THE HISTORY OF PAPERMAKING

PAPER HAS ONE HISTORY BUT TWO TRADITIONS, ORIENTAL AND EUROPEAN. EACH IS SO DIFFERENT FROM THE OTHER THAT THEY DESERVE TWO SEPARATE NAMES, BUT BOTH REMAIN PAPER. BOTH TRADITIONS ARE BASED ON THE USE OF MATERIALS AT HAND, THE WORKING PROPERTIES OF THESE MATERIALS, AND THE WRITING IMPLEMENTS AN THE DEVELOPMENT OF THE PRINTING PROCESSES WITHIN THESE CULTURES.

THE PROCESS OF MACERATING AN ASSORTMENT OF VEGETABLE FIBERS, FLOATING THEM IN WATER, COLLECTING THEM ON A SCREEN, AND ALLOWING THEM TO DRY WAS FIRST DEVELOPED IN CHINA AROUND 150 B.C.

THE FIBERS FOR PAPERMAKING, THE METHODS OF PRODUCTION, AND THE RESULTING PAPERS WERE STUDIED INTENSELY, AND THE CRAFT WAS CARRIED FROM CHINA TO KOREA AND THEN TO JAPAN SOME 500 YEARS LATER. THESE EARLY PAPERS WERE MADE FROM TRUE HEMP (CANNABIS STAVIA). AS THE TECHNOLOGY DEVELOPED IN JAPAN, THREE PLANTS WERE DISCOVERED THAT PRODUCED THIN, TRANSLUCENT PAPERS OF EXCEPTIONAL QUALITY. THE FIRST AND MOST COMMON PAPER WAS MADE FROM THE INNER BARK OF THE MULBERRY TREE (BROUSSENETIA PAPYFERA) AND IS KNOWN AS KOZO. LATER GAMPI AND MITSUMATA WERE PRODUCED FROM THE INNER FIBERS OF SMALL, SHRUB LIKE PLANTS (WIKSTROEMIA CANESCENTS AND EDGWORTHIA STROEMIA CANESCENS AND EDGWORTHIA PAPYRIFEREA, RESPECTIVELY). DURING THESE FORMATIVE YEARS MANY OTHER PLANTS WERE TESTED, INCLUDING BAMBOO, RICE STRAW, LINEN, AND BANANA. RECYCLING WAS ALSO DONE TO SOME DEGREE TO MEET AN EVER GROWING DEMAND FOR PAPER.

THE KNOWLEDGE OF PAPERMAKING TRAVELED WEST ALONG TRADE ROUTES TO THE MEDITERRANEAN. EARLY MILLS WERE ESTABLISHED BY CHINESE PRISONERS IN SAMARK AND IN CENTRAL ASIA AROUND 750 A.D.. THE ABUNDANCE OF OF HEMP AND FLAX (LINUMUSITIATISSIMUM) IN THIS AREA PROVIDED MORE FIBERS FOR PAPER MAKING, AND THE PROCESS SPREAD TO EGYPT, WHERE COTTON, GENERALLY IN THE FORM OF NEW CLOTH OR RAGS, WAS ADDED TO THE LIST OF USABLE FIBERS. THESE NEW FIBERS PRODUCED PAPERS THAT WERE THICK, OPAQUE, ABSORBENT, AND CRISP, IDEAL FOR THE EXISTING WRITING TOOLS, QUILL PENS AND STIFLES.

PAPERMAKING MOVED ACROSS EUROPE AND IN 1917 A FRENCH SCIENTIST,RENE DE REAMUR,OBSERVED THAT WASPS MADE VERY FINE PAPER FOR THEIR NESTS FROM WOOD DIGESTED IN THEIR MOUTHS. WITH A SHORTAGE OF COTTON AND LINEN CLOTH AND AN EVER GROWING NEED FOR PAPER, THIS OBSERVATION LED TO FURTHER PLANT EXPERIMENTS WITH NETTLES, MOSS, PINE NEEDLES AND THE BARKS OF SHRUBS AND TREES THE QUANTITY OF PULP PRODUCED FROM A TREE AND THE LARGE DEMAND FOR PAPER LED TO THE INVENTION OF THE FOURDRINIER MACHINE IN 1806. IT COULD PRODUCE PAPER ON A CONTINUOUS WEB AND IN ENORMOUS QUANTITIES. HAND PAPERMAKING CAME TO THE UNITED STATES IN 1690, BUT BY THE END OF THE AMERICAN CIVIL WAR, MODERN INDUSTRY, THE USE OF THE NEW PAPERMAKING MACHINE, AND THE CONVERSION TO WOOD PULP

EFFECTIVELY BROUGHT TO AN END THE PRODUCTION OF HANDMADE PAPER IN AMERICA.

IN 1928 DARD HUNTER ESTABLISHED A MILL IN CONNECTICUT FOR PRODUCING HAND SHEETS ON A SMALL SCALE, AND HIS EXTENSIVE RESEARCH COMPRISES MOST OF TODAY'S REFERENCE MATERIALS. HE TRAVELED AROUND THE WORLD AMASSING A TREMENDOUS COLLECTION OF HAND PAPERMAKING EQUIPMENT, MATERIALS, AND SAMPLES OF PAPER THAT ARE HOUSED IN THE DARD HUNTER MUSEUM AND LIBRARY AT THE INSTITUTE OF PAPER CHEMISTRY IN APPLETON, WISCONSIN.

SINCE 1946, DOUGLASS HOWELL HAS CONTINUED HIS RELENTLESS EXPLORATION OF FLAX FIBER FOR USE IN HAND SHEETS AND FOR THE PRODUCTION OF PAPER ART OBJECTS. AND HERE BEGAN A NEW PHASE IN THE TRADITION OF EUROPEAN PAPERMAKING, THE PAPER ART OBJECT. ORIENTAL PAPERS HAVE ALWAYS BEEN USED FOR KITES, SLIDING SCREENS, CLOTHING, DOLLS, FLOOR COVERINGS, AND IN SPIRITUAL CEREMONIES. EUROPEAN PAPERS HAVE BEEN THE CARRIERS OF IMAGES OR INFORMATION, SUBSERVIANT TO ANOTHER MEDIUM. NOW THE STUFF OF PAPER, ITS COLOR, ITS TEXTURE, ITS MALLEABILITY, AND ITS FIBERS ARE BEING USED TO ACCENTUATE THEIR OWN INHERENT QUALITIES. AND ARTISTS ARE TAKING ADVANTAGE OF THESE QUALITIES TO CREATE WORKS THAT SPEAK ABOUT IMAGE AND PAPER, PAPER AS IMAGE.

ORIENTAL PAPERMAKING

THE BEAUTY OF ORIENTAL PAPERS LIES IN THEIR SUPPLENESS, TRANSPARENCY, SURFACE QUALITIES, AND STRENGTH. THIS BEAUTY DOES NOT COME EASILY. THE PROCESS IS VERY LABORIOUS AND TIME CONSUMING. TO FOLLOW THE TRADITION WOULD MEAN GROWING THE SPECIFIC PLANTS, HARVESTING, STEAMING, AND STRIPPING THE BARK FROM THE WOODY CORE, SEPARATING THE BARK LAYERS TO OBTAIN THE USABLE FIBER, COOKING IT, AND RINSING IT , AND BEATING BY HAND INTO A PULP. THE PULP WOULD THEN BE ADDED TO A VAT OF VERY COLD WATER AND FORMED INTO THIN SHEETS. TRADITIONALLY PAPERMAKING WAS A FALL AND WINTER ACTIVITY. DURING THE SPRING AND SUMMER, THE LAND WAS FARMED AND THE PAPERMAKING PLANTS GROWN. THE COLD WEATHER ALSO ENHANCED THE WORKING CHARACTERISTICS OF THE MATERIALS.

THERE ARE THREE MAIN PERENNIAL PLANTS GROWN FOR ORIENTAL PAPERMAKING: KOZO (BROUSSINETIA PAPYRFERA), MITSUMATA (EDGEWORTHIA PAPYRIFERA), AND GAMPI (WIKSTROEMIA CANESCENS). ALL THREE ARE CLASSIFIED AS BAST FIBERS. EACH HAS ITS OWN CHARACTERISTICS AND IS USED TO MAKE A SPECIFIC KIND OF PAPER. ALL HAVE LONG FIBERS THAT ARE EASILY SEPARATED DURING THE COOKING AND BEATING PROCESS.

KOZO IS A LOOSELY APPLIED TERM FOR A VARIETY OF PAPERMAKING MULBERRY TREES. IT IS THE MOST COMMON OF THE THREE PLANTS AND IS HARVESTED AFTER ITS SECOND YEAR OF GROWTH WHEN THE STEMS HAVE REACHED A DIAMETER OF ABOUT ONE INCH. IT WAS ONE OF THE EARLIEST CULTIVATED PLANTS USED FOR PAPER AND PRODUCES THE TOUGHEST AND STRONGEST FIBERS. ITS FIBERS ARE NOT VERY ELASTIC, GIVING THE RESULTING SHEET GREAT DIMENSIONAL STABILITY.

MITSUMATA IS HARVESTED AFTER ITS THIRD YEAR OF GROWTH AND PRODUCES A SOFT ABSORBENT,FINE-GRAINED, SLIGHTLY ORANGE SHEET. THE FIBER CONTAINS A BITTER CHEMICAL THAT REPELS INSECTS FROM PAPERS PRODUCED WITH IT.

GAMPI HAS NEVER BEEN SUCCESSFULLY DOMESTICATED AND CONSEQUENTLY IS NOT AS READILY AVAILABLE AS KOZO OR MITSUMATA. PAPER PRODUCED FROM GAMPI IS REPUTED TO BE THE MOST NOBLE AND BEAUTIFUL OF ALL AND IS SAID TO BE CAPABLE OF LASTING FOREVER. IT ALSO REPELS INSECTS.

FIBER PRODUCED BY THE HEMP PLANT WAS USED IN CHINA AND WAS THE MOST IMPORTANT PAPERMAKING MATERIAL IN EARLY JAPAN, WHERE IT WAS GRADUALLY REPLACED BY KOZO. IT PRODUCES A SUPPLE AND STRONG SHEET WITH A SLIGHTLY ROUGH SURFACE.

TRADITIONAL EUROPEAN PAPERMAKING

TRADITIONAL EUROPEAN PAPERS ARE MOST OFTEN SEEN IN OLD BOOKS AND DOCUMENTS. THEY HAVE A WARM WHITE COLOR THAT CONTRASTS WITH THE CRISP BLACK TYPE IMPRESSED IN THEIR SURFACE. THEY HAVE A SUPPLE FEEL AND DRAPE WHEN THE BOOK IS OPENED. THE SURFACE SHOWS THE TEXTURE OF THE WOOLEN BLANKETS ON WHICH THE NEWLY FORMED SHEETS ARE PRESSED, AND THE EDGES OF THE SHEETS HAVE A SLIGHT COCKLE OR WAVE. THE EDGE ITSELF IS NOT SHARP AS IF CUT FROM A LARGER SHEET BUT IS SLIGHTLY IRREGULAR AND IS REFERRED TO AS DECKLED. THESE WHITE PAPERS ARE MADE FROM LINEN AND COTTON FIBER THAT CAME TO THE PAPER MILL IN THE FORM OF NEW CLOTH OR RAGS. THESE WERE DAMPENED AND ROLLED INTO BALLS, AND THE BALLS WERE ALLOWED TO FERMENT FOR UP TO TWO MONTHS. THIS FERMENTING WAS ACTUALLY A SLOW COOKING PROCESS THAT SOFTENED THE FIBERS. AFTER RINSING, THE CLOTH FRAGMENTS WERE PLACED IN THE BASIN OF A MECHANICAL STAMPER, AND A HEAVY WOODEN HAMMER OR SHAFT POWERED BY A WATERWHEEL ROSE AND FELL ON THE SOFTENED MATERIAL TO SEPARATE ITS FIBERS. THE STAMPING PROCESS DID NOT INVOLVE CUTTING, SO THE RESULTING PULP WAS LONG AND SUPPLE, PRODUCING PAPERS OF GREAT BEAUTY, STRENGTH, AND DURABILITY.

THE TIME CONSUMING STAMPING PROCESS WAS SLOWLY REPLACED BY THE INVENTION OF THE HOLLANDER BEATER. IN ITS OBLONG SHAPED TUB WAS A ROLLER FITTED WITH METAL BLADES, WHICH LACERATED THE RAGS AS THEY PASSED BETWEEN IT AND A STONE BEDPLATE MOUNTED IN THE BOTTOM OF THIS TANK. THIS MACHINE COULD PROCESS RAG IN MUCH LESS TIME, BUT THE RESULTING FIBER HAD BEEN CUT SHORTER AND PRODUCED A PAPER WITH LESS SUPLENESS AND STRENGTH. 1

AFTER BEATING, THE PULP IS TRANSFERRED TO A STORAGE CHEST OR PUT DIRECTLY INTO THE FORMING VAT. HISTORICALLY, THESE EUROPEAN VATS WERE BUILT OVER SMALL FIREPLACES. THESE FIRES HEATED THE FIBERS AND PULP. SINCE WARM WATER IS LESS VISCOUS THAN COLD AND DOES NOT CLING TO THE FIBERS AS WELL, SHEETS FORMED IN WARM WATER DRAIN FASTER, ALLOWING THE PAPERMAKER TO MAKE MORE SHEETS IN A DAY.

THE EUROPEAN SHEET FORMING METHOD REQUIRES THE LIFTING AND HOLDING OF LARGE AMOUNTS OF WATER. CONSEQUENTLY THE MOULDS DEVELOPED FOR THIS ARE MUCH MORE SUBSTANTIAL THAN THE ORIENTAL ONES, HAVING AN ELABORATE SYSTEM OF RIBS THAT HOLD THE WIRE SURFACE

LEVEL. THIS LEVEL SURFACE AIDS IN THE FORMATION OF AN EVEN SHEET AND AIDS DRAINAGE. IT CAN BE A WOVEN, NONCOROSIVE WIRE MESH OR A SERIES OF LAID WIRE RODS TWINED TOGETHER. 2

THE PAPERMAKING MOULD IS DIPPED INTO A VAT OF PULP, SHAKEN TO DISTRIBUTE AND CROSS THE FIBERS; AND THE SHEET FORMS AS THE WATER DRAINS. THE WET PAPER IS THEN TRANSFERRED TO A FELT, AND DRYING IS DONE BY PRESSING IN A PRESS.

BASIC PAPER CHEMISTRY

A SHEET OF PAPER IS NOT HELD TOGETHER BY MAGIC OR SIMPLY PILING FIBERS ON TOP OF ONE ANOTHER. THE BONDING OR COHESION OF SURFACES OF CELLULOSE OR WITHIN THE FIBER SHEET IS NOT DUE TO A MUCILAGE OR GLUE EITHER BUT TO AN ELECTROCHEMICAL PROCESS IN WHICH HYDROGEN BONDS FORM BETWEEN THE FIBERS. THESE FIBERS ARE DRAWN TOGETHER AND ALIGNED BY THE PRESENCE OF LIQUID WATER DURING THE SHEETFORMING PROCESS. WATER IS THE MEDIUM FOR THE ACTIVITY, AND AS IT IS REMOVED DURING THE DRAINING, PRESSING, AND DRYING OF THE SHEET, IT PRODUCES TENSION THAT DRAWS THE FIBERS TOGETHER. THIS BONDING OF THE FIBERS IS AIDED BY FIBRILS, WHICH ARE SMALL HAIRLIKE ABRASIONS ON THE SURFACE OF EACH FIBER, CAUSED DURING THE BEATING PROCESS. THESE INCREASE THE SURFACE TEXTURE OF THE FIBERS AND CONSEQUENTLY INCREASE FRICTION BETWEEN FIBERS. THIS FRICTION AS WELL AS THE PHYSICAL INTERLOCKING OF THE FIBER DURING SHEET FORMING AID IN THE BONDING OF THE SHEET. OTHER FACTORS THAT EFFECT THE COHESION ARE THE AVERAGE LENGTH OF THE INDIVIDUAL FIBERS, THEIR FLEXIBILITY, AND THE DEGREE OF FIBRILATIONON THEIR SURFACES. THESE COMPONENTS CAN BE ALTERED BY THE COOKING AND BEATING METHOD USED TO PREPARE THE FIBER. 3

HYDROGEN BONDING OCCURS WHEN TWO FIBERS OR FIBRILS ARE FORCED SO CLOSE TOGETHER THAT ELECTRONS FROM FREE HYDROXYL GROUPS OF CELLULOSE MOLECULES FROM BOTH ARE INVOLVED IN A CERTAIN ELECTROSTATIC RESONANCE. (SIMILAR BRIDGING BONDS MAY OCCUR BETWEEN CELLULOSE AND WATER ...) THE MECHANISM THAT BRINGS FIBERS INTO INTIMATE MOLECULAR CONTACT DURING DRYING IS REFERRED TO AS THE CAMPBELL EFFECT. STEMMING FROM SURFACE TENSION FORCES OF WATER EXISTING BETWEEN FIBERS OR FIBRILS IN DAMP PAPER, THE CAMPBELL EFFECT SHOWS LINEARLY INCREASING COMPACTING FORCES WHICH ARE BELIEVED TO APPROACH 110 KILOGRAMS PER SQUARE CENTIMETER (1500 POUNDS PER SQUARE INCH) AS THE SHEET NEARS DRYNESS. THE MORE INTIMATE THE CONTACT BETWEEN FIBERS AT ALL POINTS DURING THE PROCESS, THE GREATER THE COMPACTING FORCES, THE MORE PREVALENT AND LARGER THE BONDS, AND THE STRONGER THE PAPER WILL BE IN THE END. BEATING IS NORMALLY USED TO MAKE FIBERS MORE PLASTIC AND INCLINED TO INTIMATE CONTACT...4

CELLULOSE IS A HYDROPHILIC (WATER LOVING) CARBOHYDRATE COMPOSED OF A MOLECULAR GLUCOSE CHAIN OF UP TO 5,000 UNITS. IT IS FOUND IN VARYING DEGREES IN ALL PLANTS...

OTHER COMPONENTS OF THE PLANT ALSO AFFECT PAPERMAKING, PARTICULARLY LIGNIN AND HEMICELLULOSE. LIGNIN IS OFTEN REFERRED TO AS AN INTERCELLULAR CEMENT. IT HOLDS THE FIBER BUNDLES TOGETHER IN THE PLANT. IT IS HYDROPHOBIC (WATER FEARING) AND MUST BE REMOVED BY

COOKING. ITS PRESENCE IN THE PULP REDUCES FIBER SEPARATION DURING BEATING AND INTERFIBER BONDING DURING SHEET FORMING. 5