THE MOVEMENT OF THE BOOK SPINE

by Tom Conroy

Introduction.

This paper will discuss the Western codex as a moving system. The core of the paper is the influence of spine structure on the action of the book. "Structure" is the shapes, materials, and interrelationships of the parts of the book when at rest. "Action" describes the book as it moves, both visible movement and invisible changes in stress and tension. Structure and action are related but do not correspond on a one-to-one basis. For instance, Victorian hollow- and tight-back bindings in leather have very different structures; but they have the same rigid-spine floppy-joint action. On the other hand, tight-back bindings vary greatly in action according to how much the leather has been pared. Normally structure is a means toward some desired action; perhaps this is why the two are often confused.

The major divisions of my topic are the influence of the linings on the action; influence of the sewing system on the action; and relationship of joint action to spine action. I will discuss them in this order because analysis and explanation are simpler for linings, and concepts used to understand linings help to understand the effects of sewing systems and joints. The arrangement might be different with a historical, a bench-oriented, or a rigidly logical approach. The bulk of this paper will assume a tight-back stiff-board structure as the basis for analysis; where other structures are discussed the exception in question will be stated.

This is a preliminary analysis meant to provide a basis for further thought, not a finished treatment. In places the process of analysis has distorted the interaction of complex variables, as analysis of glass from wine leaves a hollow and a splash. In other places I have simplified points, or stated them without every objection and qualification, in order to keep the outline and principles clear. I have not undertaken the next logical step: binding a series of models in which only one variable at a time is altered.

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I. Linings.

For the discussion of linings, it will be assumed that the structures involved are built on flat (smooth-spine) sewing systems like unsupported sewing or sewing on tapes. Raised sewing systems alter and complicate the action of the spine; they will be discussed later. It will also be assumed that the joints and boards do not influence the action of the spine, although this is not always true; joints also will be discussed later.

Drape and the amount of throw-up needed

As the book is opened and closed the cross-section arc of the spine will normally throw up, going from convex to flat or to concave. The degree of throw-up needed will vary with the drape of the text block, modified by the book's thickness and the width of the gutter margin.

Drape is the flexibility of the page over its width. It is not a direct quality of the paper; rather, it is the stiffness of the paper divided by the page width and modified by the format. A wide page will drape better than a narrow page of the same paper (Fig. 1); for instance the paper used by William Morris drapes

Fig. 1. Good and poor drape. Folio and duodecimo from the same paper; the 12mo is cross-grained as well as narrower.

well in the Kelmscott Chaucer, but when his imitators used it in duodecimos it draped very poorly. Again, most papers drape better with the grain vertical (folio and octavo) than horizontal (quarto, duodecimo, sextodecimo)*.

The book should preferably open from the bending of the page over most of its width; there should be as little throw-up as is compatible with free opening. If a book throws up high the stresses and wear of opening are localised at the gutter instead of being spread out across the page. The paper will bend too much at the gutter and will be fatigued; worse, the tension of the sewing thread and supports will change as the book opens and closes, sawing the thread against the stations. A low throw-up is most important when the paper is both very weak and very flexible, as can happen with thin but degraded papers.

Few books have such good drape that a completely rigid spine can be used; most will need some throw-up or the book will not lie flat on the table to any given page. In general the spine

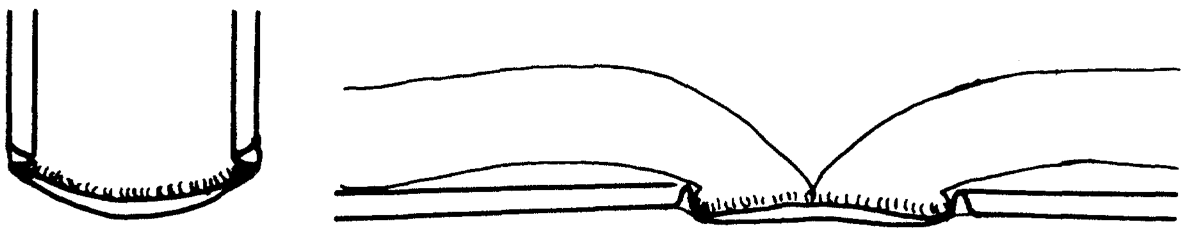


Fig. 2. "Settling down" of a flexibly-lined, tight-back book. The spine may remain slightly convex, especially at the joints, yet still have flattened out enough to be stable when lying open on the table.

should at least flatten out a bit when the book is opened, settling down on the table like a hen on her nest (Fig. 2). If the spine is rigid, especially if the round is high, the book is apt to tip over on the fulcrum of the spine, rocking to the side of the opening with more pages; the pages will flip over as the book tips, and the book will close itself (Fig. 8).

A higher throw-up is needed when the drape is poor (Fig. 3),

Fig. 3. Opening of a book with poor drape but high throw-up.

* Contrary to common opinion this includes many handmade papers, especially antique laid and some modern laid papers.

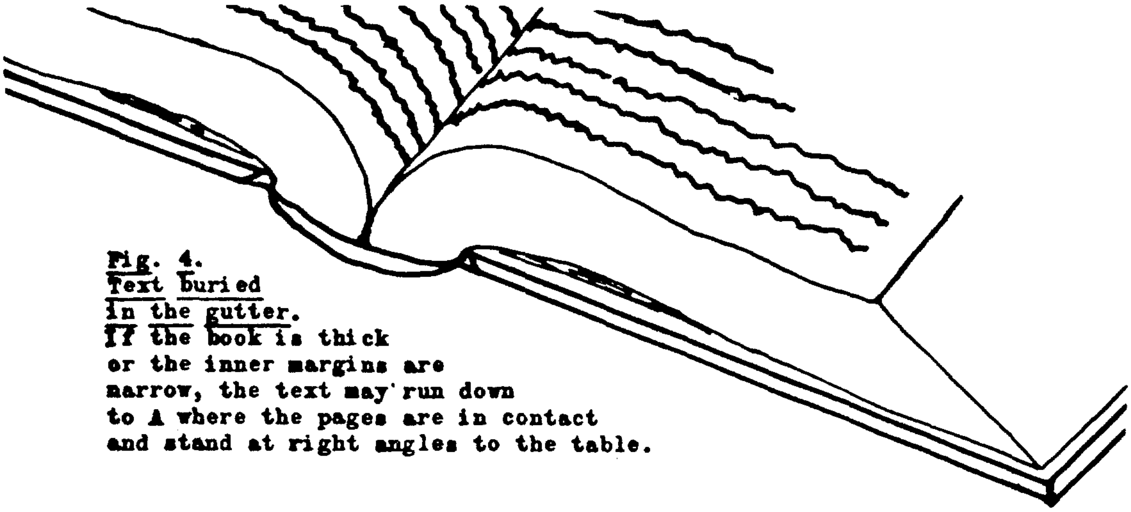


Fig. 4. Text buried in the gutter. If the book is thick or the inner margins are narrow, the text may run down to A where the pages are in contact and stand at right angles to the table.

when the book is thick, or when the gutter margin is narrow (Fig. 4). Thickness and narrow margins have similar effects, burying the text in the gutter where the page is near perpendicular to the table. With poor drape, of course, the pages simply will not settle down.

Tension and compression layers

While the throw-up needed is set by the drape modified by thickness and margins, the amount actually gained is controlled by varying the number, thickness, and material of the linings; varying the height and shape of the round; and varying the sewing structure.

The spine has layered thickness made up of linings and covering material. As the book opens, the layers farthest from the text block will be compressed, while those nearest will be put under tension (Fig. 5); I will therefore call the inner part of the spine the tension layer and the outer part the compression layer. The innermost laminate of the spine system is made

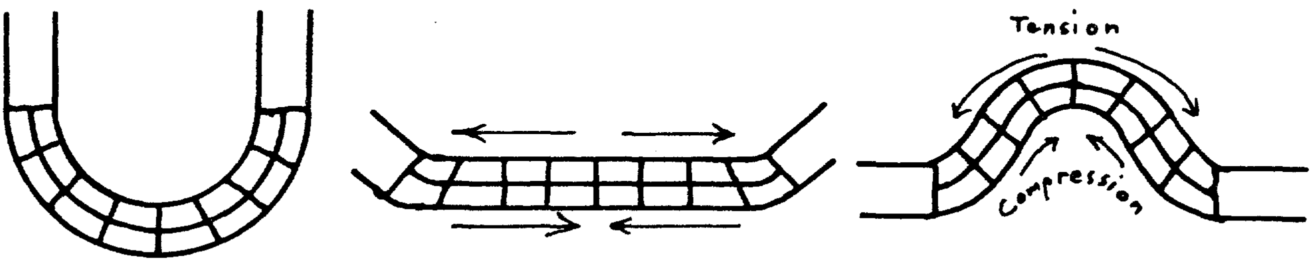


Fig. 5. Tension and compression in a single-material spine. The core remains the same length; the inner layer expands under tension as the book opens, while the outer layer contracts under compression.

up of the outermost folds of the text block (Fig. 6), and this laminate will be stressed and distorted by the movements of the other layers.

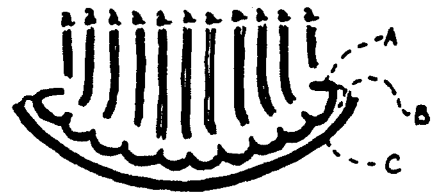


Fig. 6. Laminates of the spine.
The outer folds of the sections (A) are joined to the outer leaves of the sections (aaaaa), and so are part of the text block. However, the folds are also bonded to the liners (B) and through them to the covering material (C); thus the folds are the innermost laminate of the spine system. Here the outer folds are shown broken (analytically but falsely) from their proper leaves.

With a book sewn on flat supports the stiffness of the spine can be increased by using thicker linings, using linings of stiffer material, or using more linings without changing material or total thickness. This last effect can be seen with paper linings, where several thin laminates built up to a certain thickness will be stiffer than a single laminate of the same total thickness. Where high throw-up and a less stiff spine is wanted, the number and thickness of the linings and covering material must be kept to a minimum. This can easily lead to a lining system which is too light and weak, especially since high throw-up concentrates wear near the spine, allowing the book to distort and break up rapidly. Over-paring the leather and over-sanding the linings are common traps--- especially when the spine is lined for aesthetic as well as structural reasons.

The materials found in each layer should be suited to the stresses imposed by opening; but sometimes they are not. For instance, vellum used to cover a tight-back raised-cord book is known to hinder the opening, since vellum does not compress readily and this structure places it in the compression layer; even so, vellum has been used to cover such books.

Materials of the spine

Paper is highly vulnerable to breaking when bent under tension; several tests of paper strength use this fact*. If the first (innermost) spine lining can stretch then the folds of the sections, which are inside this lining, will be put under more tension and thus will be more likely to break. If the first lining does not stretch as it bends the text block will be much safer. I believe therefore that one should use a first lining

* It should, however, be noted that the hard-crease fold used in paper testing is rather different from the gentler flexing endured by the spine; for instance, gentle flexing is less likely to snap individual fibers or to cause a permanent line of weakness. Even so, I think it is best to protect the text block from avoidable tension.

highly resistant to tension; this will give a tension layer that will not stretch, throwing all distortion into the compression layer. Vellum is the material of choice for the first lining: it is prestretched. Linen or other strong cloth pulled crosswise when applied is a reasonable alternative, especially for small books where full-thickness vellum might be too stiff. A first lining of leather or tawed skin will stretch and thus should be avoided with paper text blocks.

If a non-stretching first lining is used, then all other linings plus the covering material must be compressible or the spine will not move; thus in this case the compression layer will include all the laminates of the spine except the first lining. The only traditional materials with the pliant strength needed in the compression layer are leather and tawed skin. If a first lining of vellum has been used it will protect the text block (but not raised-cord sewing) against the burn-in caused by leather.

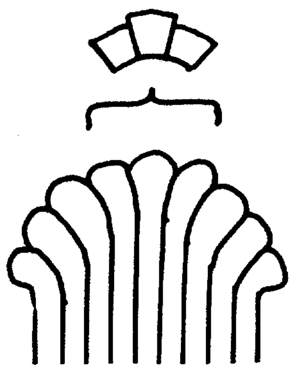
Paper linings are unwise in the tension layer because they are, like the spine folds, vulnerable to breaking when bent under tension. Paper is unwise in the compression layer because it does not compress. Paper linings are usually excessive in number and therefore rigid; they are apt to come unstuck in ridges if they move at all. I think, therefore, that paper linings should be avoided except in the rare cases where great rigidity is wanted**.

There is a common superstition that a flexible adhesive is needed if the spine is to be flexible. This is only true when the adhesive is applied far too thickly--- as commonly happens with hot glue or PVA. Nor is an exceedingly strong adhesive needed: the main stresses on the moving spine are across its width, and do not bear on the adhesive, which holds laminate to

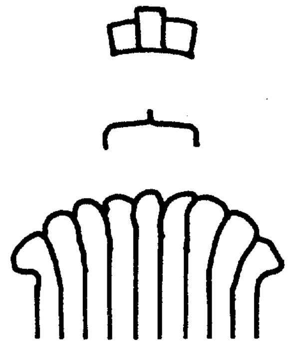
* Middleton notes that 18th century French bindings lined with vellum and covered with leather have lasted well (see his History of English Craft Bookbinding Technique, p. 109-110). I have noticed that leather-burn on the pastedowns of such books stops where the leather turn-in runs under the vellum liner.

Leather-burn is a most serious form of damage, but it has not yet been studied. To say just that it is caused by "acidity" is simplistic; migration of oils from the skin is at least as important. Traditional tawed skin did not burn paper, but modern tawed skin does; this is possibly due to the replacement of egg yolk with more modern fatliquors.

** Lining with "stippled kozo" is a possible exception to this rule: the process of application breaks up its sheet-like nature and makes it more like a reinforcement to the adhesive or an integral part of the text block. I have not made up my mind in the matter. However, even the strongest "high-fold" papers are still far weaker than vellum or linen.



A. High round
showing strong arch



B. Low round
showing weak arch

Fig. 7. The arch of the spine. Note the strong flare of the keystone on the left, and the weak, nearly rectangular form of the keystone on the right.

laminate at right angles to these stresses*. A thick layer of PVA is sometimes built up on the spine, forming in effect a compression-layer lining instead of an adhesive. This practice is inadvisable because PVA is a naturally brittle material and will lose its elasticity as plasticizers evaporate; and even internally plasticized PVAs have not been adequately tested by prolonged natural aging.

I have proposed a non-stretching first lining to protect the folds of the sections from tension. An alternative is to remove the folds from the spine system by sewing in a concertina or other non-adhesive structure. Then, however, section-to-section and cover-to-text attachment will rely entirely on the sewing threads, and the book will be vulnerable to knifing and chafing at the sewing stations. The Ethiopic codex, an apparent counter-example, has a vellum text block, which makes the stations less fragile.

Height of the round and shape of the back

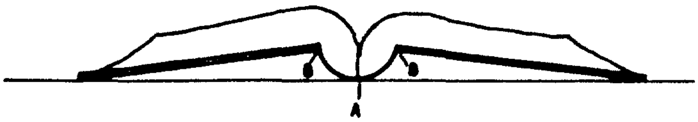
Altering the height of the round causes intricate changes in the action. Unfortunately, any advantage gained by altering the height of the round is often lost to some side effect or is balanced by some new disadvantage. Often the choice of round poses unsolvable conflicts between durability and ease of use.

A book with high round and stiff linings, for instance, holds its shape well on the shelf. The folds of the sections lock into each other like the stones of an arch (Fig. 7); this

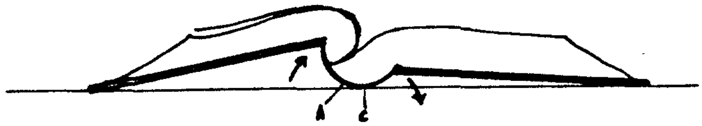
* If the linings start to seperate due to improper adhesion, seperating stresses will be put on the linings and a hollow back (in effect) may form; some binders use strong adhesives like PVA to guard against this possibility.

arch is inactive at the tail but at the head it resists sagging. Unfortunately such a book will not lie open on the table: if the joints are pliable it will flop over sideways and shut itself (Fig. 8); if the joints are stiff it must be pried open and then will try to snap closed with the rancor of a sleepy alligator. Even when the high round can be kept open, it buries the text at the gutter. Durability has been gained at the cost of ease of use; and even durability may be lost if, as often happens, an irate user purposely breaks the back to let the book open.

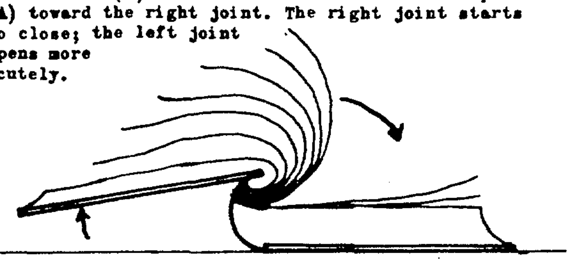
Fig. 8. "Self-closing" book. The spine is lined to be completely rigid; the joints (BB) are extremely flexible; the paper has good drape.



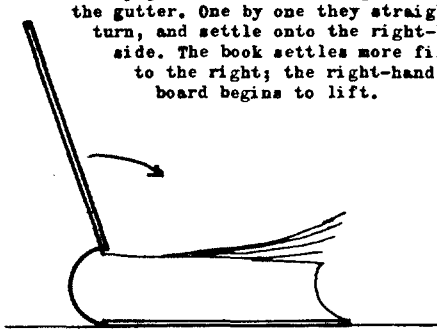
A. Resting open in unstable equilibrium. Fulcrum is at the center of the spine (A); weight of pages to left and right of the fulcrum is equal. Since the drape is good the book can remain open in this position, but the equilibrium is easily disturbed. Weight on the boards acts as if concentrated at the joints.



B. Equilibrium has been disturbed by turning a few pages to the right; the book rocks to the right as the fulcrum (C) moves from the center of the spine (A) toward the right joint. The right joint starts to close; the left joint opens more acutely.



C. As the book settles onto the right board, the left-hand pages are bent to a tight curve near the gutter. One by one they straighten, turn, and settle onto the right-hand side. The book settles more firmly to the right; the right-hand board begins to lift.



D. All the pages have settled onto the right-hand board. I have seen such a book close so quickly that the momentum of the board swung it past the verticle; the book closed with a satisfying plop.

If a book with high round is given pliable linings it will open; but to "settle down" on the table it must change shape more than would a low round. The linings must be lighter and the book will move too much for its drape; it will sag and droop sideways, and the weak but over-active spine will break up. Durability--- the original advantage sought in a high round--- will have been lost.

A book with a flat spine, on the other hand, tends to open well. It need move little if the paper drapes well, and moves less than a high spine to throw up to any given angle. However, a flat spine quickly loses its shape. The spine goes concave, putting the sewing under permanent strain; the fore-edge protrudes and exposes the text block to abrasion and pollution. Ease of use has been gained at cost of durability. If the spine is lined stiffly to improve durability, ease of use--- the advantage originally sought--- will be lost.

Because of such complications, altering the round is not much practical use in fine-tuning the action. Where durability on the shelf is an overwhelming concern, the round may perhaps be increased a little; where nothing but openibility matters it may be reduced. In general, though, there seems to be little benefit in departing from the traditional quarter- to third-circle round on 15-25% measured swelling.

Dealing with height of round is complicated by the actual shape of the round. I assumed above that a round of one height would have one shape; in fact the shape can vary, from a high hog-back to a flat semi-elipse. These variations make analysis trickier, but seem in fact to have little effect on the action. A heavy-shouldered semi-elipse may be preferable to a circular arc: it moves less to settle down, yet gives ample support behind the shoulders. The universally abhorred hog-back seems to intensify the ill effects of a high round. Another complication is that the swelling can vary independantly of the height and shape of the round: although there is a natural round for each swelling, the binder can and often does force a book into more round or less round than it wants to take--- temporarily. A soft, thick thread allows more adjustment of swell by beating down, which makes it easier to get a natural round of the desired height; hard-finish threads don't compact properly, and are prone to knife the sewing stations of thin sections. While the relation of round to swell and compactness is important to durability, it seems, again, to have little direct effect on the action.

Certain hollow backs

Hollow-back structures include case, tube, Bradel, spring-back, loose-leather, and other structures, with variations of each. Hollows show strongly how, while a certain action may be typical of a certain structure, it can often be mimicked with other structures; and also how one structure can be given quite distinct actions by minor changes. The examples discussed below demonstrate this; however, I have not tried to exhaust the complicated topic of the various actions of hollow backs.

The set-back case is attached to the text block at the seats of the shoulders, not at the folds of the endpapers, leaving the endpapers free of the case between the seats and the folds*. This, together with a hinged or pliable backstrip, gives a distinctive "self-releasing" action: the case cuddles the spine supportively on the shelf, but moves freely away from it when the book is

* Gary Frost calls this, unhistorically, "cased construction." I would rather retain the traditional meaning of "cased," since a case binding need not include the set-back attachment, while tube, Bradel, and other hollow structures can be modified to include it (and, in consequence, to take on the set-back case's distinctive action).

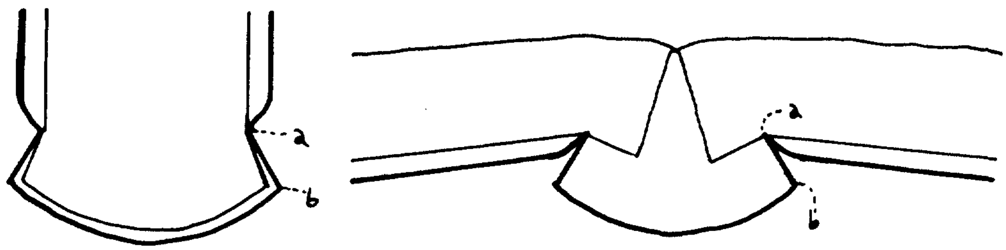


Fig. 9. Action of one form of set-back case. Movement is mostly hinged at the joint and spine folds, a and b; the backstrip changes shape little during movement.

opened (Fig. 9). In consequence the case does not alter the action of the spine; the book moves as if its linings were a tight back and its backstrip did not exist. The set-back case is perhaps most useful for small books with poor drape on weak paper: if the linings are light the book will open well, and although the binding is fragile, it is no more so than the text block. With more substantial structures the support of the set-back case is not needed.

The spring-back account book seems at first to have a similar set-back structure, but the action is different*. As the book is opened it seems to fight the hands; if released when partly open it will close itself. When a certain point is reached the book gives a little snap or thump and throws itself open. This action is caused by a rigid backstrip curled around a pliable spine; by contrast, other backstrips are pliable or hinged. The edges of this backstrip are fixed in place by its rigidity. The resistance felt on opening is the distortion of the long arc of the spine as it is forced between these edges; the snap occurs when the spine passes between them and escapes upward, relaxing (Fig. 10). The advantage of the spring-back is that it holds the points of the shoulders closer together when the book is open, which forces the book to throw up higher than normal and thus forces a flatter opening. Its disadvantage is that it puts the

* The structure of the traditional spring-back ledger is, in fact, more like a tight-back tight-jointed book than like the superficially similar hollow-back French-jointed book. The boards are extended to the points of the (unbacked) shoulders by stiff bristol "levers"; the spine liner is of substantial leather and runs over the joints into the split boards. The spring-back sits outside this basically tight-back structure, curling over onto the levers.

A similar, but less pronounced, action is caused by a rigid backstrip attached at the points of the shoulders. A semi-rigid backstrip will also give a snapping action, for slightly different reasons; at one time I confused the actions of the semi-rigid spring with that of the true rigid spring (see reply to Gary Frost, Abbey Newsletter 10:2 (Apr. 1986) p. 21).

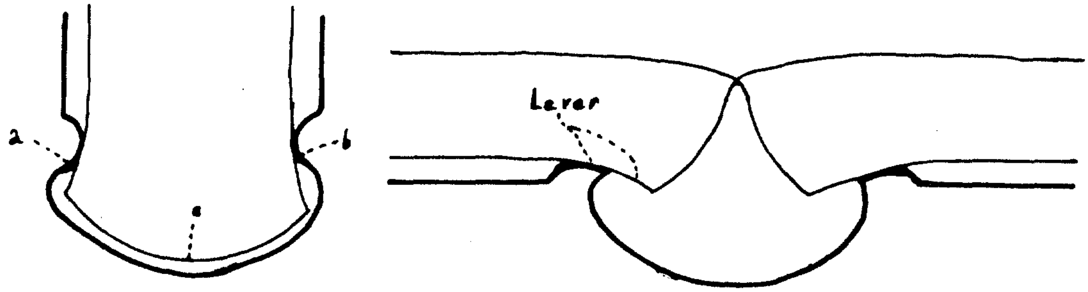


Fig. 10. Action of an account-book spring-back, showing enhanced throw-up. The distance between the edges of the backstrip (ab) is fixed; the arc of the spine (acb) must be crammed through this gap for the book to open. The curl of the spring onto the levers is somewhat exxagerated for clarity.

spine under great strains during movement and when open; thus it is most useful where a book on strong, stiff paper must open very flat. It is unwise to use a spring-back with weakened paper.

Tube hollow bindings differ in action; many are hard to analyse. As the number of linings on and off changes, the action changes; even a shift in the balance of linings, say from one-on two-off to two-on one-off, can change the action. With pliable linings on and rigid ones off (say one-on ten-off) the action resembles a spring-back; when, on the other hand, the linings on are rigid, those off are inactive and the action is that of a tight-back rigid-spine book. With less extreme variations, say two-on three-off, both spine and backstrip are pliable and the backstrip modifies the spine action to a surprising extent; this can be seen if the outer hinge splits and the backstrip comes loose, for the action becomes quite floppy. The backstrip seems to act like the compression layer of a tight-back book, even though it is attached only at the points of the shoulders. At present I think this pseudo-compression-layer effect occurs because the backstrip bends to a tighter curve as the book opens, and in trying to straighten, the backstrip pushes outward on the points of the shoulders (Fig. 11). The fascinating, and valuable,

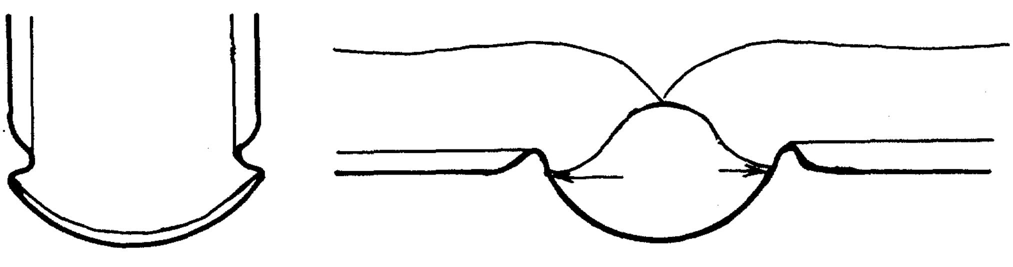


Fig. 11. Action of the tube hollow. Notice the reduced radius and lengthened arc of the backstrip, which is bent like a spring. The push of the backstrip is at the points and in the directions of the arrows.

thing about these bindings is that they can move as if they had functioning compression layers, even when the entire structure is of paper and cloth; this lets the binder, at need, do without skins, which are now scarce and unreliable.

II. Sewing supports.

Sewing supports have two functions. First, they join section to section and to boards, and thus they must resist crosswise stresses. Second, they bend as the book opens and shuts, and changing them will change the action of the whole spine.

High-quality support materials are critical to the durability of the spine; but many are no longer available. In practice, shortages may modify the choice of sewing system or even rule some systems out: for instance, completely frayed-out cords were arguably acceptable a generation ago, but no currently available cord will bear this treatment. However, we can hope to bring shortages to an end*; and for clarity of analysis I shall not dwell on this problem.

Crosswise stress and minimum total cross-section

The supports must not stretch or snap in use. This means that all the supports together must have some minimum total cross-sectional area. Given this minimum, their shape and number may be altered a good deal. Consider a book whose supports are bundles of sewing thread. The threads may lie flat like tapes, be bunched like single cords, be bunched like double cords (Fig. 12). There may be three or four or five bundles at as many sewing stations (Fig. 14). Whatever the grouping, the total number of threads needed to resist crosswise stresses will be the same.

There are some theoretical reservations. Materials vary in strength, so for each support material the total minimum cross-section of a book's supports will be different. A pliable spine imposes greater strains than a stiff one, and so may need a greater cross-section. The total cross-section needed at the joints will be different from that needed between sections.

However, although there is a minimum total cross-section for the supports, there is no natural maximum; and supports are normally given more bulk than they need. This avoids the danger of misjudgement, and allows for weakening with age. In consequence the arrangement of the supports can be varied freely provided that their total bulk does not fall below minimum. The

* While writing this paper I obtained a sample, but not a supply, of cord long-fibered enough to bear fraying-out. I still detest the practice.

action of the spine can be controlled by such variations.

Profile of the supports

Modifying the supports alters the compression layer, not the tension layer, since the supports can stand well out from the spine; this makes the binder less dependant on leather or tawed skin in building the compression layer. The supports also have the advantage of close mechanical interplay with the moving text block, while linings rely on mere adhesive connection; this gives some security against premature breakdown. On the other hand, some supports may cause localised stresses, particularly at the sewing stations. Variables of the supports include profile, number, stiffness, and tension.

The profile is the appearance when the book is cut in the plane of the text block. Altering the profile changes the action in profound and readily analysed ways. The rule is that the further the supports project from the spine, the stiffer the spine will be.

The profiles of the individual supports are readily altered. Consider again bundled-thread supports: if a support is bundled as a single cord it will project more than if bundled as a double cord, and the spine will thus be stiffer; if as a double cord, more and stiffer than as a tape (Fig. 12). The comparative

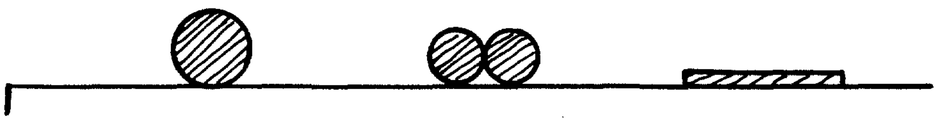


Fig. 12. Projection of sewing supports. The cross-section area of each support is the same. In this case the projection of the double cord is 4 times that of the tape (this ratio is not fixed) while that of the single cord is 1.4 times that of the double cord (this ratio is fixed).

flexibility of double-cord sewing may seem surprising, since many large, stiff books were sewn double; but such books would have been even stiffer on single cords of equivalent bulk*. Tapes, frayed-out cords, sunk cords, and unsupported sewing are all flat enough not to disturb the compression layer; they are equivalent in action.

The profile of the whole spine can be changed by changing the number of supports, as well as by changing the profiles of

* T. Harrison noted the "very free opening" of double-cord sewing, and the even freer opening of webbing (tapes): see his Bookbinding Craft and Industry pp. 43-44.

the individual supports. In practice, changing the number is an awkward means of control for several reasons: the new stations are normally chosen to use old stations or to avoid weakened ones; since one to three inches between stations gives a good balance between too many piercings and too long a stitch, the number of supports is usually three to six; the number must always be an integer. More supports should give a stiffer spine if the projection remains the same, since the bulk in the compression layer is increased (Fig. 13); however, this effect does not seem large to me. If, on the other hand, more supports are used but the total cross-sectional area remains the same, then each support projects less and the spine should be less stiff (Fig. 14)--- if this is unclear, imagine again supports of bundled thread. In practice, altering the number of supports does not do quite what one would expect if the system were ideal--- the behavior will be altered erratically by the leather over the supports, their exact profile (Fig. 15), and so on.

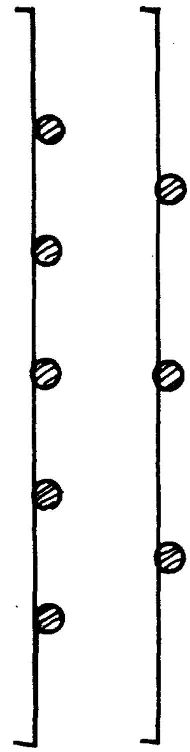


Fig. 13. Number of supports is altered, but projection remains constant; thus, total cross-sectional area is altered.

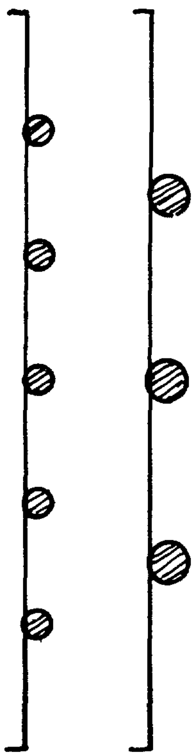


Fig. 14. Number of supports is altered and total cross-sectional area remains constant; thus, projection is altered.

Variations in profile will, of course, alter more than the flexibility of the spine. Lap sewing on tapes, for instance, uses more stations and tears at them more savagely than loop sewing on cords; with weak but stiff text blocks the greater flexibility of tapes must be balanced against this greater knifing (Fig. 16). Again, if a smaller number of supports is used, then the spine is pierced less frequently, but there is more strain on each station. Some profiles, for instance thick single cords, may give a desired action over the spine but not over the joints. Profiles that are not symmetrical head-to-tail (Fig. 17) may cause uneven strain and uneven wear; this effect will be greater if the supports control the action, but will be less if the linings have control.

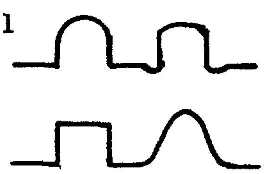


Fig. 15. Minor variations in profile of a single-cord support.

Despite complications, I believe that profile is the most

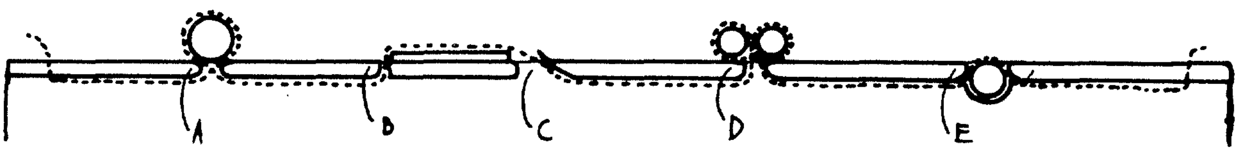


Fig. 16. Tearing of sewing thread at sewing stations. When loop sewing on cord the thread cinches the paper at A against the support; this braces the paper against ripping. When sewing on tape, the paper is unbraced, as at B; tight sewing or wear will rip the paper as at C. With double cords the bracing effect at D is more pronounced. With sunk cords there is no brace, but the thread runs a straighter course and the outward vector at E is much smaller; thus, sunk cords may be a sounder structure than has often been assumed in this century.

important variable in controlling the action of the spine, and that careful choice of profile is the best way of getting the degree of throw-up wanted for a particular text block.

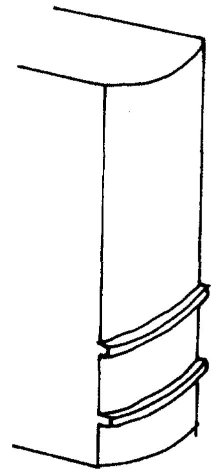


Fig. 17. Spine asymmetrical from head to tail.

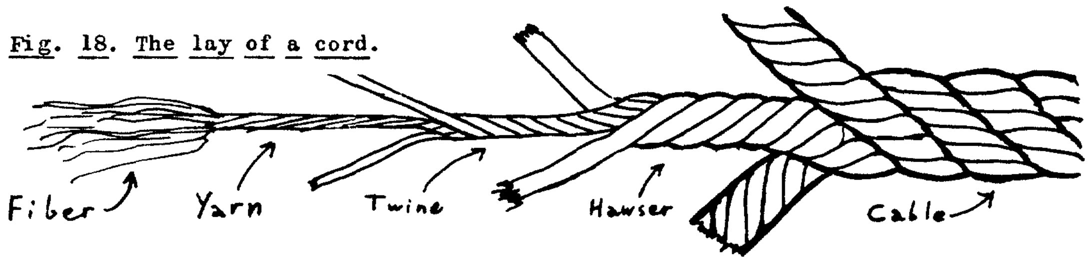
Stiffness of the support

The supports themselves may differ greatly in stiffness due to material or geometry; however, when sewn around and covered I think that these differences are reduced. Sewing system, and particularly pack sewing, can modify support stiffness to an extent readily felt in the finished binding.

Differences due to material are apparent: for instance vellum straps are stiffer than tapes, and tawed pig is apt to be stiffer than cord. However, materials cannot be ranked without question in order of stiffness: flanky tawed pig is more pliable than some cord, or tawed skin may vary greatly due to species or age of animal or from place to place in the same skin. Different materials are used in different thicknesses, so support stiffness and material stiffness cannot be referred to interchangably. Also, other relevant properties may vary from material to material: for instance I find tawed pig more elastic as well as stiffer than cord, and thus it is more apt to stretch if strung up too tight on the sewing frame.

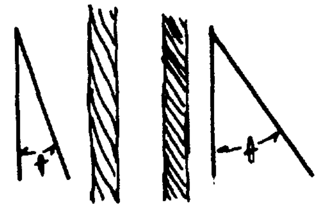
Geometry in cord includes lay, angle, and compactness. Yarn is twisted from fibers; twine from yarns; hawser ("plain-laid") from twines; and cable from hawsers (Fig. 18). "Cable has greater

Fig. 18. The lay of a cord.



elasticity and flexibility than a hawser of equal circumference, and produces a rope of high breaking strain and resistance to abrasion, distortion and wear;"* presumably hawser has the same advantages over twine (most binders' cord is twine). If the cord is twisted tighter the angle of twist will change; also, the cord will be shorter but more compact (Fig. 19). Dense, compact cord is stiffer than loose, airy cord. Angle and compactness can vary independant of each other if other factors (like number of strands) are varied. Thong has its own geometry: it may be left rectangular, cinched into a tube by the thread, or twisted (Fig. 20). I have not looked into the changes in stiffness and strength involved in thong geometry.

Fig. 19. Angle of twist. As the cord is twisted tighter, θ grows larger; at the same time the cord gets shorter and more compact.



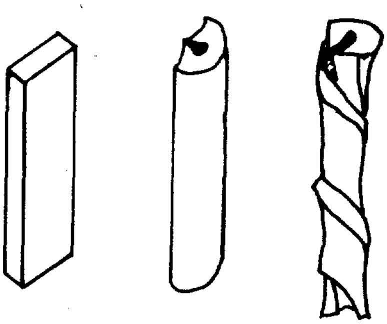


Fig. 20. Thong geometry: plain, tube, twisted. If plain thong is too soft or too wide, properly taut sewing will crumple it erratically; tube and twist thongs allow tenser sewing.

Although supports may differ dramatically in stiffness before use, sewing and covering even out support stiffness and make it only one factor in band stiffness. Much of the flexibility of cord comes from the fibers' ability to move across one another, to gape or twist more, as the cord bends. When the book has been sewn, the thread will cinch down on the cord at regular intervals, and the ability to move freely will be reduced (Fig. 21)--- an effect I think related to the tendancy of a knotted cord to break at a knot, not between knots. Sewing compresses loose, airy cord more than it does dense cord, and this reduces differences in compactness. The changes sewing causes to thong are less apparent but, I think, similar: movement is confined between loops, density is evened out, and thus differences in stiffness are reduced.

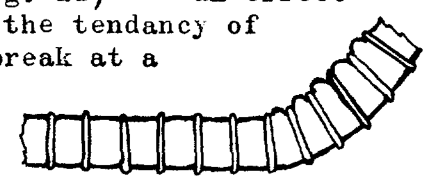


Fig. 21. Cinching of the thread on the support. Distortion of the bent cord is confined to the runs between the loops; such short, thick sections will differ little in pliability.

* Robert Espinosa, "Specifications for a hard-board laced-in conservation binding," p. 33. This specification is often illuminating, but its recommendations should be applied with caution to tight-back and working-hollow structures. Espinosa describes a lightly-lined or non-adhesive spine with loose hollow, so action and durability are dependant on the supports alone; the intention is to get maximum flexibility, which suggests suitability for a text block that is strong but drapes poorly--- the whole specification seems to me designed more for a vellum than a paper text block.

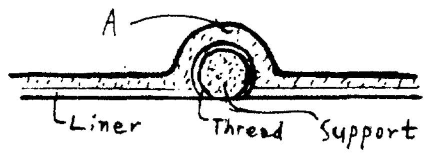


Fig. 22. The covered band as a laminated strut. Differences in stiffness caused by the support itself are reduced because the support is a small percentage of the cross-sectional area, is constricted by the leather along its whole length, and because the leather is at the outermost part of the compression layer where leverage is greatest (A).

The covering leather will reduce differences in stiffness still more. In the covered band the leather wraps the whole support; this, like the sewing, reduces the support's ability to move freely over itself. The leather is a high percentage of the cross-sectional area--- the thicker the leather the smaller the proportion of support, thus the less support stiffness matters. The leather includes the outermost part of the compression layer (Fig. 22) and thus will have more influence than the support, which is buried closer to the neutral line between tension and compression. Support stiffness is, of course, more important when the covering leather is thin or it is loose due to age or intention.

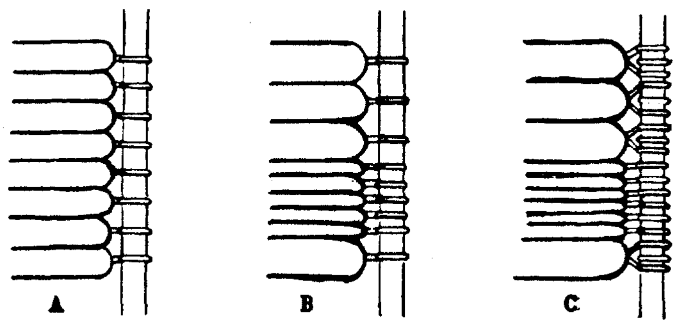


Fig. 23. Partial packing (shown on the frame). In normal loop sewing (A) the thread cinches regularly on the support. If the sections are uneven in thickness (B) the loops will be at uneven intervals, and the support will be stiffer where cinching is closer. Partial packing (C) evens out the intervals between the loops, and thus evens out the stiffness.

Sometimes supports are partially packed. Section thickness alters the reduction in movement caused by plain sewing: with thinner sections the closer loops constrain the support more. If the sections are not of equal thickness the sewn supports will not be uniformly stiff; in such cases (or if the sections are very thick) supports may be partially packed (Fig. 23). This partial packing, however, is not different in kind from plain loop-sewing: the movement of the support will still be discontinuous, confined to the unpacked runs of cord between loops.

Full-pack sewing is different in kind from partial packing, and alters the action of the covered book perceptibly. A fully packed spine throws up less than a plain-sewn spine (Fig. 24),

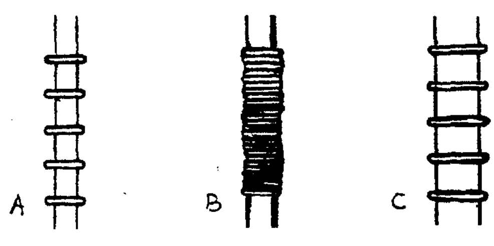


Fig. 24. Plain and packed sewing. The support at A is the same diameter as the support for packing at B. The support at C is the diameter of the packed section at B. A book sewn as at B will open on a wider arc than either A or C despite the similar profiles.

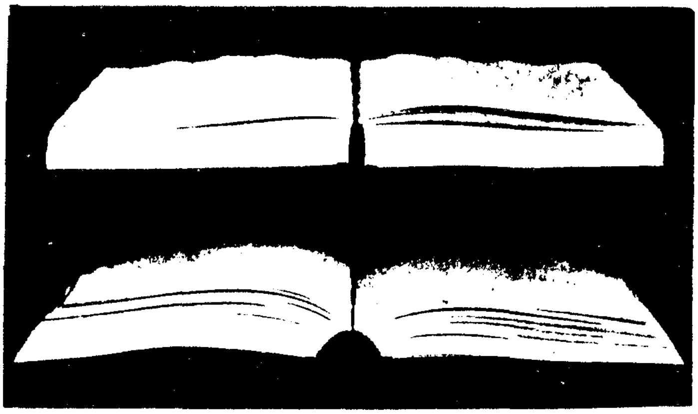


Fig. 25. The wider arc taken up by a pack-sewn book. Prior to rounding, backing or covering. Top: plain-sewn on raised cords. Bottom: packed. After Peter Franck

and takes a wider arc (Fig. 25). In effect a compression-resisting spring has been wound in the compression layer: movement of the support is no longer confined to the gaps between loops, since there are no gaps, but is spread broadly by the sewing threads' resistance to compression (Fig. 26)*. Action can vary with the thickness of thread and the closeness

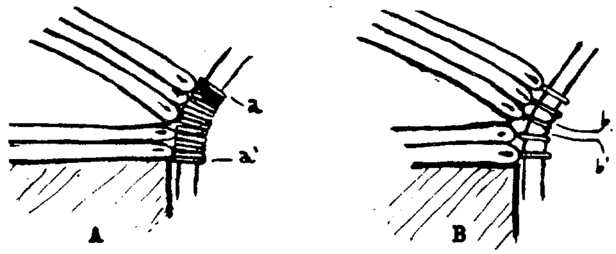


Fig. 26. The packing on support A acts as a compression spring, spreading curvature over the arc a-a'. Support B is unpacked; curvature is localised on a sharper angle, with distortion of the support at b and b' between adjacent sewing threads.

of packing: for instance if three packing turns are crammed in per section, the spring will be firmer and the throw-up less than if two had been used. Pack-sewing also gives a support that is thin (therefore flexible) over the joints and thick (therefore stiff) over the spine (Fig. 27); this is a desirable combination when paper drapes well, but quite unsuitable when it drapes poorly. Easy mistakes to make in pack-sewing include using supports too thin (in order to get more throw-up) and over-paring at the joints (to make them free enough to balance a stiff spine)— both suggest

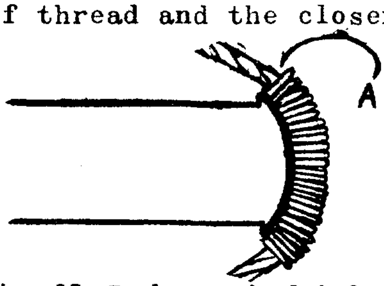


Fig. 27. Pack-sewn book before boards are drawn on. Sharp narrowing (exaggerated) at A gives thinner supports over the joints than would be the case for a comparable plain-sewn book; this allows a more flexible joint without excessive thinning of the support.

* A pack-sewn book may in fact have a satisfactory action immediately after sewing, which can be said of no other sewing style; but if it does it is unlikely to retain its good action when the spine is further stiffened by lining and covering. Some advantages of pack sewing— for instance that it protects the supports from leather and adhesives— are not directly relevant to this paper.

that unpacked supports would have been wiser. While packing is an important means of controlling the action, it is suitable only for books that drape well and can be given free joints.

The great changes in action caused by pack sewing, and the small effects of altering support stiffness, suggest that the property of the band with most influence on the action is resistance to longitudinal compression, not pliability. Thus, the effect of sewing and covering is to make the support the neutral core of a laminated compression-resisting strut.

Tension of the supports and use of the sewing frame

Varying the tension on the supports alters the shape and durability of the spine, with secondary effects on the action. This is seen more readily with thong; cord is less elastic and the effects of tension are less visible. If thongs are strung up very tight on the sewing frame, they will contract when the bar is dropped, and the spine will resist rounding or even be pulled concave (Fig. 28). The spine must then be hammered to take a

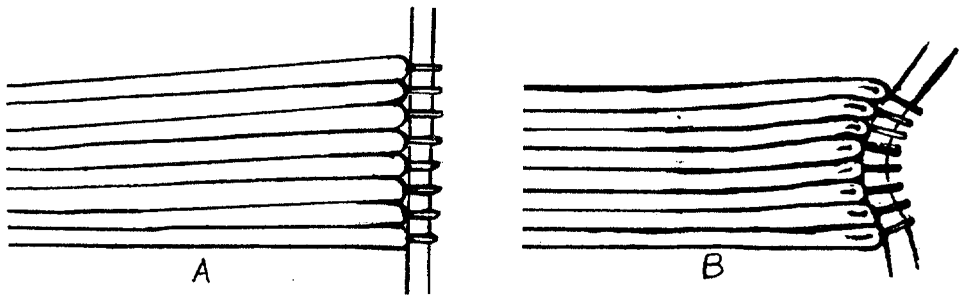


Fig. 28. Excess tension on the supports. In A, the book is still on the frame with the supports strung up very tight. In B the bar has been lowered, and contraction of the support has pulled the spine into a concave.

round, and the supports will be under permanent strain. On the other hand supports too loose will leave the spine flabby and prone to excess movement: the covers will move skew to each other (Fig. 29), and the head will sag on the shelf. In either case the binder must round and line heavily to get the spine to hold its shape.

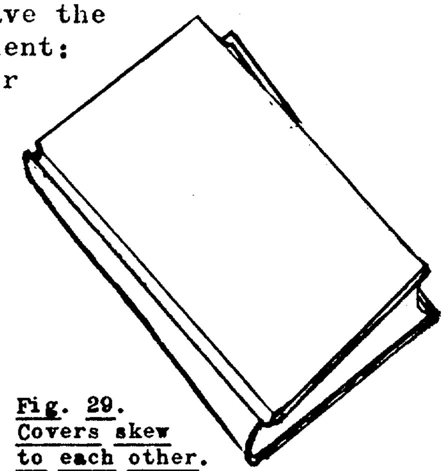


Fig. 29. Covers skew to each other.

The sewing frame is a tool for controlling the tension of the supports. Without it the tension is sure to be uneven along each support and from support to support; also, fine adjustment of the tension is impossible. Pack and herringbone sewings will disguise uneven tension by adding crosswise forces earlier than does plain-sewing: for instance a pack-sewn book just after sewing acts somewhat like a plain-sewn book after covering, which makes errors in tension harder to detect and conceivably less important. With lap-sewing the frame is not needed, since the support will run freely under the threads and thus crosswise tension can be adjusted after sewing. Despite such reservations, the current fad for loop-sewing off the frame is ill-advised: it can be likened to cutting a straight line without a straightedge--- possible, but neither sure nor fast. Sewing off the frame will normally cause cranky action and premature breakdown.

In unsupported sewing the thread takes the strains of movement normally taken by the supports, and it may be too thin for them--- that is, the total cross-section of the un-supports may fall below minimum. Also, in unsupported sewing the tension across the spine is set by the tension of the thread along the sections; however, the two directions may need different tensions. The value of independant adjustment can be seen in large books on weak paper: here excessively taut thread will knife into the sewing stations, which suggests gentle tension along the sections; however, gentle tension across the spine will cause flabbiness and excess movement, which suggests greater tension crosswise. With small, light books, unsupported sewing will seldom cause trouble.

Herringbone and other link-stitch sewings mix the traits of supported and unsupported sewings (Fig. 30). Strains from the flexing of the spine bear on the sewing thread in linkstitch sewing, but do so much less than in completely unsupported sewing. The tension across the spine with linkstitch comes partly from the supports, partly from the sewing thread. This reduces the independance of control over lengthwise and crosswise tensions: the crosswise tension can always be increased through the supports, but it cannot be reduced below the tension of the sewing thread. I find that this results in a narrow margin between too tense and too loose, so that light

Fig. 30. Herringbone linkstitch can be seen as Coptic sewing reinforced by the supports. Their decay will leave section-to-section attachment intact, though loosened and under attack from the decayed supports. After G. Bozzacchi, "Il codice come prodotto e come oggetto di restauro," Bolletino dell' Istituto Centrale per la Patologia del Libro XXXVI (1980) p. 326.

structures are often flabby or concave when sewn herringbone. This sewing is sounder when stiff boards and tight joints help to hold the shape of the spine. The great advantage of linkstitch is that the structure can survive the decay of the supports--- and currently available thread is sounder than available support materials. Lap-linkstitch can also be used to firm up a flabby spine.

Really excessive tension will, as I said, pull the spine concave; slightly less may leave it roundable but with permanent crosswise strains. It is natural to distrust such strains, but it is not clear just what damage they cause, how long it takes to develop, or what really "excessive" tension is. Gary Frost's analysis of the 16th-century stiff-board binding describes the boards as drawn on so tightly that there is deliberate gape when the book is closed but unclasped (Fig. 31); fastening the clasps "charges up" the spine with tension, making the pliable spine of the open book a firm, hard block able to hold its shape under the stresses of shelving and transport*. This analysis is supported by the practice, described by Dirk de Bray in 1658 and seen in surviving books, of beating the text block thin at the spine**. This would clearly cause crosswise tensions; but many such books have proved durable. I therefore am not inclined to worry too much about crosswise tension provided the book can take and hold a round; the skewing of a limp spine seems more dangerous to me.

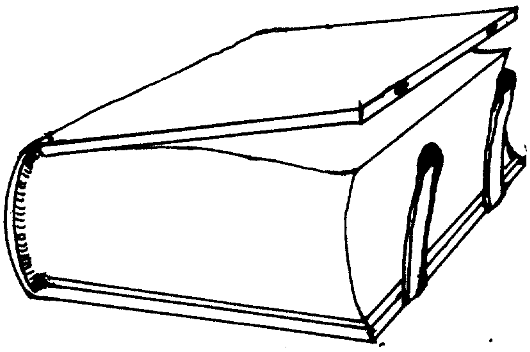


Fig. 31. Stiff-board book with deliberate gape. Closing and clasping the book will clamp it solidly

Certain non-adhesive and related structures

Longstitch, meeting-guard, and concertina-sewn bindings have certain similarities in action. These are seen most easily in the longstitch binding with completely rigid spine. Meeting-guard bindings magnify but complicate this distinctive action; sewing in a concertina gives it in muted form.

In the simplest form of longstitch binding the thread passes through a single vellum cover and a spine support of wood, horn, or other rigid material (Fig. 32). These books open better

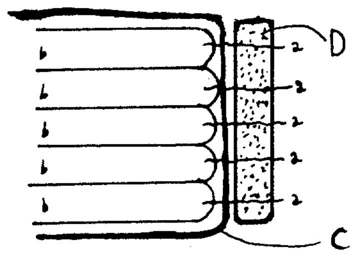


Fig. 32. Longstitch binding with rigid spine. Threads aaa pass through spine support D of wood, etc.; through vellum cover C; and into sections bbb.

* See Student Guide to Book Conservation Practice, pp. 45-7.

** See A Short Instruction in the Binding of Books, tr. H.S. Lake (Amsterdam: Nico Israel, 1977) p. 63. The spine was beaten thin for books with wood boards, but not for books bound in vellum.

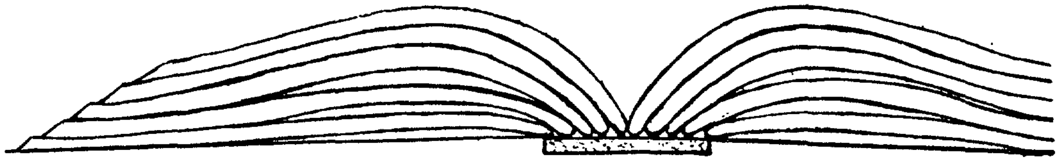


Fig. 33. Opening of a rigid-spine non-adhesive longstitch binding. The opening is freer than would be the case with a rigid-spine adhesive binding; however, stepped shape at the fore-edge shows that there is abrasion between sections, and the varying angles of strain on sewing thread will cause excessive knifing at the sewing stations.

than books lined to rigidity with adhesives. This is because the sections move independantly, and can slip slightly over one another (Fig. 33); this causes a typical stepped effect at the fore-edge, and lets the different sections take different angles to the spine. The angle of each section at the spine is the angle it would take to the table if its pages were entirely rigid; the drape of the page will disguise this angle, and thus it can be seen only in the area nearest the folds. With a rigid-spine longstitch book each section rotates on its own axis, and takes up a different angle; the first and last sections will take angles more acute than those in the center (Fig. 34). In a flat-spine book rigidly lined with adhesives (like a sewn paperback) all sections will keep an angle of 90° whether the book is open or closed, and the book must open from drape only (Fig. 35).

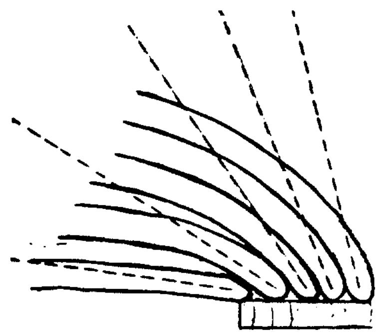


Fig. 34. Angles of the sections in an open longstitch binding. The angles vary because the sections can slip over one another; the outer section lies flat even if drape is poor, and sections further in can take a lower angle than usual. This makes drape less vital to flat opening.

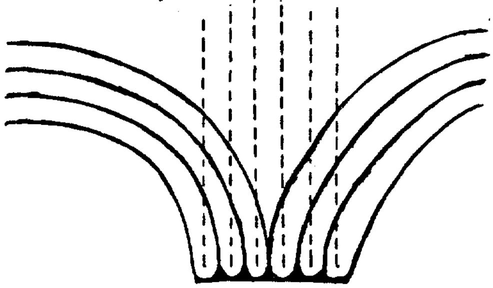
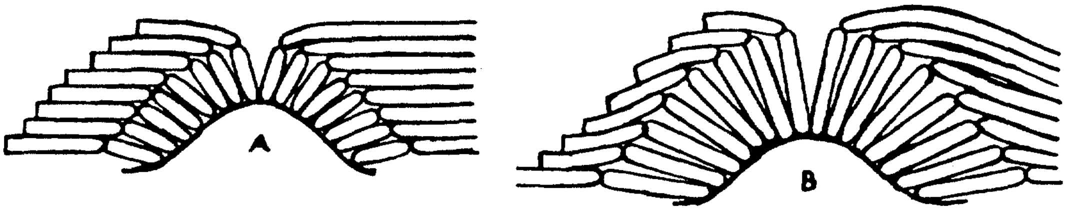


Fig. 35. Angles of the sections in a rigid-spine adhesive binding. With an adhesive spine each section will always be tangent to the spine. Opening is entirely from the drape of the pages; to open better than this the spine must throw up.

Because the sections of a longstitch binding can lie at acute angles to the table, they are less dependant on drape to open well. However, two drawbacks balance this superior opening: the outer pages of the sections rub over each other as the book moves and the stepped fore-edge comes and goes; and the free hinging of the section on the sewing thread causes strain and cutting at the stations. These drawbacks limit the use of



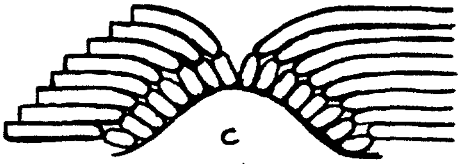
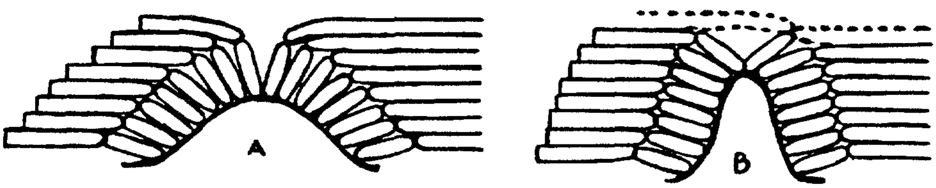


Fig. 36. Variation in length of the meeting guards. All with moderately pliable adhesive spines; non-adhesive spines introduce further complications. In A the guard length, spine pliability, and book thickness are in balance, In B the guards are too long for the thickness of the book; stepping at the fore-edge is greater, and the sections are unsupported near the guards, which strains the guard-to-section connection. In C the guards are too short for the thickness of the book; sections do not lie flat, which defeats the purpose of using meeting-guards.

non-adhesive rigid-spine structures to books in thick sections of sound paper or vellum (so stations will be strong), with page and medium not sensitive to abrasion (no fluffy papers, no flaking miniatures). Semi-flexible longstitch bindings have the same problems in smaller degree.

Meeting-guard bindings are trickier to analyse because they have two highly sensitive variables: length of the meeting guards (Fig. 36) and pliability of the spine (Fig. 37). However, a meeting-guard book shows the two distinctive signs noted in the rigid-spine longstitch book: it has the stepped fore-edge indicative of abrasion on the outer pages of the sections; and



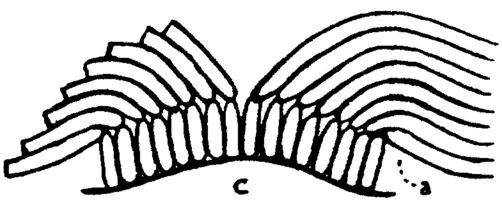
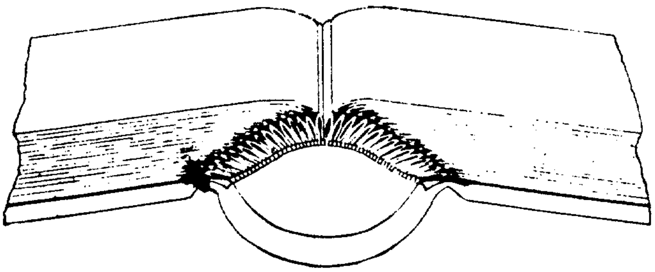


Fig. 37. Variation in the pliability of the spine. In A the guard length, spine pliability, and book thickness are in balance. In B a very pliable spine seems at first sight to be acceptable. However, with a spine so pliable the book will open flat without meeting guards; and the sections can flop back and forth too readily, straining the hinge— with a smaller throw-up, turning the section from right to left will carry the guard with it. In C a stiff spine gives almost the same action as a rigid non-adhesive spine without the guards, which thus are again superfluous; this structure also leaves the outermost sections without support next to the guards (at a).



Spring-back Guard-sewed Book, Termed Patent Back.

Fig. 38. American meeting-guard ledger, 1914. After John J. Pleger, Bookbinding and its auxiliary branches (Chicago: Inland Printer) vol.3 p.57; I have seen a number of examples a decade older.

the angle of section to spine--- even more, the angle of section to guard --- is highly variable, which gives flatter opening but strains the sewing stations. This strain is made worse by the thin thread often used to sew guards to sections (thick thread causes too much swelling). When the guard length and spine flexibility are in proper balance with page size and section thickness, meeting-guards can give very flat opening with good durability: turn-of-the-century ledgers often combined them with a spring-back (Fig. 38). However, since the variables are interdependant the least misjudgement in one is magnified by poor matching with the others (Fig. 36-37); in consequence meeting-guard bindings normally magnify the drawbacks of the rigid-spine longstitch binding.

The concertina guard is meant to keep adhesive and moisture from contact with the text block, while retaining a conventional adhesive-spine structure and action*. In practice the action is not quite the same: the opening seems freer with a concertina, and the sections move more independantly with some stepping at the fore-edge--- the symptoms, muted, that we have been looking at. I suspect that the cause is that the concertina does not act, as intended, as the outer bifolium of the section; rather, it forms a socket in which the section can rotate freely (Fig. 39). A similar section-in-socket

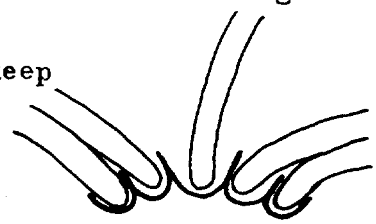


Fig. 39. Section moving freely in the socket of the concertina.

* This seems to be the commonest opinion, although many binders give other reasons for its use. Jean Gunner, for instance, feels that good openability is its primary purpose and isolation from modern adhesives for reversability is secondary (see Tradition of Fine Bookbinding in the Twentieth Century, Pittsburgh: Hunt Institute, 1979, p. 35). Gary Frost feels that the concertina's main purpose is to give full, even swelling; while admitting its special value in isolating vellum from adhesives, he goes so far as to call this "a silly rationalisation" in rebinding paper text blocks, and to call its use for paper "impractical and damaging" (see Abbey Newsletter vol.9 #7, Dec. 1985, p. 115). I believe that the concertina was carried over from rebinding vellum to rebinding paper by fashion without sufficient thought or experience of its effects, and that this has caused a great deal of confusion as to just why it is being used.

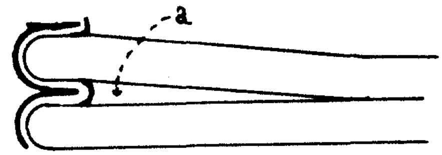


Fig. 40. Contact between sections broken by a thick-paper concertina. Diagrammatic; exaggerated. Suction is disrupted at (a).

action can be seen in heavily worn books in thick sections sewn with nylon thread (look at mystery novels in a public library), where most of the section pulls away from the outer bifolium. A concertina also tends to break the full-page contact between the outer pages of the sections (Fig. 40). Suction from this contact holds the pages together much as plates of glass will stick without an adhesive; and a concertina, by breaking the suction and the page-to-page friction, again allows the sections to act independantly In consequence, while a concertina may keep moisture and adhesive from the text block, it does not really give an adhesive-spine action. Drawbacks and benefits vary directly with the thickness of the guarding paper. A very thin paper will give almost a true adhesive-spine action, but blocks moisture poorly and may even (if kozo) allow adhesive to strike through. A thick concertina blocks moisture better, but also allows more abrasion and knifing; and knifing is a special peril, since thinner thread is used to compensate for the extra swelling caused by the concertina. These considerations limit the valid use of the concertina to vellum text blocks, where moisture is a special problem but sewing stations are strong; and to a few books on paper with a similar combination of poor drape, sensitivity to moisture, and strength (for instance some books with thick sections and horizontal grain).

III. Joints.

The action of a stiff-board binding comes partly from its spine, partly from its joints. Limp covers are not considered here. In some structures the joints act independantly of the spine; in others, moving the joints will move the spine. The analysis is still incomplete, but includes most principles. I have assumed that the covering material is leather.

Stiffness of the spine and of the joints

If joints and spine are both completely rigid, then the book cannot open. If the spine is rigid the joints must be very pliable; on the other hand, if the spine throws well up the joints need move little (Fig. 41). There seems to be no particular advantage to having both spine and joints highly pliable.

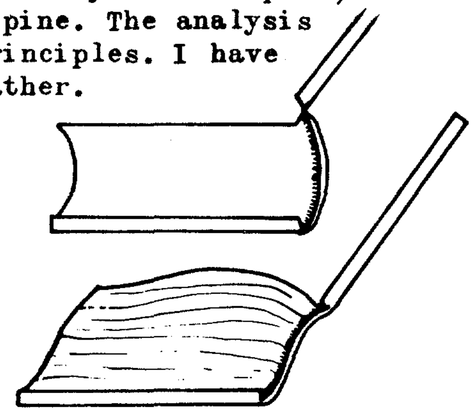


Fig. 41. Rigid-spine floppy-jointed action and pliable-spine stiff-jointed action.

Most well-bound books will lie somewhere between the extremes of rigid spine and rigid joints. The action of the two should be in balance; a stiffer spine needs looser joints. Rigid joints will force the spine to throw up too much for many text blocks, and may strain a stiffish spine causing permanent distortion and breakdown. On the other hand, a completely rigid spine concentrates all wear along the joints, which must swing the boards freely on a narrow line like a door-hinge. Floppy door-hinge joints will wear out long before the rest of the binding, and even with a French-joint structure they tempt the binder to overpare the leather; with tight joints every bit of the leather's strength may be pared away to get a door-hinge action, and the book may not survive one reading.

Historically the rigid-spine floppy-jointed action of the nineteenth century developed from the pliant-spine stiff-jointed action of the sixteenth; and it is tempting to choose a book's action from its period*. However, the paper of a period is often unsuited to the action of that period. A rigid spine, for instance, is fatal to the stiff, weak paper of the 1880's; on the other hand, it may be the best choice for the thin, strong paper of an earlier book, say a 17th century folio in twos. Weakening of paper with age must also be allowed for, particularly with post-1850 papers. It is thus important to choose the binding's action to suit the current state of the specific text block in hand, not to copy what a binder of the period would have done.

When choosing the action of the book, I think it best to suit the action of the spine to the text block, and to suit the action of the joints to the spine. The joints should in general be as firm as is compatable with full opening, since the narrowness of joints (even French joints) concentrates wear heavily, and since joints that move more freely must suffer more strain to thinner, weaker substance. These guidelines need some modification for books that want a rigid spine. In some cases one should allow some movement of the spine so that stronger joints can be used; in others it may be better to have a rigid spine

* This is a likely twist to neo-historicism. Nineteenth-century collectors favored "retrospective" bindings with an elaborate design of the book's own period on a nineteenth-century structure. Time exposed these hybrids as obtrusive, and collectors began to favor plainer bindings which copied the surface aspects of period forwarding; these blend in well on a shelf of originals. Now binders want to copy the real structures of a period; thus wood boards are favored for incunabula, limp vellum for the sixteenth century. All these approaches commit the same crucial error: they choose structure or decoration to suit a historical ideal, and not according to the physical nature of the text block in hand. Wood boards and limp vellum expose the neo-retrospective fallacy, for they serve best as large book/small book options, not as fifteenth/sixteenth century options. See for instance: Frost, Student Guide p. 40-43; B. Middleton, Restoration of Leather Bindings, revised edition only (Chicago: ALA, 1984) p. 205-217.

and door-hinge joints, accepting more rapid board detachment rebacking as a smaller evil than resewing fractured sections. Thin text blocks also can cause complications; some may be too thin to open from the flexing of the spine, and may need looser joints than would a thicker text block on the same paper.

Flow and the bending radius of the covering material

The stiffness of the joints is not exactly the stiffness of the covering material. The interplay of joint action and spine action can be seen better through the concepts of bending radius, flow, and drag on the endpapers.

Bending radius is an aspect of the stiffness of the covering material. An image of it is seen in one way of checking the grain of paper: a square sheet is laid back on itself in one direction, then in the other; its radius under its own weight will be larger when bent across the grain, that is, against stiffer resistance (Fig. 42). Covering materials act much the same; each sample, if put under a set force, will tend to curve to a certain radius dependant on its stiffness. Bending radius isn't an absolute quantity, since the force applied can vary; however, it would seem that the force applied when opening a book is a rough constant.

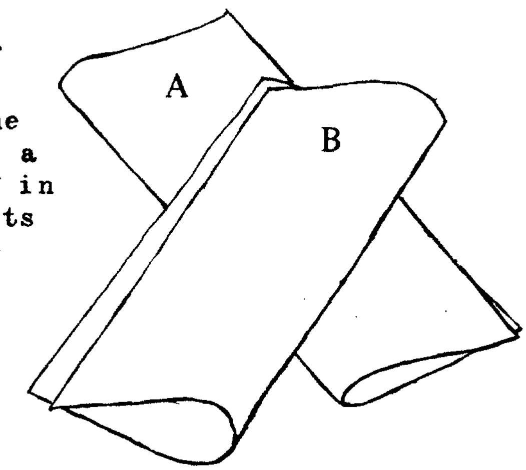


Fig. 42. Bending radius and the grain of paper. When bent with the grain (A) the sheet takes a small radius under gravity; when bent across the grain (B) the same sheet takes a broader curve.

Consider the implications to a tight-jointed book with a highly pliable spine. If the covering material has a very small bending radius it can flex just over the joint, and the board can be opened without disturbing the spine; if the bending radius is slightly larger, opening the board will bend some of the material over the spine; if the radius is quite large, then much of the spine will be moved (Fig. 43). Remember, the covering material

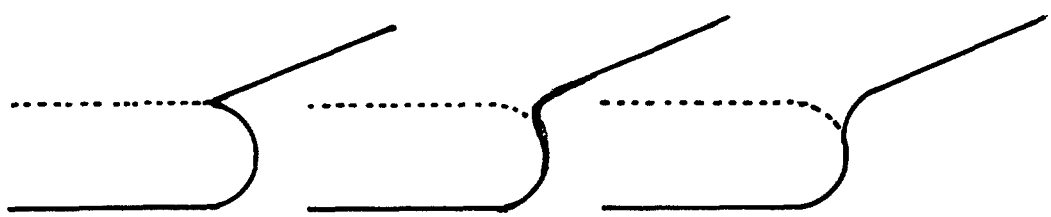


Fig. 43. Bending radius over the joint. When the bending radius of the covering material over the joint is small, the board can move almost independantly of the spine; as the bending radius increases, the influence of joint action on spine action increases.

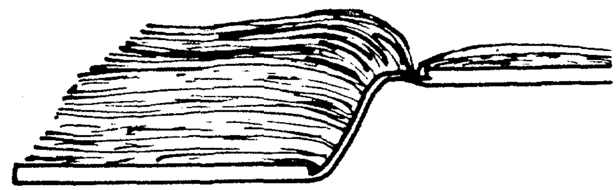


Fig. 44. Pages of a pliable-spine book lifted by the curve of the spine. Drawn from the same book as Figs. 31 and 41.

cannot flex over the board; if it cannot flex exactly over the joint, then it has to flex over the spine. The pages of the book will always be roughly perpendicular to the spine at the point of tangency (Fig. 35 above); thus, when the spine starts to bend open, the pages will start to lift (Fig. 44). In other words, with a tight-jointed book with large bending radius, opening the board will start to open the text block. This transfer of movement from boards to pages is the essential part of what is now being called "flow." A more general definition would be: the specific way in which, when one part of the book is moved, the other parts of the book will move with it. Each bound book has its own flow, which can be changed by rebinding or even by age, wear, or damage.

In the Victorian floppy-jointed book there was a deliberate effort to avoid flow; the small amount encountered was called "drag on the endpapers," and was considered a sign of incompetance. Douglas Cockerell adapted the French joint from common ledger binding in order to avoid drag on the endpapers when using thicker leather with its larger bending radius (Fig. 45). Although this broke radically with Victorian letterpress joint structure, the purpose was to retain Victorian letterpress joint action*. There is, however, no functional reason to avoid drag on the endpapers, and good reason to tolerate it: it is, like visible lacing-in, a sign that substance has not been sacrificed in forwarding.

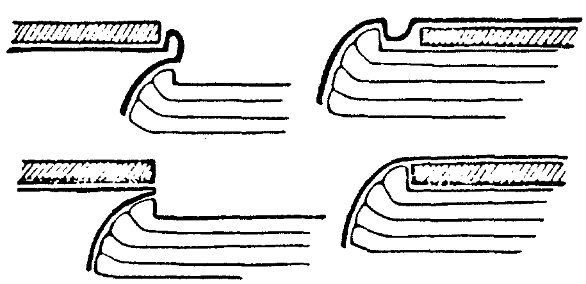


Fig. 45. French-jointed and tight-jointed books. After Cockerell, Some Notes, p. 38. The French joint permits use of leather with a large bending radius, without causing drag on the endpapers.

The bending radius of the covering material is not the only factor in the interplay of joint and spine action. If the linings

* In Cockerell's Specifications III and IV, now commonly called "English library style." See Bookbinding and the Care of Books p. 168-9, 174, 176; Some Notes on Bookbinding p. 37-8, 79-80. Cockerell also advocated an unlined spine, giving good pliability; thus, although he retained Victorian joint action, he abandoned Victorian spine action. It is interesting that most later texts prefer fairly heavy spine lining for "library style," returning to a true Victorian action; the motive seems to be the old one—preservation of the decoration at the expense of the text.

are not carried over the joint then they will stiffen the spine but not the joint. Reinforcing the endpaper is just the opposite: the joints are stiffened but not the spine. Heavy boards (like wood boards) will apply greater force to opening, and thus can give a smaller bending radius to the same covering material at the cost of greater strain.

A single-material joint might seem best in theory, since it would allow the compression layer and the tension layer of the joint to distort equally; at the joints this need not attack the text block as it does over the spine. In practice a laminated joint structure will always result from the endpapers, supports, and soaked-in adhesive; therefore it is best to plan for appropriate materials in compression and tension layers, just as one should on the spine. The tension-layer lining should be carried over onto the boards; localised stress will cause weakness if it stops short at the spine edge. Reinforced endpapers should be used with caution as a local reinforcement will simply throw the stress deeper into the text block. The exact balance between joint and spine action can be adjusted by cutting short or carrying over the compression-layer linings.

Certain effects of age and use

Although this paper has appealed to the effects of wear in a number of cases, no attempt has been made to generalise these effects. The effects of time often present problems beyond the range of analysis, and empirical evidence must be appealed to; thus some of the details above might have to be modified in light of a hundred years' passive aging or a hundred hours' active wear.

General consideration of age and wear must balance these factors among others:

Binding materials stiffen with age;
Binding materials weaken with age;
Binding materials are weakened by use;
Binding materials are made more supple by use.

Note that while passive aging is always harmful, wear has both good and bad effects: a binding kept in use will remain supple even though weakened, but if left to sit it may stiffen and then fracture the first time it is opened. The independant variation of these factors can make wise choice in binding very difficult, since their proper balance can only be found in light of likely use, and future use can never be known with certainty.

Acknowledgements and Bibliography.

I am indebted to those who read and commented on various drafts of this paper, including William Anthony, Gillian Boal, Christopher Clarkson, Louise Genest-Cote, Gary Frost, Pamela Spitzmueller, and Shannon Zachary. Since I continue to disagree with each of them at one point or another, I must emphasize that any errors are my own.

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