Steel

The Framework of Our Civilization

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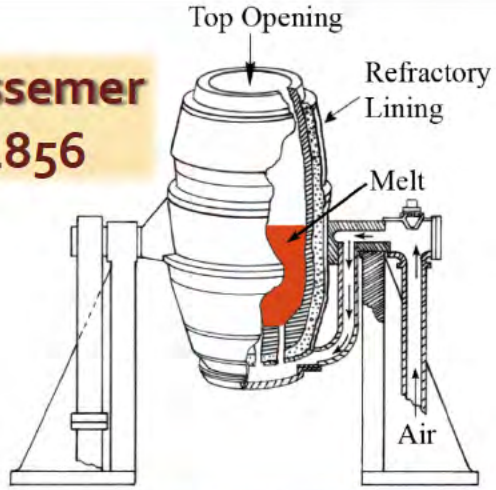
Steel & Modern Civilization

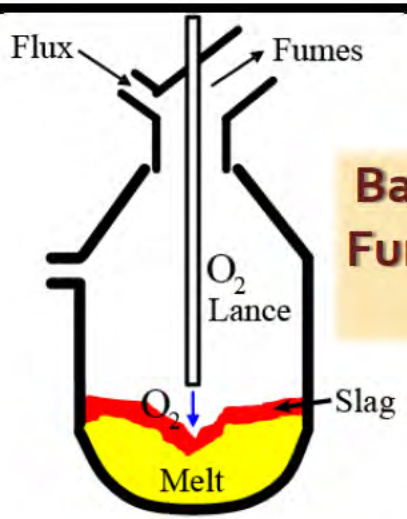
Energy
Structures
Transportation
Drinking Water
Waste Management

Modern Steelmaking

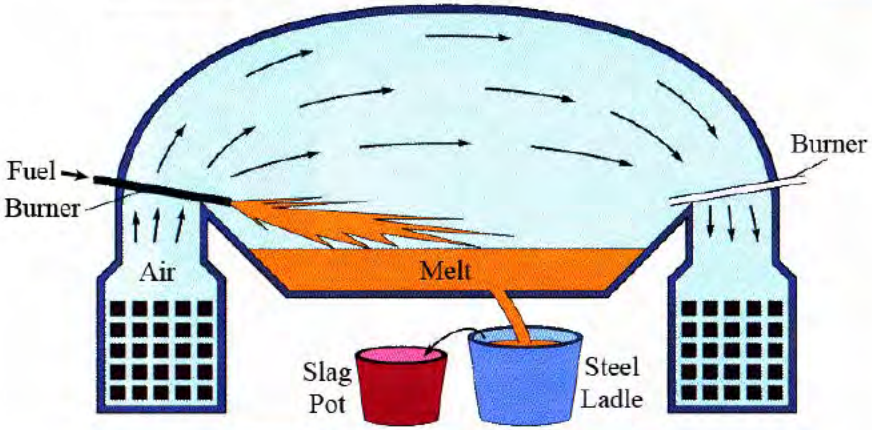
Bessemer
1856



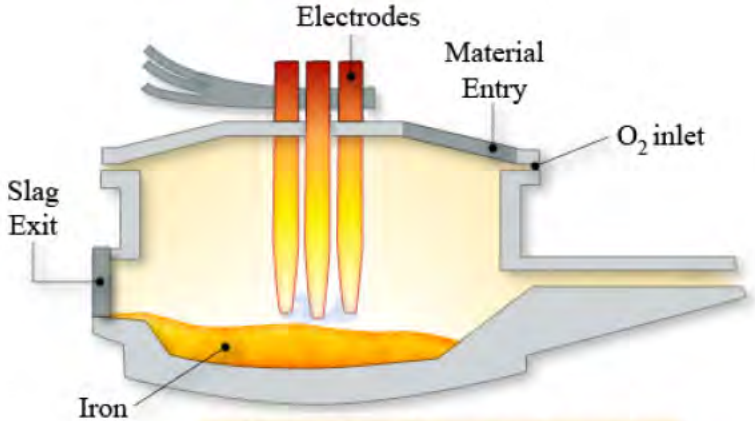
High-Volume Liquid Steelmaking



Basic Oxygen Furnace (BOF)
1952

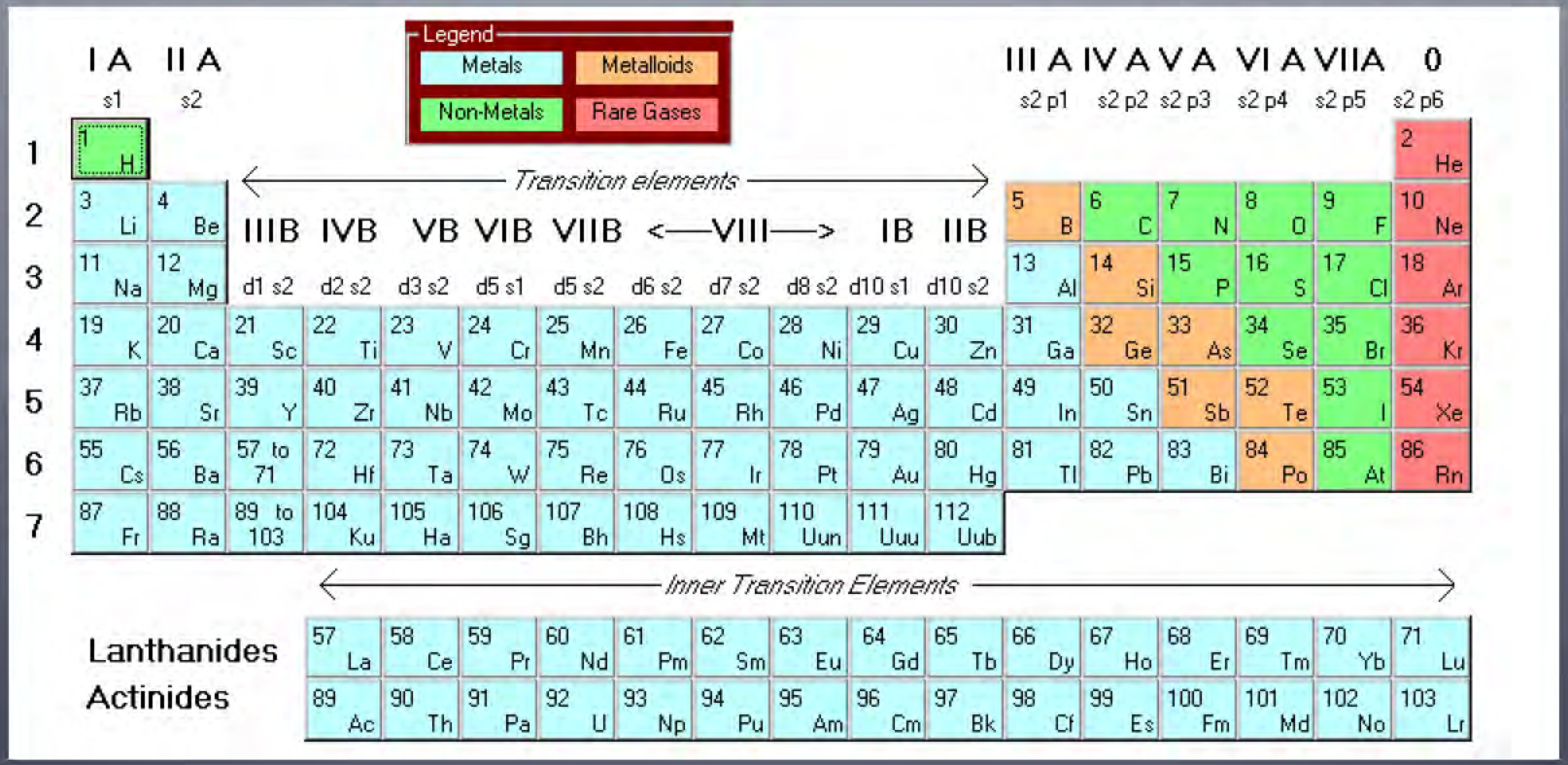


Siemens Open-Hearth Process
1858

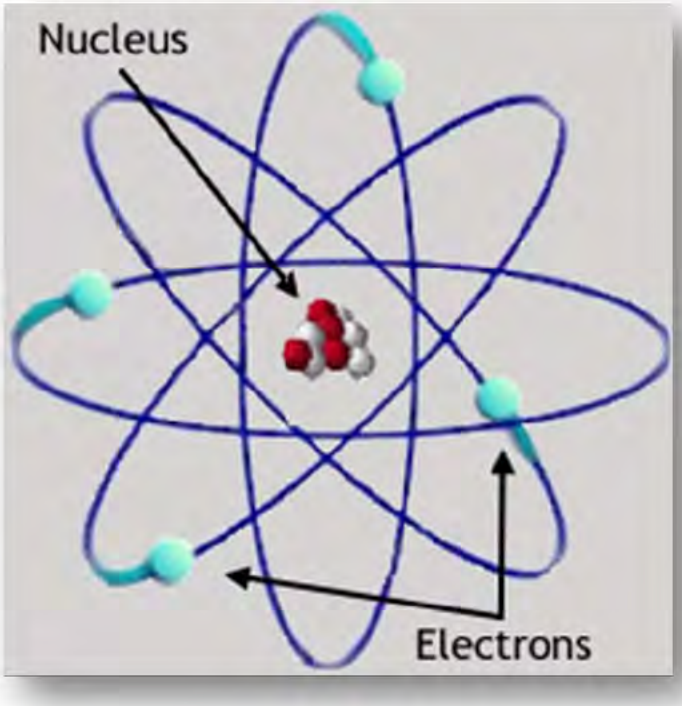


Electric Arc Furnace
1907

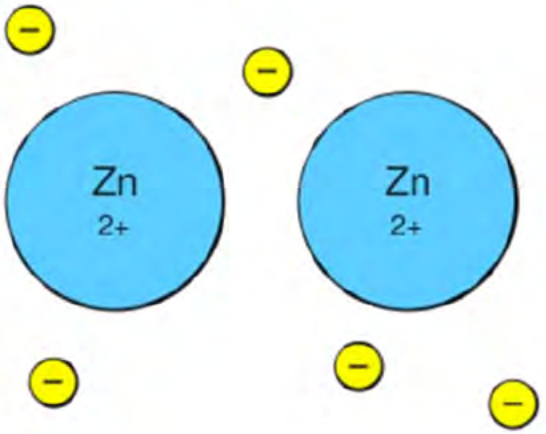
What Is a Metal?



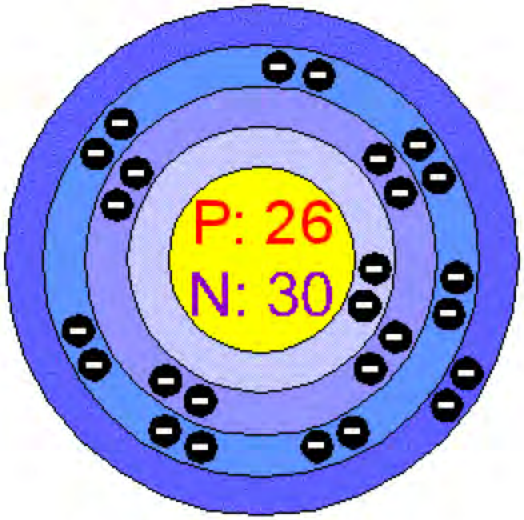
It's All About the Electrons



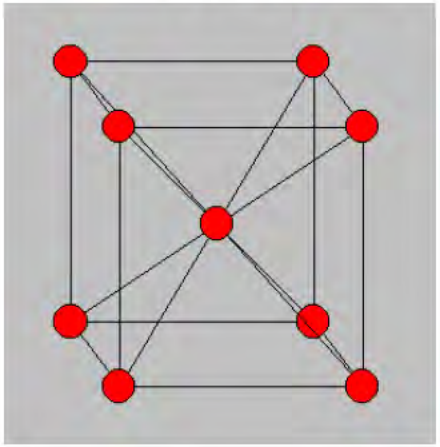
METALLIC BONDING



Phases of Iron



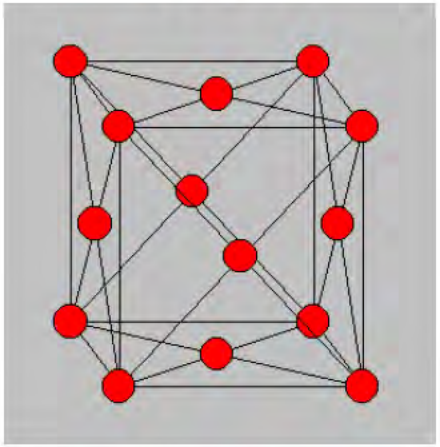
BCC



Room T

- Lower density
- Magnetic
- Stable

FCC

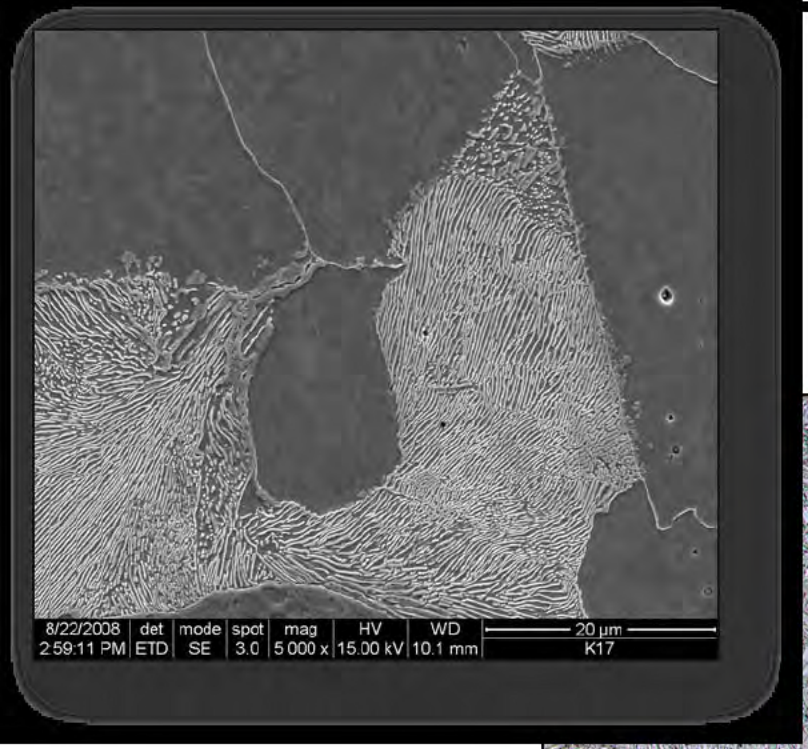


High T

- Higher density
- Non-Magnetic
- Quasi-Stable

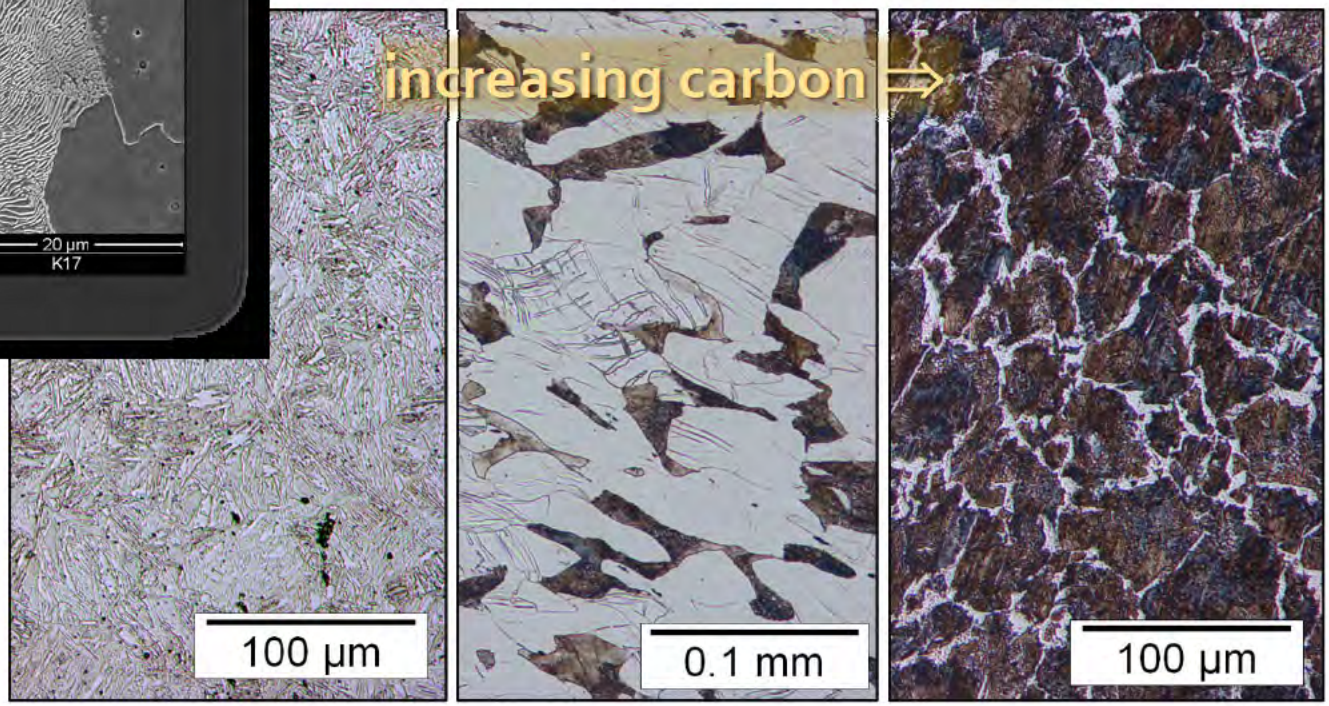
What is Steel?

Plain Carbon Steel



Iron + Carbon

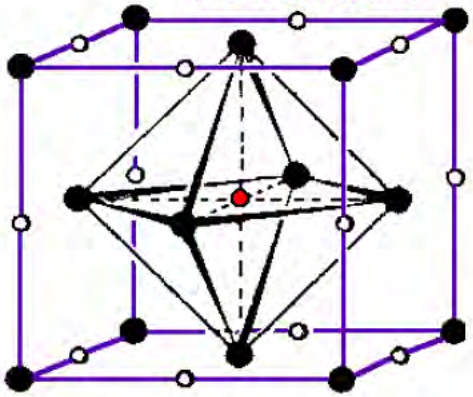
= A Mixture of Phases



Where Does the Carbon Go?

octahedral interstitials

tetrahedral interstitials



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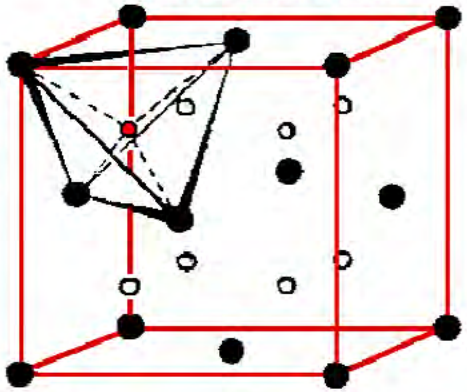

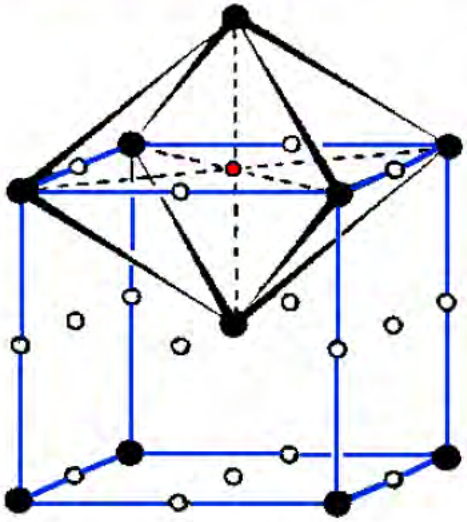

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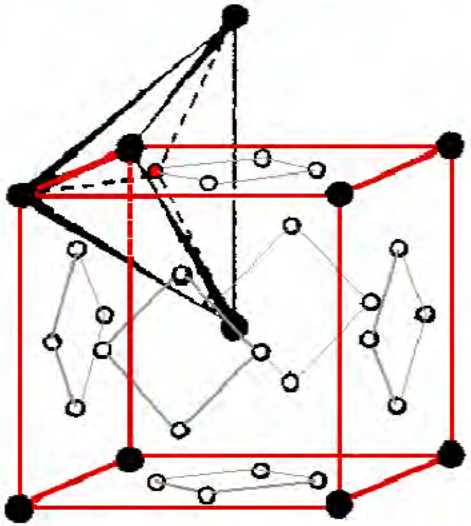


Low-Carbon

Up to 0.30 wt.% C

Medium-Carbon

0.3 to 0.60 wt.% C

High-Carbon

0.6 to 1.00 wt.% C

Ultrahigh-Carbon

1.25 to 2.0 wt.% C

Alloy Steel

Iron + other elements

= Special Properties

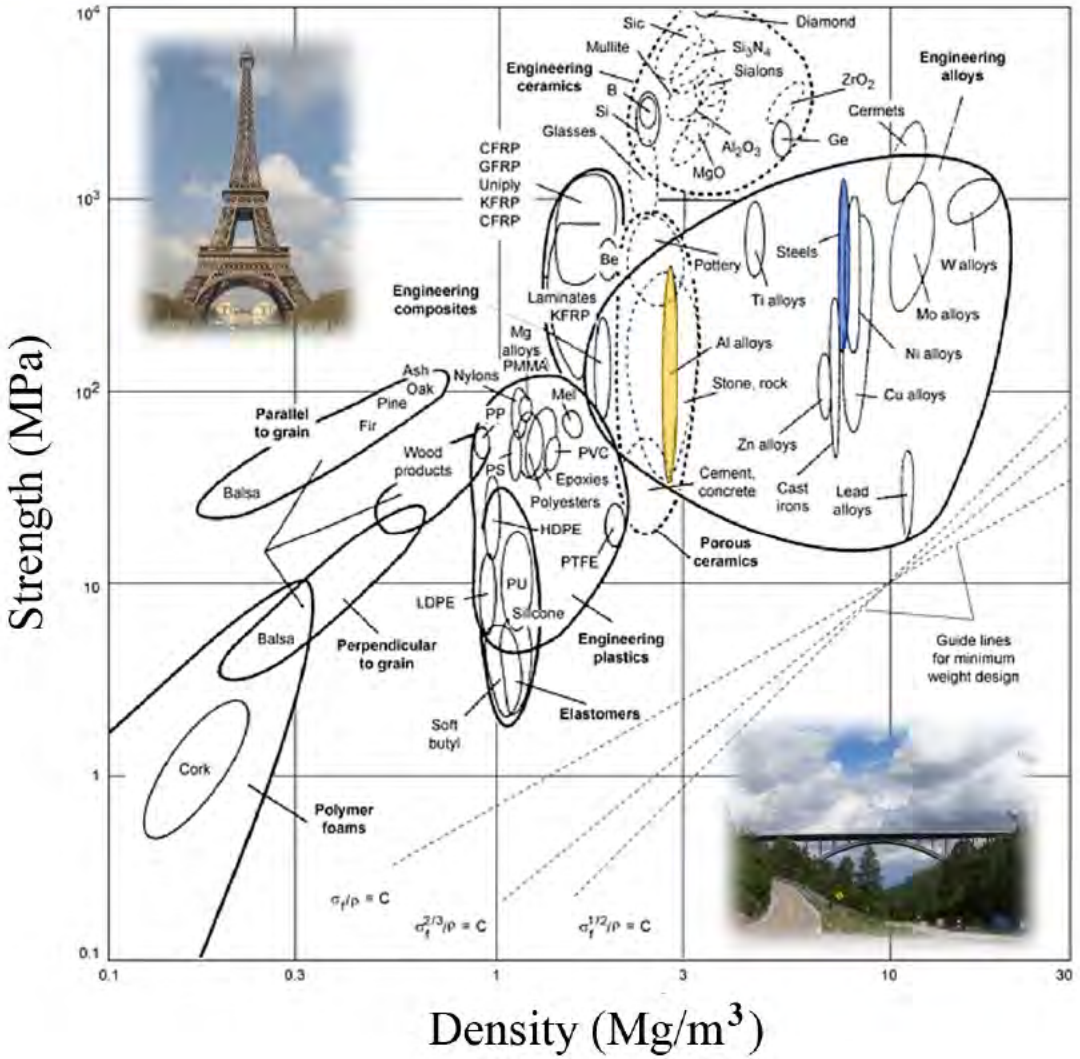
STAINLESS STEEL ⇒ Forms a protective oxide

10.5 to 30 wt.% chromium

How Does Steel Compare?

Structural Applications

- High strength
- Good ductility
- Fatigue resistant
- Cheap



Specialty Applications

- Nuclear reactor vessels
- Orthopedic implants
- Missile casings
- Tool steels

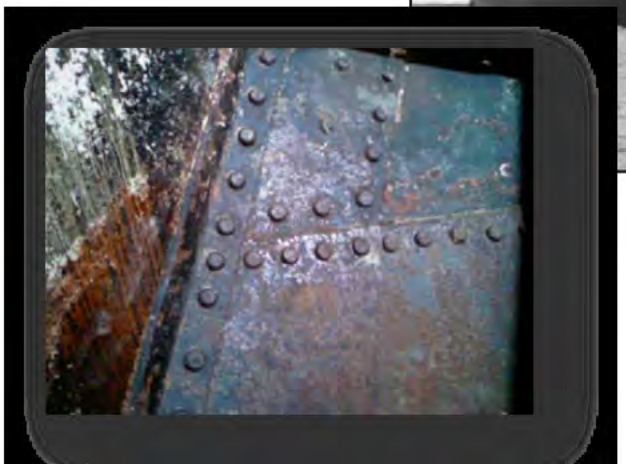
Why Does Steel Fail?

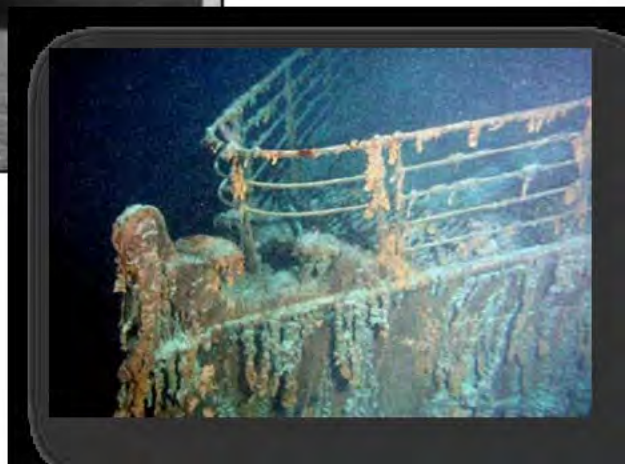
Impurities

The Sinking of the Titanic

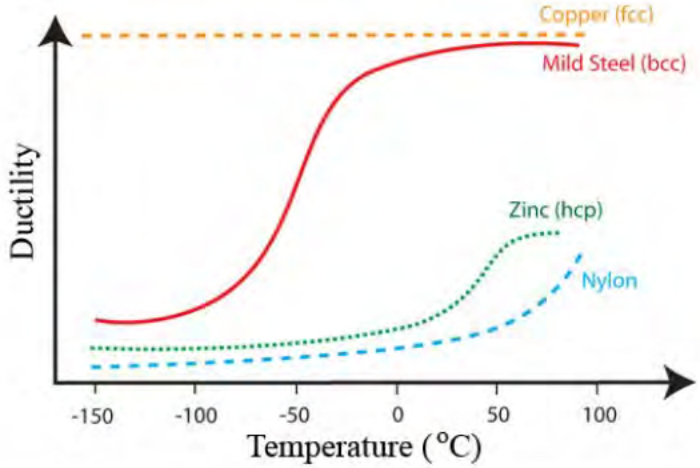
Too much slag in the rivets?

Sank in 1912 (1,517 dead)



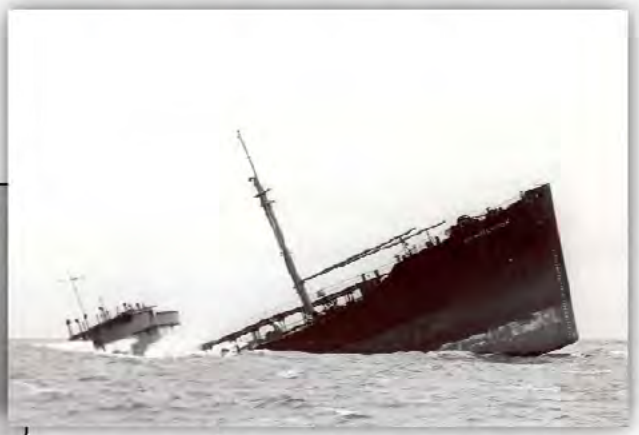


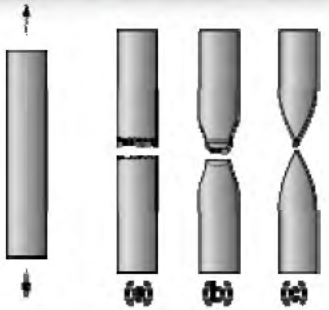
Wrong Type of Steel



Ductile to Brittle Transition

- Unique to ferritic steels
- Ductility lost at low temperatures
- 19 Liberty Ships sink in North Atlantic





Stress Corrosion Cracking

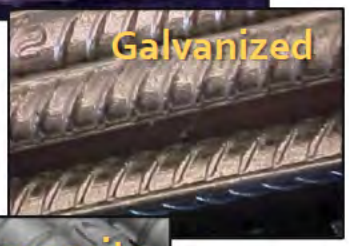
Collapse of pedestrian bridge in NC in 2000
(106 injured)

Mianus Bridge collapse in CT in 1983
(3 dead, 5 injured)

Steel Corrosion

- Salts & deicers
- Cyclic loads
- Sudden failure

Epoxy-coated



Galvanized

Microcomposite

GFRP

Overloading

I-35 bridge over the Mississippi in 2007 (13 dead, 145 injured)

Too Much Traffic

- Aging bridges
- Increasing loads
- Insufficient maintenance

Our Declining Infrastructure

Infrastructure Category	1998 Report (Clark, 1998)	2001 Report (ASCE, 2001)	2003 Trends (ASCE, 2003)	2005 Report (ASCE, 2005)
Aviation	C-	D	No Progress	D+
Bridges	C-	C	No Progress	C
Dams	D	D	Declining	D
Drinking Water	D	D	Declining	D-
Energy	Not Graded	D+	Declining	D
Hazardous Waste	D-	D+	No Progress	D
Mass Transit	C	C-	Declining	D+
Public Parks	Not Graded	Not Graded	Not Graded	C-
Rail	Not Graded	Not Graded	Not Graded	C-
Roads	D-	D+	Declining	D
Schools	F	D-	No Progress	D
Security	Not Graded	Not Graded	Not Graded	I
Solid Waste	C-	C+	No Progress	C+
Wastewater	D+	D	Declining	D-
Waterways	Not Graded	D+	Declining	D-
Overall Grade	**D**	**D+**	**D+**	**D**
Overall Need	**$1.3 Trillion**	**$1.3 Trillion**	**$1.6 Trillion**	**$1.6 Trillion**

Questions

1. What are things you do every day that you could not do without steel?
2. What are some ways that steel might have influenced societies …
   - … in transportation?
   - … in exploration?
   - … in architecture?
   - … in warfare?
3. Why do you think the condition of our national infrastructure—much of which depends on steel—is in a poor or declining condition? What should be done about it? Why isn't it being done? What can you do about it?