Medieval Glues Upto 1600 CE

Class Notes - SCA Estrella 23 Collegium, Feb 18, 2007
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Overview of Medieval Glues

There are many glues which were used in period. Several glues and glue ingredients are as follows:

Cheese glue	wood	natural polymer made up of globular polypeptide casein protein molecules	must be made up and used immediately, sets permanently, subject to attack by microorganisms in damp conditions, stronger in thin coats, impervious when cured
Hide Glue	general all-around glue, sizing, vellum, paper, wood, gilding mordant ingredient	natural polymer made up of strands of polypeptide colloid protein molecules	rehydration undoes the adhesive, stores forever in the dried state, can make stronger bonds than cheese glue but is not impervious or permanent, brittle
Wheatpaste	vellum, paper, bookbinding	Natural polymer made up of gluten proteins	Weak glue, edible, subject to attack by microorganisms or water
Gum Arabic	Vellum, paper, pigment binder, food binder, medicine binder	A true vegetable gum	weak glue, edible
Gum Ammoniac	Vellum, paper, universal gilding mordant	An oleoresin	Weak glue, can be rehydrated to a tacky state, dries hard, is flexible
Turpentine (real period turpentine, not the modern spirit turpentine)	Vellum, paper, pigment binder, gilding mordant, wood, wood filler	An oleoresin	Moderate glue, dries hard, flexible when young, may yellow or cloud with age
Plasters	Stone, brick, tile, ceramics, masonry filler, mordant ingredient	Calcined gypsum compounds	Moderate to strong adhesive qualities, sets permanently
Sugar, honey	mordant ingredient, food and medicine binder	hygroscopic sugars	Weak glue, can be rehydrated to a tacky state, subject to mold

Hide Glue and Other Collagen/Gelatin Glues

Collagen is the principle protein in the bone, muscle and skin tissues of mammals and certain fish. It is made up of strands of protein polypeptide polymers. Collagen-based glues include those made from the hides and hooves of animals and the skin, air bladders and bones of fish. Depending on the species, age and type of tissue material being used to make collagen-based glue, there may or may not be other substances mixed in with the collagens. The purer the collagen content and the milder the cooking-down processes, whiter or clearer the glue will be. The purest rendered collagen glues are hoof gelatin and sturgeon isinglass.

The chemical process for making collagen based glue is to cook epidermal or skeletal-muscular material down in water so that the peptides bonds between strands of collagen polymers break apart. The protein strands get disassociated in the watery goop. When water is removed from the goop, the strands kink and rebind (see diagram below). The re-gelled material is not as strong as the original tissue. It has the virtue that it can be dried as sheets or as solid granules. For use, it is rehydrated and it sets up as a glue by simply letting it dry out again. It has the virtue that it can be stored for forever if kept dry. It has the detraction that it can be destroyed by penetration of moisture after it has set. It was and still is commonly used as paper and cloth sizing. The better grades of collagen-based glue, like isinglass, were and still are superior glues for fine handcrafted woodworking projects like lute and other musical instrument building.

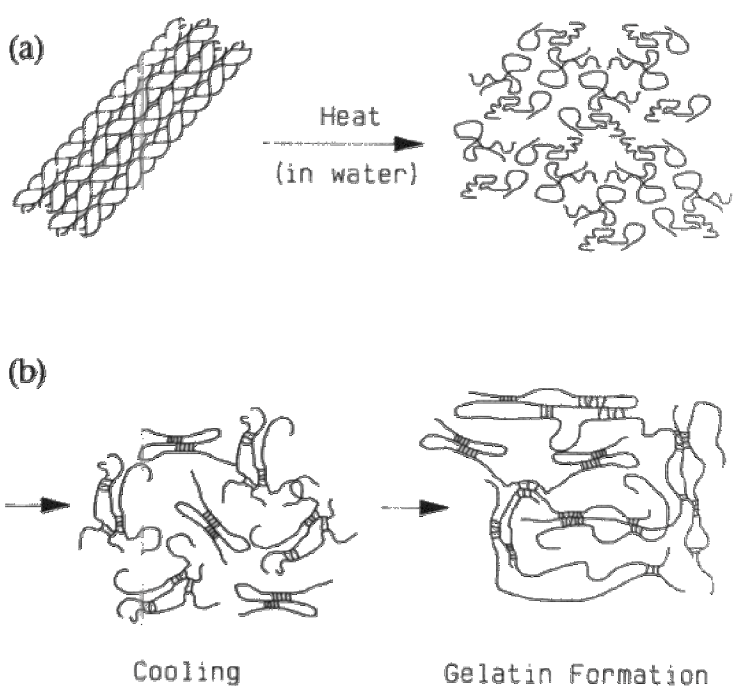


Figure from" The Chemistry of Filled Animal Glue Systems, David W. von Endt and Mary T. Baker, http://albumen.stanford.edu/library/c20/vonendt1991.html (accessed Feb 5, 2007)
Here is one version of a period animal collagen glue recipe:

Theophilus:
Glue from Hide and Stag Horns When this has been carefully dried out, take some cuttings of the same hide [horse, ass, or cow-hide], similarly dried, and cut them up into pieces. Then take stag horns and break them into small pieces with a smith's hammer on an anvil. Put these together in a new pot until it is half full and fill it up with water. Cook it on the fire without letting it boil until a third of the water has evaporated. Then test it like this. Wet your fingers in the water and if they stick together when they are cold, the glue is good; if not, go on cooking it until your fingers do stick together. Then pour this glue into a clean vessel, fill the pot again with water, and cook as before. Do this four times.

Comment: I'm not sure if the four-times over cooking of the glue really does anything – but I've never sat down and made a comparison with any hide glue batches I've made.

I confess that when I want to use a collagen-based glue, I cheat and use Knox brand unflavored gelatin found at almost every grocery store in the US

Cheese Glue (glues based on casein proteins)

Casein is a globular protein that is actually a mix of 3 phosphoprotein molecules known as α-casein, β-casein and κ-casein which are wrapped up in a ball-like structure called a micelle. The soluble k-casein wraps around the insoluble a-casein and b-casein, making the whole micelle soluble by isolating the two latter insoluble casein molecules. In milk, it exists as a "salt" called calcium caseinate, which is the casein micelle with calcium bonded to it. It is water soluble at pH>4.6. By acidifying milk and dropping pH below 4.6, the casein precipitates out and the calcium reacts with the acid anion to make a salt which stays behind in solution. For example, in the case of acetic acid (vinegar is 5% acetic acid), the reaction is:

Ca-Caseinate + acetic acid -> casein + calcium acetate

Rennin also causes insoluble casein molecules to precipitate. It breaks up the κ-casein molecule on the outside of the micelle, thus exposing the insoluble α-casein and β-casein molecules to the milk solution, thus causing some of these to precipitate. 75% of the casein molecules in milk are α-casein.

Mixing precipitated casein in curds in an alkaline solution containing lime or baking soda makes it soluble again. This solution is casein glue. When cheese curd and lime are used, it is called cheese glue. Cheese glues were the most common wood glue prior to the 20th century when displaced by synthetics.

The adhesive mechanism is as follows: the dissolved casein molecules in the alkaline water-based solution penetrate the surface of the wood (or other porous material), making a mechanical bond by infiltration. The mechanical bond from this penetration is usually stronger than the chemical bond between the glue molecules. The glue sets because the water in the solution evaporates away, allowing for the strands of casein molecules to ball back up and re-bond with one another.

The following high school chem experiment by a high school chem. teacher from Illinois highlights some of the chemistry

High School Science Experiment in making casein glue by Mr, Christopherson of Normal Community High School in Normal, Illinois
Comments by Helm-Clark in italics
From http://www.unit5.org/christjs/10caseinglue.doc:

1. Pour about 100 mL of skim milk into a 400 mL beaker. Add 15 mL of white vinegar (5% acetic acid).

Skim milk has a much higher concentration of casein than homogenized whole milk, unseparated milk or cream. So use skim milk if you're going to make your own casein glue starting from milk itself. Or get not-homogenized milk from a dairy or a goat or sheep or horse or cow, skim the cream fraction and then make your curds using vinegar.

2. Place the mixture on a hot plate and heat, stirring gently with a glass stirring rod. Observe the mixture carefully and stop when you see turbidity (solid curds floating in the beaker). Do not overheat the mixture; the protein will denature and your glue won't work.

If your temperature exceeds 40 °C, the protein will be destroyed in your acidified milk solution. All the heat does is speed things up a bit. You can use a candy thermometer to watch the heat or you can make your curds the old fashioned way, which is to be patient while they form more slowly at room temperature.

3. Filter the mixture, using a folded piece of paper towel, into an Erlenmeyer flask. The curds should remain in the paper towel, while the filtrate (i.e., the liquid) will filter through into the flask. Discard the liquid filtrate; this contains the whey.

Real lab equipment is optional. A pot and your stovetop will work just fine. You can separate your curds with a spoon (REALLY slow) or use a basket-type paper coffee filter.

4. Scrape the curds from the paper towel into a small plastic cup.

Most any dilute acid will work to clot the casein into curds. For example, the "sour milk" reaction is driven by the transformation of lactose in the milk into lactic acid.

5. Add _ teaspoon of baking soda (NaHCO3) to the cup and stir with a wooden splint. Slowly add drops of water, stirring periodically, until the consistency of white glue is obtained.

The original on line has lost the number of teaspoons to use – it should read "1 teaspoon." This recipe makes a decent casein glue which after being applied takes 12 to 24 hours to dry/cure.

You will make an even better glue using this recipe if you do a 1:1 substitution of pickling lime for the baking soda (see discussion on lime vs baking soda below)

Source:
Christopherson, J. (2002-2007), Chemistry, Normal Community High School, Normal IL http://www.unit5.org/christjs/10caseinglue.doc. (accessed 5 Feb 07)
The main site at http://www.unit5.org/christjs is worth checking out if you like fun chemistry sites.

I have not seen any period recipes that actually start with milk, make the curds and then use the curds in an alkaline solution as glue. Pliny, who is a classical Roman author of the 1st century AD, discusses glue made this way starting with milk. In general, if Pliny mentioned it, it is a good chance that it was done this way in period since Pliny was one of the sources that late medieval and renaissance people consulted.

Here are two period cheese glue recipes:

Theophilus:
Cheese Glue The individual pieces for altar and door panels... should be stuck together with cheese glue, which is made in this way. Cut soft cheese into small pieces and wash it with hot water in a mortar with a pestle, repeatedly pouring water over it until it comes out clear. Thin the cheese by hand and put it into cold water until it becomes hard. Then it should be rubbed into very small pieces on a smooth wooden board with another piece of wood, and put back into the mortar and pounded carefully with the pestle, and water mixed with quicklime should be added until it becomes as thick as lees. When panels have been glued together with this glue, they stick together so well when they are dry that they cannot be separated by dampness or by heat.

Using part-skim mozzarella, you end up with a third of the cheese you started with at the "wash in hot water" step. Tends to be thin if you pre-mix the lime, especially if you're using hydrated lime (pickling lime). If you want truly "thick as lees" (which is about the same as thick as commercial apple sauce), then use 4 parts post-washed/tortured cheese to two parts dry pickling lime and mix them together. Add no more than one part water, and add it dribble by dribble and not all at once! If you mix the water and lime together first, the batch will be thin. Good for paper but not so good for wood. Overall, I would skip Theophilus's recipe and use Cennini instead.

Cennini
To Make a Glue out of Lime and Cheese. There is a glue used by workers in wood; this is made of cheese. After putting it to soak in water, work it over with a little quicklime, using a little board with both hands. Put it between the boards; it joins them and fastens them together well. And let this suffice you for the making of various kinds of glue.

First off – try to avoid using real quicklime (CaO). It looks like it's safe to handle and in most cases, it won't do anything nasty to you – but if you get any in your eyes, it causes *blindness. If you have and/or use quicklime, ALWAYS wear safety goggles (not glasses) that are rated for preventing chemical splashes. They are commonly available in the paint or safety equipment departments of most hardware stores for less than the price of a combo meal at the local fast food burger joint.*

Hydrate lime works just fine. It's sold as pickling lime in small containers or as garden lime in big bags. The pickling lime variety is better quality and finely ground but slightly more expensive. You don't need to make it on a board like Cennini recommends. A mortar and pestle work fine. Proportions are 1 part by volume part-skim mozzarella cheese, one part by volume pickling lime ($Ca(OH)_2$) and one or two dribbles of water added while mixing.

Depending on the cheese, this recipe can really STINK!!!

Avoid using cottage cheese or Neufchatel or cream cheese since some modern commercial formulations may contain whey cheese. Whey cheese will not make glue – only a curd cheese will make glue. Part-skim mozzarella will always work. Provolone cheese will work too. When in doubt, make your own curds using part-skim or skim milk and vinegar.

Lime vs. baking soda

Modern cheese research (e.g. Guo, C., B.E. Campbell, K. Chen, A.M. Lenhoff, O.D. Velev (2003), Casein precipitation equilibria in the presence of calcium ions and phosphates, *Colloids and Surfaces B: Biointerfaces* 29: 297-307) has demonstrated that sodium based alkaline solutions like water+baking soda are nowhere near as good for rebinding the drying caseins as calcium-based solutions. So baking soda will work as the solution base for a casein-based glue but lime solutions will always be better. If you want really-gnarly totally-awesome homemade wood glue, use calcium phosphate instead of lime – but be aware that it's not period…)

Hydrated Lime safety note

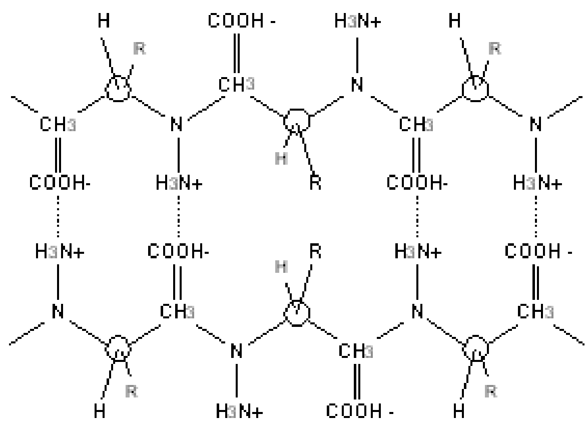
I'm really not an alarmist – but I have handled a lot of chemicals professionally and have seen and also personally experienced some nasty mishaps in the lab.

Ca(OH)2 aka hydrated lime aka pickling lime aka slaked lime aka calcium hydroxide isn't as dangerous as quicklime – but you still want to be very careful with it. Hydrated lime can still damage eyes – just not as quickly as quicklime.

If you get hydrated lime in your eyes, flush with running water for 15 minutes. The flushing step is really important here – don't wait for anything before getting those eyes under running water. After flushing, go immediately to an ER, trauma center or urgent care center, because any damage to the surface of your eye must be treated right away or you can damage your eyesight. If your eyes don't hurt after flushing, don't assume they are ok because corneal damage doesn't always hurt since there are no nerves in the clear part of the eye.

The simple precaution of good wrap-around safety glasses or goggles can help prevent a nasty chemical burn injury to your eyes. This may sound goofy, but you just might try simulating an eye injury in your kitchen or garage, complete with groping your way to the nearest source of running water and then seeing if you can get your eyes flushed (not possible in some sinks, by the way – but garden hoses and sink-mounted squirter hoses always will do the job). If you're playing with eye-damaging chemicals in a place where you can't get to water to flush your eyes with your eyes shut in less than 20 or 30 seconds, you probably don't want to use that area.

All lime products will dry out your skin. Some people are much more sensitive than others. Too much lime on your skin can give you a rash (I found this out the hard way working at a limestone quarry one summer) and way too much lime will cause chemical burns – though it is really rare and not at all likely with pickling lime in your kitchen.



This is a geometrical diagram of a Casein protein chain. It incorporates the amino acids, the lactic acid, CH_3 and the inverted ammonia molecules H_3N^+.

this is a figure of a casein monomer plus some – I'd cite the source but I can't seem to find it again! ☹ if anyone finds it, please email me…

Wheatpaste

The world of gluten proteins is way beyond my ability to decipher (I'm an inorganic chemistry nerd – organic chemistry is not really my cup of tea). As far as I can tell from my survey of protein chemistry, the gluten proteins seem to work by being bound to one another by sharing bonds with disulfide connecting ligands. Whereas there were only three casein molecules, the number of gluten protein molecules are "many" – more than I could count. I think it is safe to assume that the setting process of a wheat flour + water solution is similar to the setting process for collagen-based glues: as the water evaporates or is chemically bound, the many monomers and polymers of gluten proteins either bond or rebond, thus making an adhesive. I will refer the real organic chem nerds to the most recent review article on the subject by one Herbert Wieser who seems to show up on at least half of all the gluten chemistry journal articles: Wieser, H. (2007), Chemistry of gluten proteins. *Food Microbiol*, 24 (2):115-9.

If you've gone through kindergarten or day care, then you've played with wheatpaste, a mixture of flour and water. My assumption is that it was ubiquitous throughout western civilization wherever wheat was grown: its quality as an adhesive is apparent to anyone who has ever made wheat-based bread. There are almost no recipes for wheatpaste, however, in my collection of period sources. I have an irreverent thought that there are no recipes just because no one really needs one.

I do know of at least one wheatpaste recipe, from the "Bolognese Manuscript," also known as the *Segreti per Colori*. It is included in Merrifield's translated collection, *Medieval and Renaissance Treatises on the Arts of Painting*. My opinion is that the recipe was documented in the Bolognese Manuscript because it is an uncommon use of wheatpaste.

Bolognese Manuscript:
Glue for making any mould you like for casting figures. Take Armenian bole, flour and clear water, and knead them together until they form a rather stiff paste; model what you like with it.

The Armenian bole is a clay. It can play two roles: to color something clear or white and to suck up non-compositional (unbound, unnecessary) water, thus shortening curing/drying time.

The above recipe underscores one of the most important qualities of wheatpaste: it can be used as a filler. It sets up quickly (with or without bole) and can be shaped to fill any hole or gap, as itself, as a paper mache or as a "leather mache." It can decompose in humid environments. It is not really useful for anything other than paper or vellum since it's a really wimpy glue.

Gum Arabic

True gums either dissolve in water to make a viscous fluid or absorb water until forming a jelly-like paste. Gum arabic, the wound sap of *acacia* trees, dissolves completely in water with little or no residue. In the middle ages, it is more than likely that other gums were also sold as gum arabic. In the period gum trade from North Africa and Arabia, if it looked like gum arabic to a trader or harvester, then that's what it was. The precision of having the right name for the right object is a modern phenomenon. Medieval people did not have the benefit of modern chemistry to help them identify a gum variety. The only good tests were to eyeball the gum, to check the viscosity of the gum-water solution and to dissolve it to see if it left a large residue. Even then, if the gum really was gum arabic, it could include impurities.

Gum arabic is usually dried and granulated. Pre-made gum arabic solutions are available at most good art stores but it's too wimpy to use as glue. Get the dried granules and make your own if you want to use it as a glue.

Gum Arabic is best known as a binder for pigments. It also is a good paper glue and a good binder for sweets and a binder for medicines. It is edible and essentially tasteless when there are no impurities. There are too many recipes for gum Arabic as a pigment binder to touch on

here. There are also many gilding recipes that call for gum arabic, e.g. in Merrifield's collection. The following is a candy recipe using gum arabic:
From Curye on Inglische, Part V: Goud Kokery.
Recipe #15: Ymages in suger MS Source: Harl. 2378

To make ymages in suger. And if 3e will make any ymages or any o[th]er
[th]ing in suger [th]at is casten in moldys, sethe [th]em in [th]e same manere
[th]at [th]e plate is, and poure it into [th]e moldes in [th]e same
manere [th]at [th]e plate is pouryde, but loketh 3oure mold be
anoyntyd before wyth a litell oyle of almaundes. Whan [th]ei are
oute of [th] moylde 3e mow gylde [th]em or colour [th]em as 3e will.
3if 3e will gilde [th]em or siluer [th]em, noynte [th]em wyth gleyre
of an egge and gilde [th]em or siluer [th]em, and if 3e will make
[th]em rede take a litell gum araby, and [th]an anoynt it all abowte
and make it rede. And 3if 3e will make it grene, take ynde wawdeas
ii penywey3te, | ii penyweyte of saffron, [th]e water of [th]e gleyr
of ii egges, and stampe all wele togeder and anoynte it wyth all.
And if 3e will make it lightly grene, put more saffron [th]erto. And
in [th]is maner mow 3e caste alle manere froytes also, and colour it
wyth [th]e same colour as diuerse as 3e will, and [th]er [th]at [th]e
blossom of [th]at per of apel schull stand put [th]erto a clowe &
[th]er [th]e stalke schall stand makes [th]at of kanell.

I got lazy and instead of typing it in from my copy of Curye on Inglische, I downloaded the above recipe from the Floriligium at:
http://www.florilegium.org/files/FOOD-SWEETS/sugar-paste-msg.html
(accessed 5 Feb 07).
The [th] *characters are thorns in the original manuscript.*

For those who live in mesquite land, the gum that is exuded from mesquite is an acceptable substitute for gum arabic in almost every respect and property. They are very similar in composition.

Gum Ammoniac

Gum ammoniac is not a true gum. It's not a gum at all – it's really an oleoresin (a mix of a soft resin with an essential oil)

Gum ammoniac is probably the worst smelling medieval sticky stuff around. It is the wound sap of the *Dorema ammoniacum*, which grows in Iran and Iraq. It was used in the middle ages as a stand-alone gilding mordant and with gum arabic as another gilding mordant (period recipes can be found in Merrifield's collection). It is the only gilding mordant that works on leather. It also makes a good leather glue if made double strength. To make it, you take the "tears" of gum ammoniac, grind them and separate out as much of the veggie matter trapped in the gum as possible. Let it soak 12 to 24 hours in a class or ceramic jar with just enough water to cover the broken up and cleaned up ammoniac. Stir it every few hours. Strain the liquid; toss the solids. The icky looking off-whitish liquid is the glue/mordant. If it dries and is still exposed, you can breath on it through a straw (to concentrate humidity in your breath) and rehydrate where you've brushed it onto something. It will be tacky when hydrated. If you're using it on leather, lay down two coats of the liquid before gilding or gluing.

You can take a short cut and vastly reduce the soaking time by putting the water and ammoniac tears in the microwave.

Turpentine

Turpentine is another oleoresin. The glue variety is Venice turpentine, which is the processed and cleaned up wound sap from the European larch tree, *Larix decidua* or *Larix Europaea*. Two or three fractions are made from the exuded sap: colophony resin (solid), turpentine (viscous) and spirits of turpentine (very liquid). The spirits of turpentine is what is sold and known as modern turpentine – and it bears no resemblance to period turpentine, a sticky gooey viscous fluid. Mixed with fibers like flax or hemp, it was used a filler for caulking boats. It is sticky enough to use as a minor wood glue and as one of the two ingredients of medieval wax-based sealing wax. As a glue, it can degrade in heat.

Commercially available Venice turpentine is often too processed to work as a sealing wax ingredient, so you have to heat it up and add powdered resin back into it before making medieval sealing wax. *Note that lac and shellac based sealing waxes are not period – they are just out of period.*

Waxes, turpentine and resin are really easy to ignite – so always use a double boiler when heating these on a stove top and have a fire extinguisher and/or a bucket of sand handy.

Plasters, mortars and grouts

Gypsum ($CaSO_4 \bullet 2(H_2O)$) is baked at high temperatures to drive off the hydroxide groups. The final product is $CaSO_4$ which is now really anxious to get it's water groups back. By mixing $CaSO_4$ with water, the calcined calcium sulfate rehydrates and reforms the bonds that were broken in the calcining process. This is the basis for all mortars, grouts and plasters, both medieval and modern. It sticks well to itself better than it sticks to surrounding bricks or stones: it grabs onto bricks and stone only through penetration into the bricks' or stones' pores to set up a mechanical bond.

Sugars in glues

Sugars are generally hygroscopic, meaning they want to grab onto anything with some water in it. That's why sugars and honey are sticky. In the middle ages, sugars and honey were not used as stand alone glues – because they would be too weak, but these were commonly added to gum arabic and other glues recipes (e,g, gesso sotile) where they improve glue quality due to their sticky hygroscopic nature.

Period Sources: must-have books

Pliny's *Natural History*
There are two versions available. There's a Penguin Books edition with is abridged – I don't much like having found translations mistakes in it in the past. The other version is the Loeb Library version, which is put out by the Harvard University Press. It has several volumes covering the entirety of Pliny's work with the translation on one side of the page and the original Latin on the other. I greatly prefer this version over the abridged version. The Loeb Library version has the great detraction of being rather expensive once you have bought all ten or so volumes. All of Pliny is also online at the Lacus Curtius website – but it is in Latin only, so if you didn't take Latin in school, it doesn't do much for you. *(The Lacus Curtius website used to be hosted at U. Kansas but as of 2007 is hosted at the University of Chicago – a great place just to surf even if you don't do Latin; the stuff just in English is spiff all by itself)*

Pliny the Elder, Natural History (in 10 volumes) trans. By H. Rackham,1958, Loeb Classical Library/Harvard University Press.

Pliny the Elder, Natural History : A Selection, trans. By Healy, J. F., 1991, Penguin USA, 399 pp., ISBN: 0140444130. [This is the edition I DON'T recommend, due to bad word choices in the translation in the sections covering mining and minerals]

Cennini's *Il Libro dell'Arte*:
Fish glue! Cheese glue! Mordants! Who could ask for more? This is a 15th century manual of techniques and materials for artists. It's a must have for medieval material science.

Cennini, C., *The Craftsman's Handbook,* trans. by Thompson, D. V., 1933, Yale University Press, 142 pp. (available as a Dover book)

Cennini is also available online for free at: http://www.noteaccess.com/Texts/Cennini/

Theophilus's *On Divers Arts*
Theophilus was a 13th century monk who wrote up an artist's and craftsman's handbook on pigments, casting, stained glass, etc. This is another must-have medieval material science book.

Theophilus, *On Divers Arts (De Diversis Artibus*), trans. By Hawthorne, J., and Smith, C., 1979, Dover Publications, 216 pp., ISBN 0486237842.

Merrifield's Collection of Translated Treatises

Merrifield, M. P., (1967), *Medieval and Renaissance Treatises on the Arts of Painting*, Dover Publications, ISBN 0-486-40440-4.

Merrifield was funded by a British royal commission to translate medieval Italian and Latin manuals on painting and related crafts. The original was published in 1849. The 1967 date is the date of Dover's copyright on their edition of this work. *There are at least over 20 glue recipes I didn't have time or room to include in these class notes. If you are interested in the medieval material sciences, this is a must-have book.*

Non-Period Sources used in writing up these class notes:

Thompson, D. V., 1956, *The Materials and Techniques of Medieval Painting,* Dover Publications.

Mayer, 1977, *The Artist's Handbook,* Viking Press, NY.
Though a bit dated, the sections on materials are copious and instructive. Mayer included a lot if info on traditional materials that are now hard to impossible to find.

Parry, E. J. (unknown date), Gums and Resins, Sir Issac Putnam and Sons, Bath, England, 106 pp.
For the contents, I suspect this was published around 1910. It traces the commonly traded gums and resins at a time when they were still extensively used, before they were replaced by modern synthetics.

Howes, F. N. (1949), *Vegetable Gums and Resins,* Chronica Botanica Co., Waltham, Mass., 188 pp.
This is THE BOOK on resins and gums. It was published just before the natural gums and resins disappeared from the market because of the introduction of new synthetic glues and epoxies. It includes where all the different gums and resins come from as well as all their properties.

Massey, R. (1967), *Formulas For Painters*, Watson-Guptill Publications, NY, 224 pp. ISBN 0-8230-1877-6.
I find that I can often cut down on the guess work as to proportions of things like gums, rosins, varnishes, mordants, etc. because Massey very often has a recipe he has already used and tested which will be close to what I want to try. A good shortcut book.

And no, superglue is not period…

One Last Note Regarding collagen and casein glues:
The biochemist in the house has pointed out to me that since all proteins are polypeptides and all polypeptides are polymers, this is a case of redundant redundancy being redundant…but what do you expect when you have an inorganic physical chemist type trying to be intelligent about all that organic chemistry studied 25 years ago and then cheerfully forgotten? Regardless, you can still use "protein polypeptide polymers" at your next cocktail party to impress people – though it will make any biochemists present just roll their eyes…