A Cross-Linked Glossary of Some Terms from the History of Metal Working

For a very good overview of the various types of steel in todays terminology activate the link

You may also want to check the following modules of the Hyperscript

Damascene Technique in Metal Working

History of Steel

A commented Internet literature list to the history of metal working

Advanced

These are my personal notes, reflecting **my** major points of interest while perusing the Internet data in May **2000**. I may update them occasionally.
You are welcome to share these notes with me, but I cannot guarantee for their scientific soundness (in contrast to almost everything else in this Hyperscript).

Bloom

- The iron-rich spongy stuff left over after smelting iron ore at temperatures of roughly **(1100 - 1200)^{o}C** - well below the melting point of (pure) iron of **1550^{o}C**.
  Steel in Ancient Greece and Rome by: E.A.Ginzel **1995**
  Metallurgical Heritage of India by S. Srinivasan and S. Ranganathan

Cast iron

- Everything with more than about **2% C** content; low melting point of **1100^{o}C** (eutectic composition) to **1200^{o}C**, depending on the **C** conc.
  Steel in Ancient Greece and Rome by: E.A.Ginzel **1995**
- First produced in China.
  Short history including furnace design:
  Early progress in the Melting of iron by V.H.Patterson and M.J.Lalich

China and steel

- First producers of cast iron; but seem to have used it mostly for agricultural and home keeping equipment "on a very large scale". (Now here you have really cultured people!)
  Steel in Ancient Greece and Rome by: E.A.Ginzel **1995**
- Produced cast iron **800 - 700 BC**
  Early progress in the Melting of iron by V.H.Patterson and M.J.Lalich

Damascus steel and blades

- Something made from **330 BC** on from wootz steel (and only from wootz steel, i.e. not with forge welding two kinds of steel). Shows "swirl coloration" and is of "amazing strength and toughness".
  "Could be bent at right angles and still snap back"
  Steel in Ancient Greece and Rome by: E.A.Ginzel **1995**
- Source for Damascus steel was wootz steel; modern reconstruction yields blades with superplasticity (?).
  "One blow of a Damascus sword would cleave a European helmet without turning the edge or cut through a silk handkerchief drawn across it" (from the crusades)
  Blades have "water pattern... whose wavy streaks are glistening - it is like a pond on whose surface the wind is gliding" (from a **6th** century writer).
  Metallurgical Heritage of India by S. Srinivasan and S. Ranganathan
- "Wootz" is the true Damascus steel.
  Damascus Steel - A Brief History by Motoyasu. (Edited by WarAngel)

- The term Damascus steel can refer to two different types of artifacts, one of which is the true Damascus steel from wootz steel (with the water pattern) and the other is a composite structure.
  The mechanical properties of the traditional Damascus blades and the degree of exploitation of the unique properties of the steel are less well understood.
  Comments on the major paper of Verhoeven et al.
  Wootz steel: An Advanced Material of the Ancient World by S. Srinivasan and S. Ranganathan
- Two types from before **500 AD**: "Normal" (two kinds of steel) and "oriental" (or otherwise "true") Damascus from wootz steel.
  Pattern from alignments of **Fe_3C** particles
  Last high-quality blade produced around **1750**; even low-quality stopped in early **1900**.
  Highest quality wootz blades from **16th- 17th** century.
  Chemical analysis of old blades.
  Reproduces "**Mohammeds latter**"
  Note "It is relatively easy to make an ingot that will not pattern on forging"
  Art was lost because change in impurity content of wootz (no more V traces)?
  The Key Role of Impurities in Ancient Damascus Steel Blades by J.D. Verhoeven, A.H. Pendray, and W.E. Dauksch
- Verhoeven summarized his findings in an Scientific Aerican article in Jan **2001**
  (*The Mystery of Damascus Blades*, John D. Verhoeven
  Essentially; Verhoeven together with the black smith Pendray could reproduce "true" damascus including specific patterns.
- The Romans were not impressed by the (early forge welded) blades of the Celtic tribes (they bent easily and broke).
  (Folded) Damascus steel is far superior to homogeneous (ancient) iron, but inferior to good homogeneous steel.
  The Road to Damascus - Sorting Modern Pattern Welding from Myth and Legend by Kevin R. Cashen
- Third technique to create Damascus blades (immersion of a wrought iron package in liquid cast iron)
  Story of Saladin and Richard Lion-Heart)
  True Damascus steel was no longer produced after the Tartar conqueror Timur Leng raided the city in the 14th century and took all blacksmith with him
  Watered steel, wootz and true Damascus, by Lord Mikal Isernfocar called Ironhawk
- In the **7th** century the Syrians in Damascus came up with their own version of wootz steel
  Damascus sword of later times in forging two-metals-technique.
  "Hummels" book

Defects and steel

- Relationship between iron and steel (the role of carbon) first described by **Torben Bergman 1781** in his "Disseratatio Chemica de Analysi Ferri".
  Steel in Ancient Greece and Rome by: E.A.Ginzel **1995**
- Relationship between iron and steel (the role if carbon) first described by Torben Bergman **1774**
  Steel in Ancient Greece and Rome by: E.A.Ginzel **1995**
- Ferrosilicon introduced around **1810**
  Early progress in the Melting of iron by V.H.Patterson and M.J.Lalich
- Relationship between iron and steel (the role if carbon) first described by the Swedish chemist Torben Bergman **1774**.
  The carbide banding mechanism (forming the water pattern in Damascus blades) was found to be assisted by the addition of P, S along with **V**, **Cr**, and **Ti**.
  Wootz steel: A Advanced Material of the Ancient World by S. Srinivasan and S. Ranganathan
- The type of impurity elements (especially **V** and **Mn** besides **C**) in the wootz steel is the most decisive element for true Damascus blades.
  True damascene depended on trace impurities. It may have be decisive were the ore came from!
  The Key Role of Impurities in Ancient Damascus Steel Blades by J.D. Verhoeven, A.H. Pendray, and W.E. Dauksch
- Could **W** (tungsten) have played a role in true Damascus steel?
  Watered steel, wootz and true Damascus, by Lord Mikal Isernfocar called Ironhawk

Europe (after the Romans) and steel

- Significant progress only in late medieval times; due to the use of coal for improved blast processes
  Relationship between iron and steel (the role if carbon) first described by Torben Bergman in **1781** in his "Disseratatio Chemica de Analysi Ferri".
  Steel in Ancient Greece and Rome by: E.A.Ginzel 1995
- Development from the Catalan forge (**8th** century) on:
  Early progress in the Melting of iron by V.H.Patterson and M.J.Lalich
- Description of the diverse periods (Bronze, Hallstatt, La Tene, Celtic, ...) and their swords.
  From Rapier to Langsax - Sword Structure in the British Isles in the Bronze and Iron Age
  by Niko Silvester
- British, French and Russian metallography developed largely due to the quest to document this structure (water pattern in Damascus blades from wootz steel).
  Wootz steel: A Advanced Material of the Ancient World by S. Srinivasan and S. Ranganathan
- Invention of the Catalan furnace was the end of ancient pattern welding (but came back later in an effort to emulate "true" Damascus steel?).
  The Road to Damascus - Sorting Modern Pattern Welding from Myth and Legend by Kevin R. Cashen
- Highly developed pattern welding technology in Europe from about **3rd** to **5th** century AD.
  The Serpent in the Sword: Pattern-welding in Early Medieval Swords by Lee A. Jones
- Toledo was the center of steelmaking from pre-roman times! Repeats what my smith told me. I have no idea about how much of it is halfway accurate.
  History of Swords from Toledo from some tourist agency

Japan and steel

- In Japan, around **600 A.D**., smelting technology was introduced from China and Korea. The Japanese speciality was the mass production of (impure) steel, which was folded so many times and forge welded again that all the impurities were driven out of the steel and the carbon became as evenly distributed as modern steels we have today.
  Damascus Steel - A Brief History by Motoyasu. (Edited by WarAngel)
- "Tamahagane" steel from selecting suitable pieces from a bloom; much folding and hammering homogenized and carburized the steel.
  The Road to Damascus - Sorting Modern Pattern Welding from Myth and Legend by Kevin R. Cashen
- Some Japanese samurai had their swords made in Toledo!
  History of Swords from Toledo from some tourist agency
- There are many ways to compose a Japanes sword from different types of steel.
  Japanese Sword: Blade lamination methods

Hittites and steel

- First culture to produce iron (wrought iron?) in quantities ; about **1500 BC**. Had a monopoly for some time.
  Metallurgical Heritage of India by S. Srinivasan and S. Ranganathan
- Hittites vanished into oblivion around **1200 BC**, being overrun by the "sea people". This may have caused the scattering of the iron working skills throughout the Mediterranean.
  "Hummels" book

Pattern welding

- Pattern welding is about as old as iron and steel. Vikings were best at it (**500 AD**).
  Pattern welding in the West fell into disuse (around **1000 AD**, when full steel blades could be made) until around the time of the Crusades, when the knights brought back Wootz blades, and the smiths began pattern welding again to duplicate the appearance of the watering patterns found on Wootz Damascus blades.
  This seems to be the reason for the wrong assumptions that Damascus blades were obtained by forging together two kinds of steel.
  Damascus Steel - A Brief History by Motoyasu. (Edited by WarAngel)
- Relatively primitive before **500 AD**; but used by the Celts much earlier. The trick was (among many things) the twisting of the single rods.
  Later it became an art form (around **1000 AD**).
  Pattern not necessarily due to difference in C content (homogenizes considerably), but other impurities, mainly P.
  The Road to Damascus - Sorting Modern Pattern Welding from Myth and Legend by Kevin R. Cashen

- Pattern welding from **3rd - 10th** century; before that more simple techniques; zenith in the 6th and 7th century
  Patterns due to different kinds of iron, not necessarily only in **C** content, could be **P** or slag or whatever.
  Started for better quality, in the end purely decorative.
  Many swords with names of maker, but counterfeiting must have been rampant!
  The Serpent in the Sword: Pattern-welding in Early Medieval Swords by Lee A. Jones
- The Romans used pattern welding.
  Patter welding used less by around the 9th century.
  From Rapier to Langsax - Sword Structure in the British Isles in the Bronze and Iron Age
  by Niko Silvester

Recent issues; open points and contradictions

- Can you get "good" steel by roasting wrought iron in a charcoal fire?. J. Rehder **1989** said you can't, but D. B. Wagner in **1990** shows that you can.
- Is wootz steel (or Damascus blades) showing superplastic properties or shatters on impact at high temperatures? It is all a matter of having the temperature right!
- Did anybody in modern times ever made a blade which could be bent at right angles (or tried with an ancient blade)? Not mentioned anywhere.
- Was the art of damascene technique lost? Certainly not the two-steel folding kind; possibly the true (wootz) kind.
- How about true Damascus from soaking bundles of wrought iron (or mild steel) in molten cast iron?
- Was **W** (tungsten) important in creating true Damascus blades?
- When did true Damascus disappear? In the **14th** century or around **1750**?
- Did the Romans use pattern welding? Why were their swords superior to the (pattern welded?) swords of the "Franks"?
- What really happened in Toledo before the **7th** century or so?

Toledo and steel

- About **1000 AD**, a form of this technology (= Wootz) made its way up via the Moors to Spain - this technology allowed the Spanish smiths to create small amounts of smelted steel, which vastly improved the quality of their blades (this is the origin of the reputation of Spain, and the city of Toledo in particular, for manufacture of high quality blades - far better then the pattern welded blades.).
  Damascus Steel - A Brief History by Motoyasu. (Edited by WarAngel)
- Invention of Catalan furnace crucial to development of steel technology in Europe.
  The Road to Damascus - Sorting Modern Pattern Welding from Myth and Legend by Kevin R. Cashen
- The Catalan furnace, invented in **1300**, produced enough good steel and pattern welded blades went rapidly out of style.
  Watered steel, wootz and true Damascus, by Lord Mikal Isernfocar called Ironhawk
- In the **7th** century the Spaniards in Toledo came up with their own version of wootz steel
  "Hummels" book
- "There are stories of how the wrought iron swords of the Gauls bent during their battles against the Romans legions armed with **Toledo steel blades**, which were <<so keen that there is no helmet that cannot be cut by them>>. The hapless Gauls had to stop and straigthen their blades after each blow before continuiung fighting"
  "Sass'" book, p. 96.

Wootz steel

- Carbon rich steel produced on a consistent base in India from about **330 BC** up to the renaissance. Two methods are quoted.
  Steel in Ancient Greece and Rome by: E.A. Ginzel **1995**
- Anglized version of "ukku", denoting steel
  Still exported to Europe, China, the Arab world and the Middle East in the 12th century (and supposedly still a secret).
  Source for Damascus blades with "water pattern".
  Played a major role to the development of metallurgy (together with the "secret" of Damascus steel). Everybody in the **19th** century, it seems (incl. **Michael Faraday**), tried to figure out what it was and how it was made.
  Was the first "advanced" material, used in three continents for well over a millennium - unparalleled by anything else.
  Metallurgical Heritage of India by S. Srinivasan and S. Ranganathan
- Wootz was (the source of) the true Damascus.
  Damascus Steel - A Brief History by Motoyasu. (Edited by WarAngel)

- Superplasticity and other mechanical properties of wootz steel. "Superplastic material essentially comprise a two-phase material of spherical grains of extremely fine grain size of not more than **5** microns at the working temperature".
  Details on production techniques.
  High tech material of the ancient world.
  Wootz steel: A Advanced Material of the Ancient World by S. Srinivasan and S. Ranganathan

Wrought iron

- "What you get upon pounding the bloom. Relatively pure iron. Soft, easy to weld, cannot be hardened. Around since about **1500 BC**.
  Steel in Ancient Greece and Rome by: E.A.Ginzel **1995**
  Metallurgical Heritage of India by S. Srinivasan and S. Ranganathan