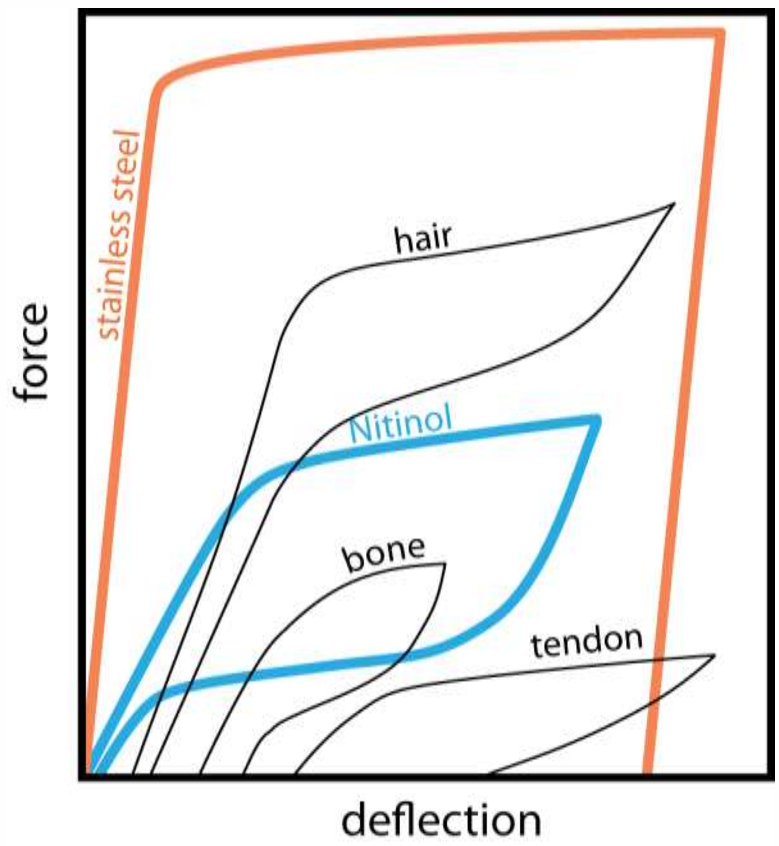


Physical Properties of Implanted Metals

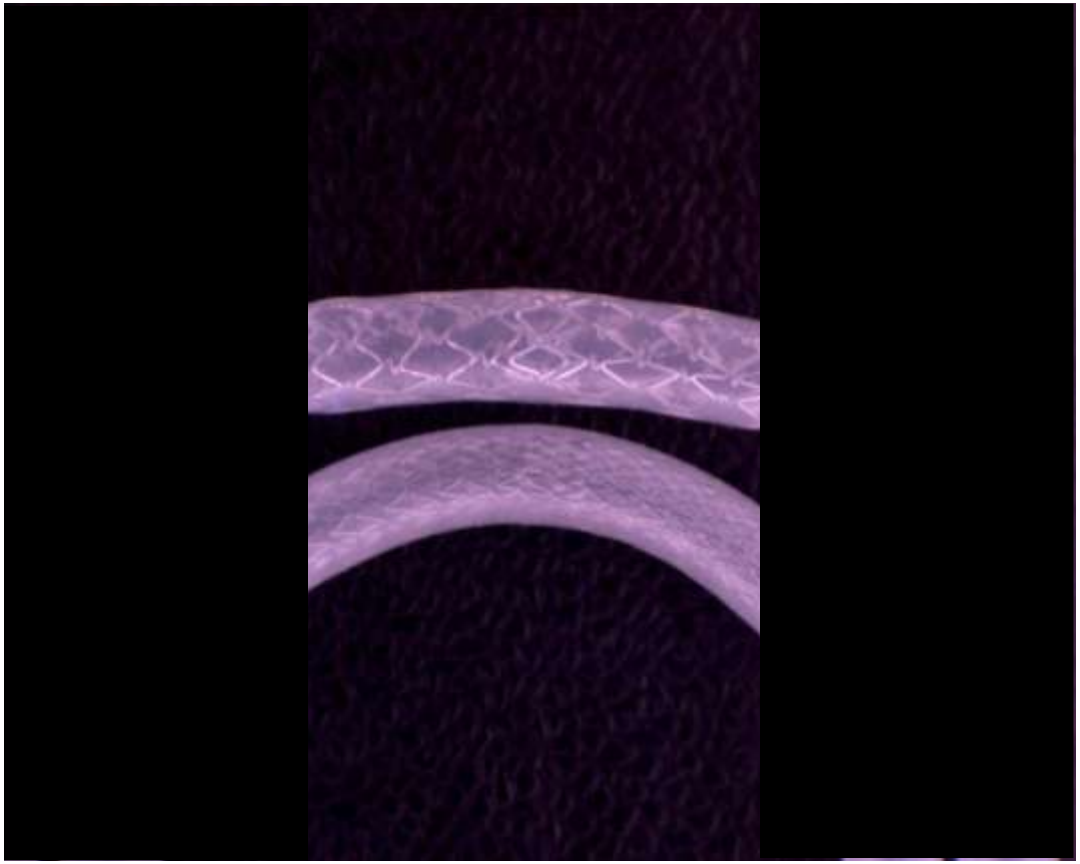
Attribute	Stainless Steel	Cobalt-Chrome	Titanium	Nitinol
Strength	medium (300/560 MPa)	high (600/1140 MPa)	high (880/950 MPa)	high (500/1400 MPa)
Stiffness				
Fatigue				
Corrosion				
Other				

"Strength" is often confused with "Stiffness"

Stiffness is the opposite of compliance



Significance to a stent

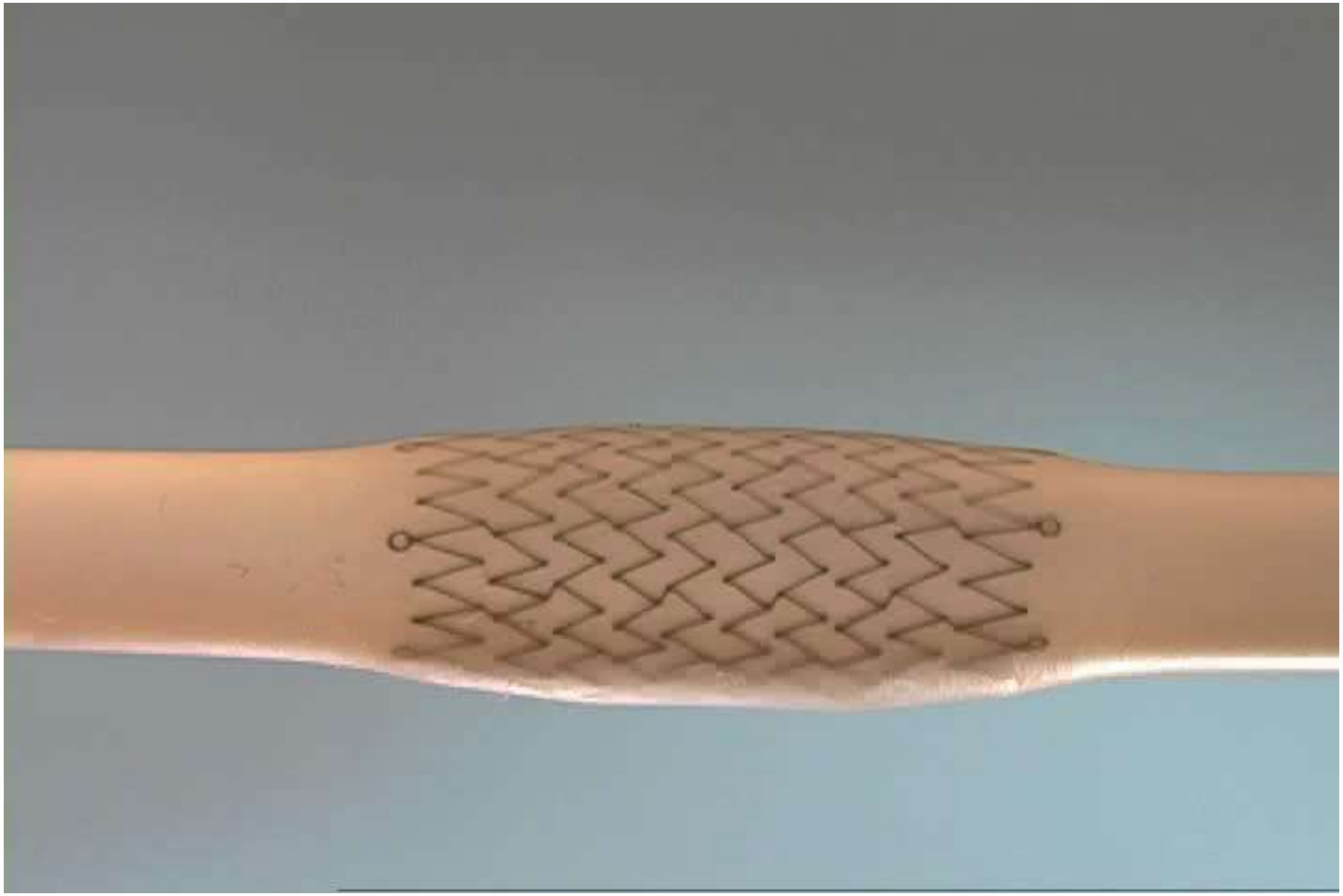


Significance to a stent

Physical Properties of Implanted Metals

Attribute	Stainless Steel	Cobalt-Chrome	Titanium	Nitinol
Strength	medium (300/560 MPa)	high (600/1140 MPa)	high (880/950 MPa)	high (500/1400 MPa)
Stiffness	high (200 GPa)	High (200 GPa)	moderate (90 GPa)	very low (~25 GPa)
Fatigue				
Corrosion				
Other				

Pulasatile durability



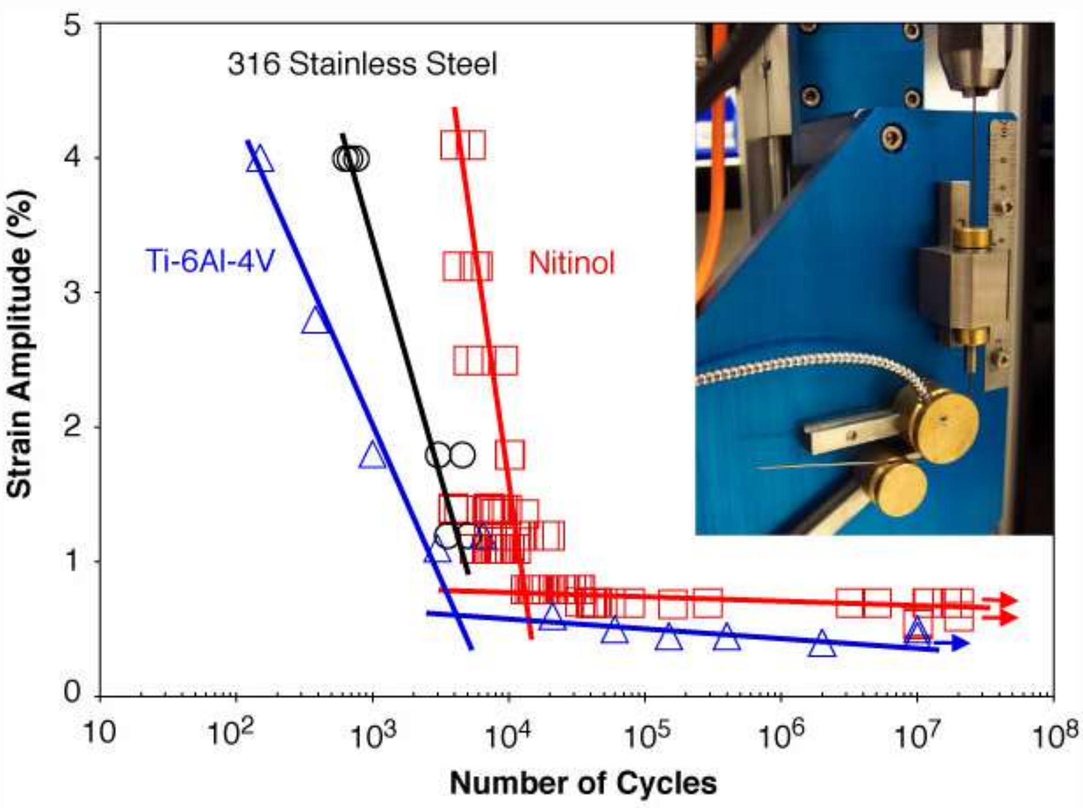
Which is more fatigue resistant,
a rubber band, or a steel band?

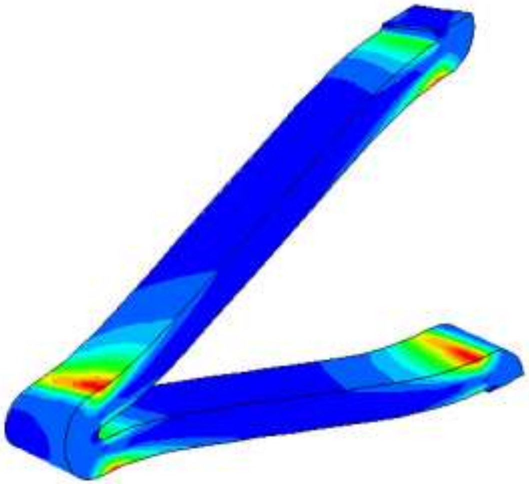
They both are.

A rubber band resists cyclic displacements better, but

a steel band resists cyclic loads better.

Fatigue Resistance is Related to Stress/Strain

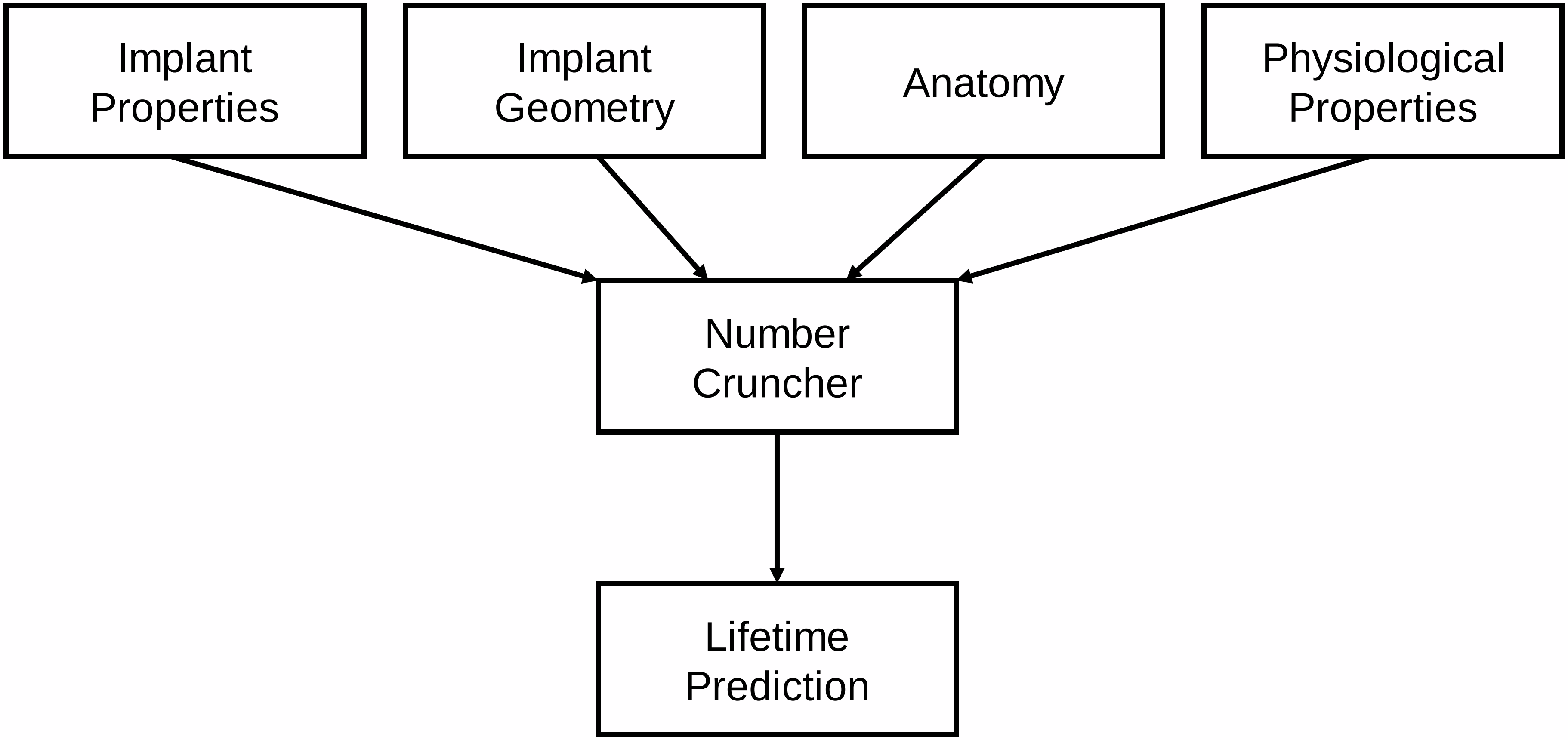




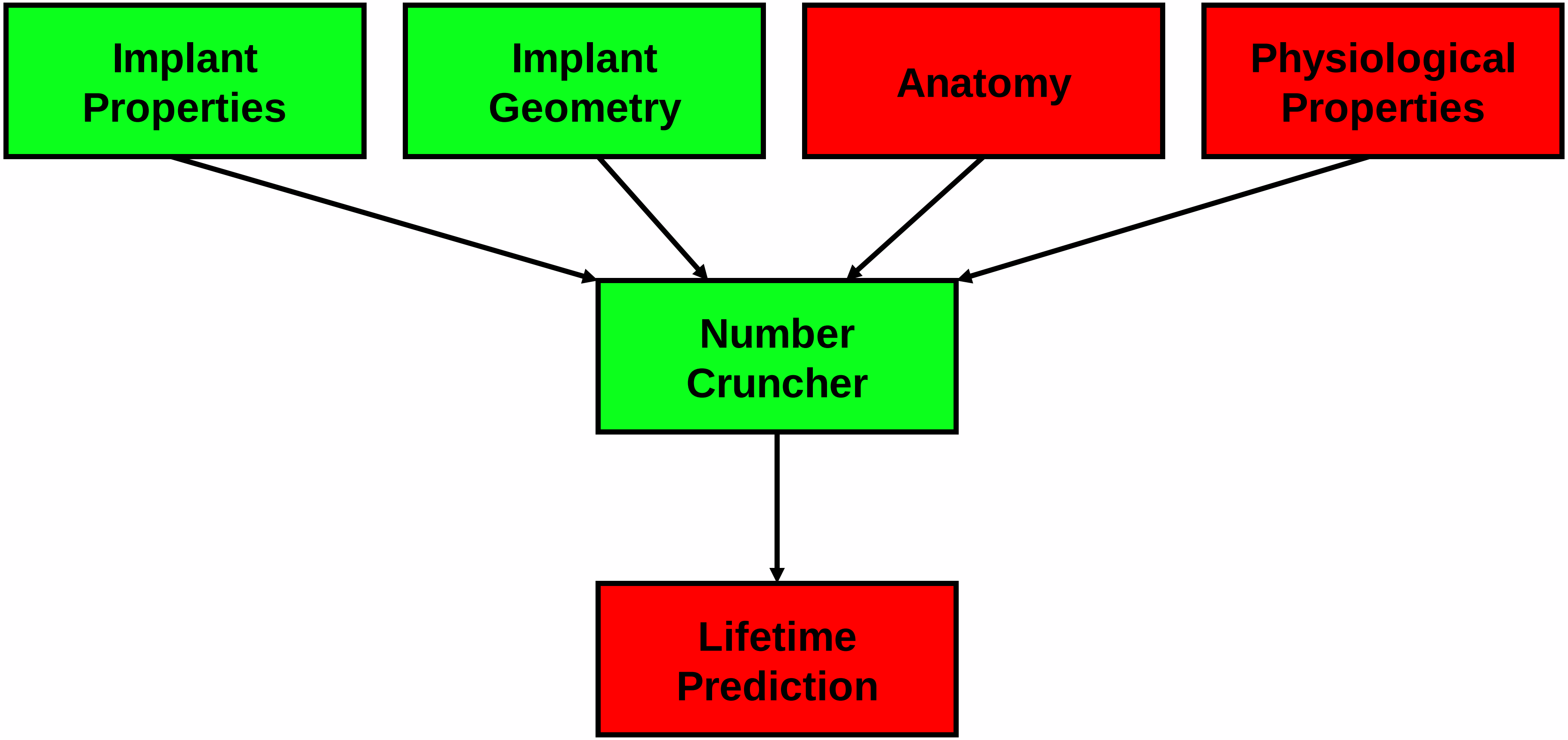
Physical Properties of Implanted Metals

Attribute	Stainless Steel	Cobalt-Chrome	Titanium	Nitinol
Strength	medium (300/560 MPa)	high (600/1140 MPa)	high (880/950 MPa)	high (500/1400 MPa)
Stiffness	high (200 GPa)	High (200 GPa)	moderate (90 GPa)	very low (< 50 GPa)
Fatigue	Good in load control	Good in load control	Good in load control	Good in strain control
Corrosion				
Other				

Why do we still design devices that fracture?

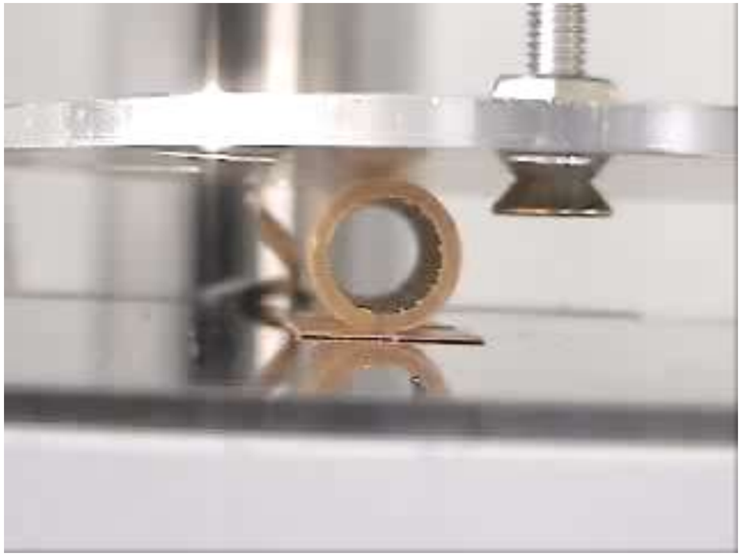


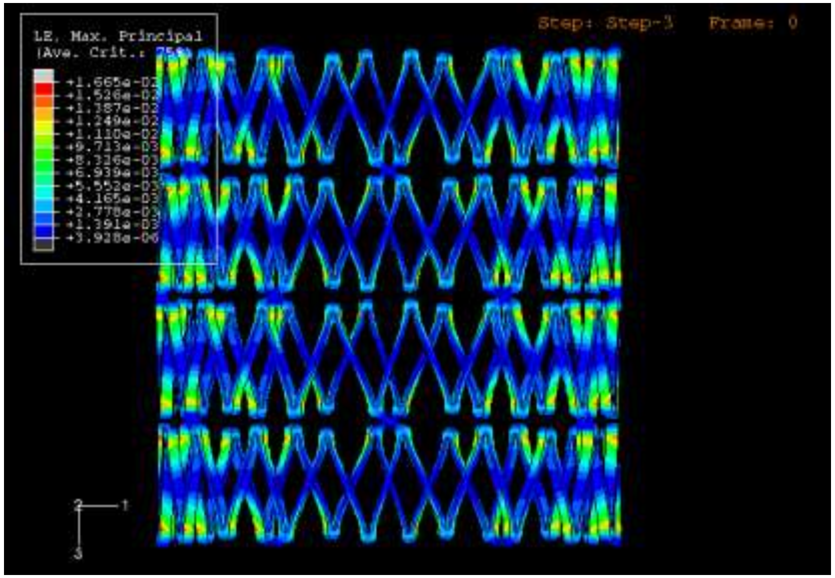
Why do we still design devices that fracture?



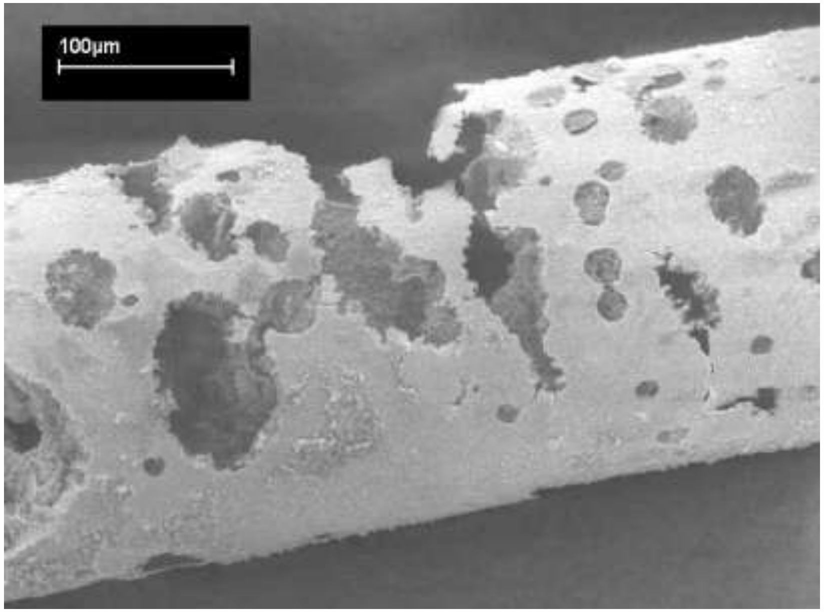
Non-pulsatile Influences

Non-Pulsatile durability





Corrosion Resistance



Physical Properties of Implanted Metals

Attribute	Stainless Steel	Cobalt-Chrome	Titanium	Nitinol
Strength	medium (300/560 MPa)	high (600/1140 MPa)	high (880/950 MPa)	high (500/1400 MPa)
Stiffness	high (200 GPa)	High (200 GPa)	moderate (90 GPa)	very low (~25 GPa)
Fatigue	Good in load control	Good in load control	Good in load control	Good in strain control
Corrosion	Good – Cr_2O_3 (500 mV)	Good – Cr_2O_3 (500 mV)	Excellent – TiO_2 (800 mV)	Excellent – TiO_2 (800 mV)
Other				

Physical Properties of Implanted Metals

Attribute	Stainless Steel	Cobalt-Chrome	Titanium	Nitinol
Strength	medium (300/560 MPa)	high (600/1140 MPa)	high (880/950 MPa)	high (500/1400 MPa)
Stiffness	high (200 GPa)	High (200 GPa)	moderate (90 GPa)	very low (~25 GPa)
Fatigue	Good in load control	Good in load control	Good in load control	Good in strain control
Corrosion	Good – Cr_2O_3 (500 mV)	Good– Cr_2O_3 (500 mV)	Excellent – TiO_2 (800 mV)	Excellent – TiO_2 (800 mV)
Other	MRI artifacts	L-605 is radiopaque	Can be radiopaque	Shape Memory