3. The rabbit ovulation unit was found experimentally to be equivalent to 1 rat unit per Kg. body weight of rabbit.

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PARKE, DAVIS AND COMPANY,
DETROIT, MICH.

DRUG EXTRACTION. I. A STUDY OF VARIOUS MENSTRUA FROM THE STANDPOINT OF SWELLING EFFECTS, PENETRATION AND EXTRACTION.[1, 2, 3]

BY WILLIAM J. HUSA[4] AND LOUIS MAGID.

INTRODUCTION.

The extraction of drugs is a time-honored process. However, there has been a feeling in recent years that the fundamental principles involved in this basic pharmaceutical procedure have received insufficient attention. Such factors as the swellings of drugs in liquids and the penetration of menstrua have not been studied quantitatively and many official formulas are based to a considerable extent on empiricism and tradition.

The purpose of the present investigation has been to make a critical study of the fundamental principles of drug extraction with special reference to permeation of cell walls by a selected series of pharmaceutical solvents, to swelling of cellular tissue during maceration with selected menstrua, and to the influence of menstrua upon the structure of vegetable drugs and extraction of the constituents.

SWELLING EFFECT OF SOLVENTS.

Chestnut wood, being a relatively simple vegetable structure, was chosen as the first material to be studied with the idea that the methods evolved and the data collected would be applied in the course of the investigation in the study of various types of drugs. Chestnut wood consists largely of fibrous tissue and one of its constituents is tannin.

Swelling of Strips of Chestnut Wood.—A study of the swelling effect of solvents on thin sections was deemed advisable as the first point of attack. The liquids

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[2] This investigation was aided by a grant from the AMERICAN PHARMACEUTICAL ASSOCIATION Research Fund.

[3] This paper is based on a dissertation submitted by Louis Magid to the Graduate Council of the University of Florida in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

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customarily used to soften hard tissues for sectioning, such as solutions of hydrofluoric acid, potassium hydroxide, etc., obviously could not be used. By the use of a "smoother" at a planing mill, thin cross-section shavings, suitable for microscopical study, were obtained. A plan was devised of cutting a strip of a section of chestnut wood, 0.25 to 0.50 mm. wide, so that the strip could be observed in the field of the microscope under low power and measurements made with a filar micrometer of the width of the strip before and after the addition of solvents. The width of the strips ranged from 0.14 to 0.65 mm., and the length from 3 to 6 mm. The thickness of the strips ranged from 0.045 to 0.070 mm. The strips examined consisted largely of summer wood, inasmuch as strips of spring wood generally tore on the addition of water. Measurements of swelling were made in units of the filar micrometer and for concise presentation in the tables which follow all results have been recalculated on a percentage basis with the width of the dry strip taken as 100. The results given are the average of 3 or more determinations in each case.

Effect of Various Menstrua on Strips of Chestnut Wood.—Scoville (1) has listed 20 different alcohol-water mixtures used as menstrua in official preparations and has suggested that some of these which differ slightly in percentage strength could well be eliminated. From this list, 8 alcohol-water mixtures were selected and their effect on the width of strips of chestnut wood was determined. Glycerin-water and glycerin-alcohol mixtures were studied similarly.

The results in Table I indicate that mixtures of equal volumes of alcohol and water and mixtures containing less than this proportion of alcohol have practically the same swelling effect as water alone, causing an immediate swelling with very little further change during the two hours. The weaker alcoholic menstrua apparently reach a swelling equilibrium within a few minutes. With concentrations of alcohol exceeding 58 per cent by volume there is an increasing tendency toward a smaller immediate swelling and a more gradual approach to equilibrium (see Graph 1).

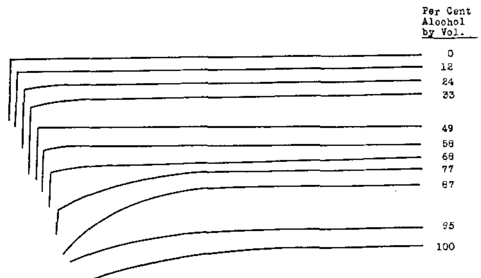
TABLE I.—EFFECT OF VARIOUS ALCOHOL-WATER MIXTURES.

Per Cent, Alcohol by Volume.	Dry. 0.	After Time Intervals (Minutes). 1.	5.	10.	20.	40.	60.	80.	100.	120.
0 (Water)	100	120	120	120	120	120	120	120	120	120
11.8	100	118	119	119	119	121	120	118	118	118
24.0	100	119	119	120	120	121	121	120	120	120
32.8	100	121	122	122	123	124	124	124	124	124
49.0	100	117	116	116	116	116	116	116	116	116
58.4	100	114	115	115	115	115	115	115	115	116
68.1	100	112	112	113	113	114	114	114	115	115
77.4	100	108	111	113	115	118	120	120	120	120
86.5	100	101	105	110	115	118	121	121	121	121
95.2	100	101	102	102	107	107	109	110	110	110
99.9	100	99	100	102	104	108	109	110	110	110

The results in Table II indicate that a mixture of 1 volume of glycerin and 7 volumes of water has practically the same effect as water alone. With increasing concentrations of glycerin the primary rise decreases and a longer time is required for equilibrium to be reached. Glycerin alone and a mixture of glycerin 9 volumes and water 1 volume both cause an immediate swelling of about 1 per cent with no further change during two hours (see Graph 2).

TABLE II.—EFFECT OF VARIOUS GLYCERIN-WATER MIXTURES.

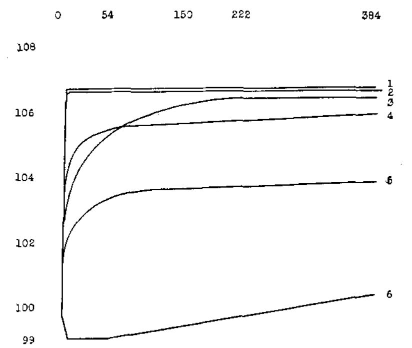
Volume of Glycerin.	Volume of Water.	Dry. 0.	After Time Intervals (Minutes). 1.	5.	10.	20.	40.	60.	80.	100.	120.
0	1	100	120	120	120	120	120	120	120	120	120
1	7	100	122	124	124	124	124	124	124	124	124
1	3	100	116	119	121	121	121	121	121	121	121
1	2	100	113	119	120	121	122	122	122	122	122
1	1	100	103	106	108	112	114	116	116	116	116
3	2	100	101	102	103	106	111	115	116	117	117
7	3	100	103	103	105	108	111	114	116	117	118
4	1	100	103	103	103	104	105	106	107	108	109
9	1	100	101	101	101	101	101	101	101	101	101
1	0	100	101	101	101	101	101	101	101	101	101



Swelling of Strips of Chestnut Wood in Various Alcohol-Water Mixtures.

For numerical data see table 1.

Graph 1.

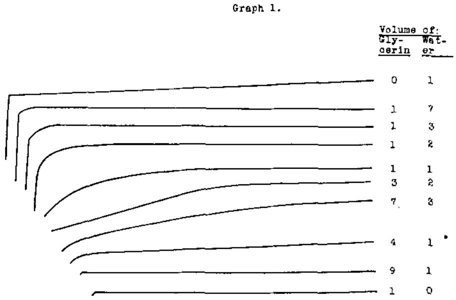


Curve 1 - Water.
Curve 2 - Mixture Alcohol 1 Vol.-Water 1 Vol.
Curve 3 - Mixture Glycerin 1 Vol.-Alcohol 1 Vol.
Curve 4 - Mixture Glycerin 1 Vol.-Water 1 Vol.
Curve 5 - Alcohol.
Curve 6 - Glycerin.

Swelling of Chestnut Wood Blocks in Solvents.
Swelling Expressed on Basis of Original Thickness = 100.

Abscissa: Time in Hours.
Ordinates: Percentage Swelling or Shrinking Based on Dry = 100.

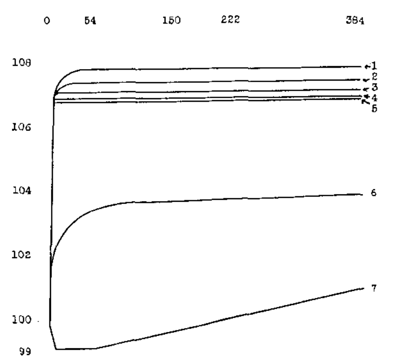
Graph 4.



Swelling of Strips of Chestnut Wood in Various Glycerin-Water Mixtures.

For numerical data see table 2.

Graph 2.

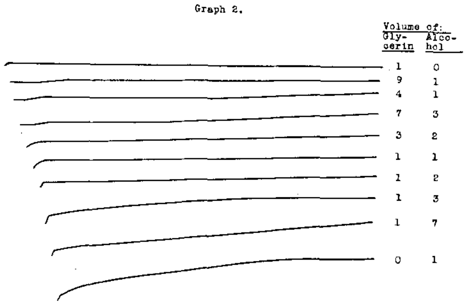


Curves:
1 - Mixt. Glycerin 75 Vol.-Alcohol 675 Vol.-Water 250 Vol.
2 - Mixt. Glycerin 1 Vol.-Alcohol 5 Vol.-Water 4 Vol.
3 - Mixt. Glycerin 1 Vol.-Alcohol 3 Vol.-Water 5 Vol.
4 - Mixt. Glycerin 65 Vol.-Alcohol 250 Vol.-Water 685 Vol.
5 - Water.
6 - Alcohol.
7 - Glycerin.

Swelling of Chestnut Wood Blocks in Solvents.
Swelling Expressed on Basis of Original Thickness = 100.

Abscissa: Time in Hours.
Ordinates: Percentage Swelling or Shrinking Based on Dry = 100.

Graph 5.



Swelling of Strips of Chestnut Wood in Various Glycerin-Alcohol Mixtures.

For numerical data see table 3.

Graph 3.

TABLE III.—EFFECT OF VARIOUS GLYCERIN-ALCOHOL MIXTURES.

Volume of Glycerin.	Volume of Alcohol.	Dry. 0.	After Time Intervals (Minutes). 1.	5.	10.	20.	40.	60.	80.	100.	120.
1	0	100	101	101	101	101	101	101	101	101	101
9	1	100	100	100	100	101	101	101	101	101	101
4	1	100	100	100	101	101	101	101	102	103	103
7	3	100	100	100	101	101	101	102	103	104	105
3	2	100	101	102	102	102	103	103	103	104	104
1	1	100	102	103	103	103	104	104	104	105	105
1	2	100	102	102	102	103	104	105	105	106	106
1	3	100	103	104	105	105	108	109	110	110	111
1	7	100	102	103	104	104	106	108	110	112	114
0	1	100	101	102	102	107	107	109	110	110	110

The results in Table III indicate that there is practically no swelling with glycerin and with a mixture of 9 volumes of glycerin and 1 volume of alcohol. With increasing concentrations of alcohol there is an increase in the rate and amount of swelling (see Graph 3).

Effect of Acidity and Alkalinity on Swelling of Strips of Chestnut Wood.—There is abundant evidence in the literature showing that acidity and alkalinity are important factors in the swelling of colloids and plant tissues. In view of these facts and the established use of acids in menstrua of some official extractive preparations, it seemed desirable to know whether changes in acidity and alkalinity affect the swelling of drugs. Using sodium hydroxide and hydrochloric acid, distilled water was adjusted to a series of p_H values by the colorimetric method with LaMotte indicators and standards. The effect of these liquids on the swelling of strips of chestnut wood is shown in Table IV.

TABLE IV.—EFFECT OF WATER ADJUSTED TO VARIOUS p_H VALUES.

p_H of Water.	Dry. 0.	After Time Interval (Minutes). 1.	5.	10.	20.	40.	60.	80.	100.	120.
0.9	100	121	121	121	121	121	121	121	121	121
1.9	100	120	120	120	120	120	120	120	120	120
3.1	100	121	121	122	122	122	122	122	122	122
4.7	100	120	120	120	120	120	120	120	120	120
5.7	100	120	120	120	120	120	120	120	120	120
6.9	100	120	120	120	120	120	120	120	120	120
7.5	100	120	121	121	121	121	121	121	121	121
8.9	100	122	122	123	123	123	123	123	123	123
10.5	100	120	121	121	121	121	121	122	122	122
12.0	100	119	121	122	122	123	123	123	123	123

From the above results it is seen that a variation in p_H of aqueous solutions from 0.9 to 12.0 has practically no effect on the swelling of simple woody tissue such as chestnut wood.

TABLE V.—EFFECT OF ACIDITY AND ALKALINITY OF ALCOHOL.

Alcoholic Solution.	Dry. 0.	After Time Intervals (Minutes). 1.	5.	10.	20.	40.	60.	80.	100.	120.
Alcohol alone	100	101	102	102	107	107	109	110	110	110
0.01N NaOH	100	100	101	102	107	111	112	113	113	113
0.1N NaOH	100	102	103	105	108	113	115	117	117	117
0.01N HCl	100	100	101	102	105	107	108	108	108	108
0.1N HCl	100	101	102	102	102	102	103	104	104	105

The effect of varying the acidity and alkalinity of alcohol on the swelling of strips of chestnut wood is shown in Table V.

The results indicate that in alcoholic solutions, an increase in alkalinity increases the swelling of strips of chestnut wood, while an increase in acidity decreases the swelling normally caused by alcohol.

Effect of Successive Addition of Liquids on Strips of Chestnut Wood.—The technique employed for determining the effect of successive addition of various liquids on the swelling of chestnut wood strips was that of adding the first liquid during a definite period of time to the strip, removing as much as possible of the liquid by means of filter paper, and then adding the second liquid, etc. The effect of successive additions of water, alcohol and absolute alcohol on strips of chestnut wood are shown in the following tables.

TABLE VI.—EFFECT OF SUCCESSIVE ADDITION OF WATER, ALCOHOL AND ABSOLUTE ALCOHOL.

Time in	Dry.	Water.		Alcohol.						Abs. Alc.	
Minutes.	0.	1.	5.	1.	5.	10.	20.	40.	60.	1.	5.
Average of 2 strips	100	114	115	112	112	112	112	113	114	110	111

It is seen that alcohol shrinks a strip swollen by water, and then causes a gradual swelling. The addition of absolute alcohol at this point causes a shrinking.

TABLE VII.—EFFECT OF SUCCESSIVE ADDITION OF ALCOHOL AND WATER.

Time in	Dry.	Alcohol.						Water.	
Minutes.	0.	1.	5.	10.	20.	40.	60.	1.	5.
Average of 2 strips	100	101	102	103	105	109	114	124	127

The results show that alcohol causes the characteristic gradual swelling; the addition of water after one hour causes an immediate marked increase in swelling.

Experiments were also carried out on the successive addition of liquids as follows: (*a*) absolute alcohol, alcohol and water, (*b*) alcohol and absolute alcohol, (*c*) water and absolute alcohol and (*d*) absolute alcohol and water. Each liquid tended to exert its own effect regardless of whether this resulted in an increase or decrease of the swelling caused by the previously added liquid.

Swelling Effect of Various Liquids on Extracted Strips of Chestnut Wood.—To obtain materials for these tests, cross sections of chestnut wood were exhaustively extracted with water and with alcohol, until the presence of tannin in the extraction liquids was no longer detected. The sections were then air-dried and used in the following experiments, using the technique of measuring the width of strips with a filar micrometer. The following tables show the effect of various liquids and the successive addition of various liquids on strips of extracted chestnut wood. The results in each case are the average of 3 or more determinations.

TABLE VIII.—EFFECT OF VARIOUS LIQUIDS ON EXTRACTED STRIPS OF CHESTNUT WOOD.

	Dry.	After Time Intervals (Minutes.)								
Liquid.	0.	1.	5.	10.	20.	40.	60.	80.	100.	120.
Water	100	118	119	119	119	119	119	119	119	119
5 per cent aqueous solution of tannin	100	119	120	120	120	120	120	120	120	120
Glycerin	100	100	100	100	100	100	100	101	101	101

TABLE IX.—EFFECT OF SUCCESSIVE ADDITION OF VARIOUS LIQUIDS ON EXTRACTED STRIPS OF CHESTNUT WOOD.

Abbreviations: alc. = alcoholic; sol. = solution; N = normal.

Time in Minutes.																	
0.	1.	5.	10.	20.	40.	60.	120.	1.	5.	10.	20.	40.	1.	5.	10.	20.	40.
Dry.	Alcohol.							0.1N alc. HCl					Alcohol.				
100	101	103	104	106	108	110	110	110	110	110	110	110	110	110	110	110	110
Dry.	Alcohol.							0.1N alc. NaOH.					Alcohol.				
100	101	102	103	104	107	109	109	109	109	110	110	111	111	111	110	110	110
Dry.	0.1N alc. HCl.							Alcohol.									
100	101	102	103	105	107	107	107	108	108	108	108	108					
Dry.	5 per cent alc. sol. tannin.							Alcohol.									
100	101	102	103	103	105	106	107	107	107	107	108	108					

Since the extracted strips of chestnut wood showed the same degree of swelling with various liquids as the unextracted strips, it is apparent that treatment with water and alcohol causes no permanent change in the structure of the tissues, or at least no change capable of affecting the swelling properties; it is also apparent that the soluble constituents of this tissue are of no importance in swelling, although a 5 per cent solution of tannin in alcohol decreased the swelling to a slight extent. The results in Table IX show that on successive addition of liquids, usually each liquid tends to exert its own effect regardless of whether this results in an increase or decrease of the swelling caused by the previously added liquid.

Swelling of Blocks of Chestnut Wood.—The swelling of blocks of chestnut wood immersed in various solvents was studied. The wood was cut into uniform 24-mm. blocks, with the grain running the long way, and varying from 1.75 to 1.80 mm. in thickness at the center (across the grain). Three blocks were placed in each solvent in stoppered flasks kept at a constant temperature of 30° C. in a Freas large size water thermostat. The blocks were weighted below the surface of the liquids by pieces of glass rod fastened by a thread. The amount of swelling was based on the change in thickness (across grain), measurements being made with a micrometer caliper. The results obtained from the effects of various liquids on the swelling of blocks of chestnut wood are given in Table X. The results have been recalculated on a percentage basis, with the original thickness of the dry blocks taken as 100, and are based on the average of 3 blocks.

TABLE X.—EFFECT OF VARIOUS LIQUIDS ON BLOCKS OF CHESTNUT WOOD.

Abbreviations: alc. = alcohol; abs. = absolute; gly. = glycerin; mixt. = mixture; v. = volume.

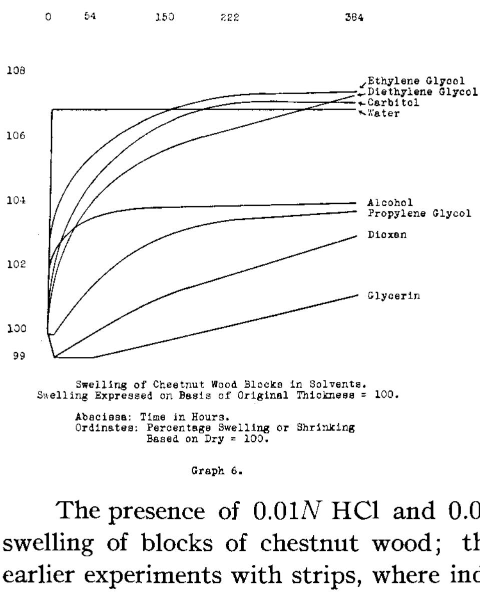
Liquid.	Dry. 0.	After Time Intervals (Hours). 6	12.	24.	54.	150.	222.	384.
Water	100	106.9	106.9	106.9	106.9	106.9	106.9	106.9
Alcohol	100	102.6	102.8	102.9	103.6	103.7	103.9	104.0
Glycerin	100	99.3	99.3	99.3	99.3	100.0	100.3	101.1
Dioxan	100	99.3	99.4	99.5	99.8	101.3	101.8	103.0
Carbitol	100	101.3	102.7	103.5	104.4	106.5	107.1	107.1
Diethylene glycol	100	101.0	101.8	102.8	104.0	105.6	106.3	107.3
Propylene glycol	100	100.0	100.2	100.4	101.7	102.8	103.5	103.7
Ethylene glycol	100	103.7	104.0	104.5	105.3	107.0	107.3	107.4
0.01*N* aqueous HCl	100	107.5	107.6	107.6	107.5	107.7	107.7	107.8
0.01*N* aqueous NaOH	100	107.8	107.8	107.8	107.8	107.9	107.9	107.9
0.01*N* alcoholic HCl	100	102.2	102.5	103.0	103.5	103.9	103.9	103.9
0.01*N* alcoholic NaOH	100	102.2	102.7	102.9	103.2	103.3	103.3	103.3
Mixt. alc. 1 v.—water 1 v.	100	106.7	106.8	106.8	106.8	106.8	106.8	106.8
Mixt. gly. 1 v.—water 1 v.	100	104.6	105.2	105.6	105.7	105.8	106.1	106.1
Mixt. gly. 1 v.—alc. 1 v.	100	103.4	104.1	105.3	105.4	106.0	106.6	106.6
Mixt. gly. 1 v.—alc. 5 v.—water 4 v.	100	107.2	107.4	107.4	107.5	107.5	107.5	107.5
Mixt. gly. 1 v.—alc. 3 v.—water 5 v.	100	107.1	107.2	107.2	107.2	107.2	107.2	107.2
Mixt. gly. 75 v.—alc. 675 v.—water 250 v.	100	107.3	107.4	107.9	107.9	107.9	107.9	107.9
Mixt. gly. 65 v.—alc. 250 v.—water 685 v.	100	107.0	107.0	107.0	107.0	107.0	107.0	107.0

The results of the above table show that water causes greater swelling than alcohol, and alcohol causes greater swelling than glycerin. Considering the binary mixtures of water, alcohol and glycerin, we find that a mixture of alcohol 1 vol.—

water 1 vol. produces a swelling equal to that of water, but not reaching equilibrium quite as rapidily. A mixture of equal parts of glycerin and alcohol produces greater swelling than a mixture of equal parts of glycerin and water, but the rate of swelling is slower (see Graph 4).

The ternary mixtures of water, alcohol and glycerin cause a slightly greater swelling than that brought about by water. The ternary mixtures used are 4 of the glycerin-alcohol-water mixtures used in U. S. P. and N. F. extractions. The results indicate that the variations in the 4 official menstrua studied have practically no effect on swelling (see Graph 5).

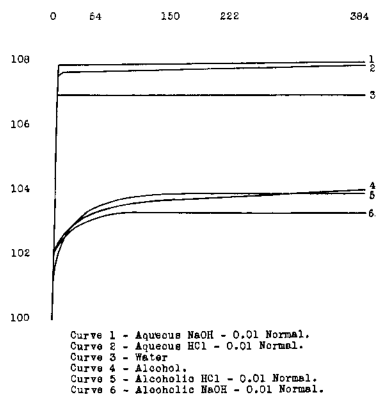
Ethylene glycol, diethylene glycol and carbitol cause about the same percentage swelling as water, except that water comes to equilibrium more rapidly. Dioxan and propylene glycol cause less swelling than alcohol but more than glycerin (see Graph 6).



Swelling of Chestnut Wood Blocks in Solvents.
Swelling Expressed on Basis of Original Thickness = 100.

Abscissa: Time in Hours.
Ordinates: Percentage Swelling or Shrinking Based on Dry = 100.

Graph 6.



Swelling of Chestnut Wood Blocks in Solvents.
Swelling Expressed on Basis of Original Thickness = 100.

Abscissa: Time in Hours.
Ordinates: Percentage Swelling or Shrinking Based on Dry = 100.

Graph 7.

The presence of $0.01N$ HCl and $0.01N$ NaOH in water slightly increases the swelling of blocks of chestnut wood; this slight difference was not observed in earlier experiments with strips, where individual differences are more pronounced. In alcohol, $0.01N$ NaOH caused a slight decrease in swelling (see Graph 7).

Comparative Swelling with Grain and across Grain.—It is a generally accepted fact that swelling is greater across grain than with the grain. An experiment was carried out to secure quantitative data on this point. Chestnut wood blocks of the same size used in the preceding experiment were placed in water and measurements of the length (with grain) and width (across grain) made at various time intervals. Measurements were made both at the edge and at the center of the blocks. The data, expressed on the basis: dry = 100, were as follows, the results being based on the average of 3 blocks.

TABLE XI.

Swelling.	0. Dry.	Time in Hours. 4.	13.	24. Water.	36.	72.	124.
Across grain (long way) edge	100	101.2	102.0	102.3	102.5	102.5	102.5
Across grain (long way) center	100	100.9	101.8	102.2	102.3	102.4	102.4
With grain (edge)	100	100.5	100.5	100.6	100.6	100.5	100.5
With grain (center)	100	100.6	100.6	100.5	100.6	100.6	100.6

The results show that swelling across grain is greater than with the grain. Swelling at the center and edge of the blocks is practically the same.

Photomicrographic Study of Swelling.—The chief kinds of tissues in chestnut wood are fibres, vessels and medullary rays. The structure is not uniform throughout, on account of the variations in growth at different seasons. Thus Plate 1 shows clearly the occurrence of spring wood, early summer wood and late summer wood.

Photomicrographs were made of sections of spring wood and summer wood cut from blocks which had been immersed for 4 months in water, alcohol, glycerin and the respective mixtures of these liquids used in the swelling and penetration tests. With water the cell walls appear filled out and under tension and the cavities appear fully opened. From the difference in appearance of the tissues in alcohol and in glycerin it seems that alcohol may cause less swelling than glycerin. With mixtures of equal volumes of glycerin and water and glycerin and alcohol, the cell walls appear to be completely swollen. Ternary mixtures of glycerin-alcohol-water which were used, produced much the same effects as water alone. Because of the variations in growth at different seasons there is a gradual change in the nature of the cells and it would not be safe to draw conclusions from fine measurements of cells from two different sections.

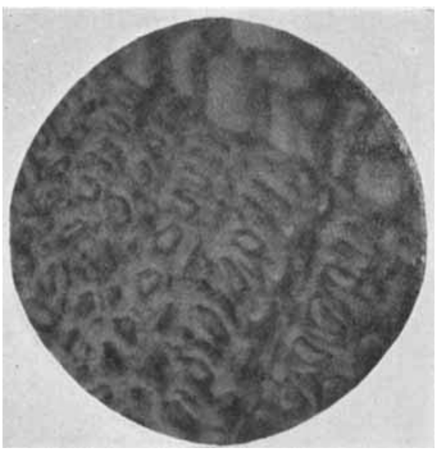


Plate 1.—A section cut from a block immersed in alcohol for four months, showing the different types of wood, namely, spring wood (large cells), early summer wood and late summer wood (adjacent to spring wood).

Due to inherent difficulties standing in the way of direct comparisons between different sections, a study was made of the effects of consecutive addition of different solvents to the same section. Since it was difficult to make thin sections of dry wood on the microtome, the procedure was adopted of obtaining sections from a block which had been immersed in alcohol for 4 months, the sections being air-dried for several days before use, during which time they apparently reverted to approximately the original condition.

Plate 2 shows the appearance of an air-dried section of summer wood, and the appearance of the same section after successive treatment with alcohol (2 hours), water (1 hour) and glycerin (6 hours). By identifying certain cells and thus measuring the same cells after treatment with different liquids, the following measurements were obtained from the photomicrographs, using a reading glass and a metric scale, and expressing the results in mm. Below are given the averages of the results.

	Air-Dried.	Alcohol.	Water.	Glycerin.
Across cavities	1.75	2.40	2.75	2.85
Between cavities (across double cell wall)	2.60	2.90	4.15	4.35
Between medullary rays	36	38	40	42

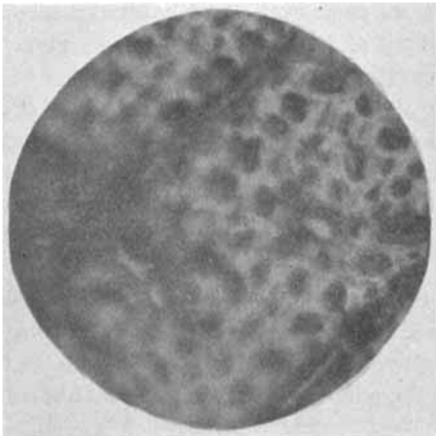


Fig. 1.

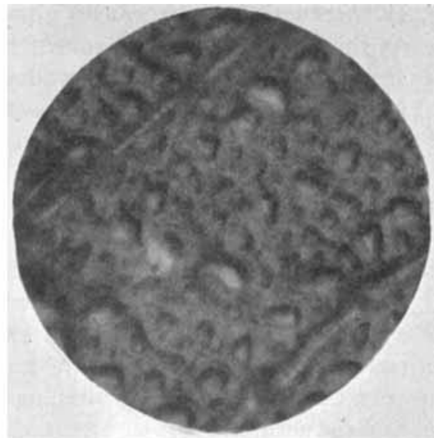


Fig. 2.

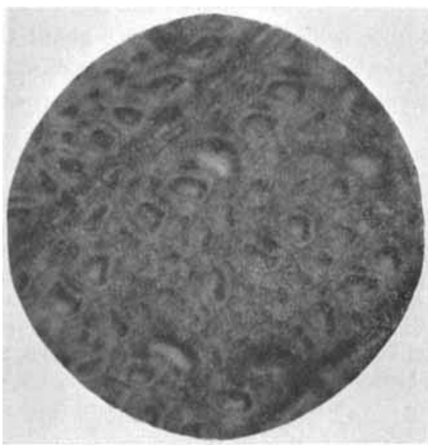


Fig. 3.

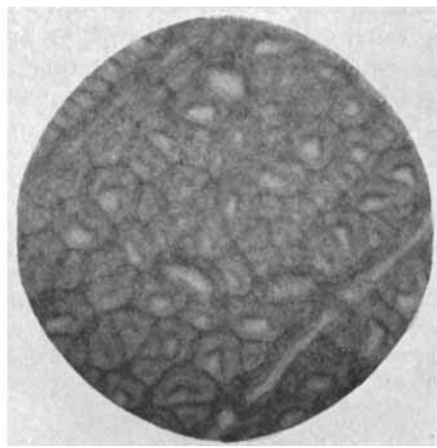


Fig. 4.

Photomicrographs of Chestnut Summer Wood.

Plate 2.—A section cut from a block immersed in alcohol for four months was air-dried (Fig. 1), and treated consecutively with alcohol (Fig. 2), water (Fig. 3) and glycerin (Fig. 4).

Thus it is seen that alcohol swells both the walls and cavities of the air-dried wood, both of which are enlarged by the successive addition of water and further slightly enlarged by glycerin.

Photomicrographs were also prepared to show the successive treatment of an air-dried section with (*a*) water, alcohol and glycerin, (*b*) glycerin and water, (*c*) glycerin and alcohol.

Below are given the averages of measurements taken from photomicrographs of an air-dried section of summer wood, treated consecutively with water (1 hour), alcohol (2 hours) and glycerin (6 hours).

	Air-Dried.	Water.	Alcohol.	Glycerin.
Across cavities	1.65	2.00	2.00	2.25
Between cavities (across double cell wall)	3.85	5.30	4.75	5.15
Between medullary rays	34	38	36	37

It is seen that water causes a swelling of both walls and cavities; alcohol shrinks the walls but does not reverse the effect of water on the cavities; glycerin then increases the size of both the walls and cavities.

Measurements were made between medullary rays in photomicrographs of an air-dried section treated with glycerin (6 hours) and then with water (12 hours), and are as follows: air-dried 16 mm.; glycerin 17 mm.; water 18 mm. Glycerin is thus shown to cause swelling. There is a further swelling with water, which may be due to a more complete penetration by glycerin, since the addition of glycerin after water (Plate 2) caused an increase.

An air-dried section was treated with glycerin (6 hours) and then with alcohol (12 hours). The distance between two medullary rays in photomicrographs of sections are as follows: air-dried 29 mm.; glycerin 33 mm.; alcohol 31 mm. It is thus seen that glycerin causes swelling and the subsequent treatment with alcohol caused some shrinking.

Discussion of Results.—In general, the results bear out the previous conclusions obtained on blocks and strips of chestnut wood, *i. e.* that alcohol causes some swelling, water causes a greater swelling than alcohol, while glycerin causes about the same swelling as water, although this effect is not shown when glycerin (undiluted) acts on dry wood, due to the very slow penetration by glycerin under these conditions.

Swelling of Blocks of Other Woods.—Tests were made on blocks of fresh oak sapwood of the water oak, Quercus nigra, 1. (Fagaceæ), in three conditions, namely, (*a*) fresh, (*b*) dried to constant weight at room temperature and (*c*) dried to constant weight at 90° C. in an oven. The blocks were about 25 mm. square, about 5 mm. thick (across grain) and averaged about 3 Gm. in weight. Using 3 blocks to each solvent, blocks were immersed in water, alcohol and glycerin in bottles placed in a thermostat at 30° C. After various intervals the blocks were removed and measured. The results of the swelling tests are given in the following tables, the figures in each case being based on the average of 3 blocks.

TABLE XII.—SWELLING OF FRESH OAK SAPWOOD BLOCKS IN LIQUIDS.
(Dimensions of blocks stated on basis: dry = 100.)

Time in Hours.	0.	3.	22.	46.	96.	528.	912.	1536.
			(Thickness—across grain)					
Water	100	100.0	100.0	100.0	100.0	100.1	100.1	100.1
Alcohol	100	100.0	100.0	99.9	99.8	99.9	99.9	99.9
Glycerin	100	100.0	100.0	100.0	100.0	100.0	100.0	100.0
			(Width—across grain)					
Water	100	100.0	100.0	100.0	100.0	100.1	100.1	100.1
Alcohol	100	100.0	100.0	100.0	100.1	100.2	100.3	100.3
Glycerin	100	100.0	100.0	100.0	100.0	100.2	100.2	100.2
			(Length—with grain)					
Water	100	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Alcohol	100	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Glycerin	100	100.0	100.0	100.0	100.0	100.1	100.1	100.1

The blocks of fresh sapwood of oak are apparently in a state of maximum size, inasmuch as there is practically no swelling in any of the three dimensions in water, alcohol or glycerin.

TABLE XIII.—LOSS IN SIZE OF BLOCKS OF FRESH OAK SAPWOOD ON DRYING.

Time in Hours.	0.	3.	22.	46.	96.	528.	912.	1536.
		(Thickness—across grain)						
Room temp.	100	99.8	97.4	95.5	94.5	94.5	94.0	94.0
At 90° C.	100	98.4	95.7	92.3	92.2	92.2	92.1	92.1
		(Width—across grain)						
Room temp.	100	99.8	95.8	90.7	89.2	88.9	88.8	88.8
At 90° C.	100	94.0	90.2	85.4	85.4	85.2	85.1	85.1
		(Length—with grain)						
Room temp.	100	100.0	99.9	99.7	99.7	99.7	99.7	99.7
At 90° C.	100	99.9	99.7	99.7	99.7	99.7	99.6	99.6

The loss in size of the blocks, as shown in the table, occurs chiefly across the grain and is greater in the samples dried in the oven at 90° C. than in the ones dried at room temperature. It is strikingly shown that there is only a negligible shrinking with the grain on drying.

TABLE XIV.—SWELLING IN LIQUIDS OF OAK SAPWOOD BLOCKS DRIED AT ROOM TEMPERATURE.

(Dimensions of blocks stated on basis: dimensions of fresh blocks *before drying* = 100.)

Time in Hours.	0.	3.	10.	24.	72.	240.	720.
			(Thickness—across grain)				
Water	94.7	99.1	99.2	99.6	99.6	99.6	99.6
Alcohol	93.2	99.0	99.0	99.0	99.0	99.0	99.0
Glycerin	95.1	94.9	94.7	94.7	94.7	94.8	95.7
			(Width—across grain)				
Water	89.4	95.2	98.8	99.2	99.4	99.4	99.5
Alcohol	88.6	97.3	97.4	97.5	97.5	97.6	97.7
Glycerin	88.5	88.1	88.3	88.4	89.6	91.7	93.7
			(Length—with grain)				
Water	99.7	100.1	100.2	100.2	100.2	100.2	100.2
Alcohol	99.6	99.9	99.9	100.0	100.0	100.0	100.0
Glycerin	99.6	99.7	99.7	99.7	99.7	99.9	100.0

TABLE XV.—SWELLING IN LIQUIDS OF OAK SAPWOOD BLOCKS DRIED IN OVEN AT 90° C.

(Dimensions of blocks stated on basis: dimensions of fresh blocks *before drying* = 100.)

Time in Hours.	0.	3.	10.	24.	72.	240.	720.
			(Thickness—across grain)				
Water	92.8	96.1	98.2	98.4	98.6	98.7	98.8
Alcohol	91.4	94.6	95.2	95.8	96.1	96.3	96.4
Glycerin	92.0	92.0	92.0	92.1	92.1	92.1	92.8
			(Width—across grain)				
Water	84.4	90.9	95.9	96.6	97.1	97.6	97.8
Alcohol	86.5	94.9	95.1	95.5	95.8	96.0	96.0
Glycerin	84.5	85.0	85.0	85.0	85.0	85.2	85.8
			(Length—with grain)				
Water	99.6	99.9	100.0	100.1	100.1	100.2	100.2
Alcohol	99.5	99.8	99.8	99.8	99.9	100.0	100.0
Glycerin	99.8	100.0	100.0	100.0	100.0	100.0	100.0

The dried blocks when immersed in liquids recover the slight decrease in length which occurred on drying, and the shrinkage across grain is reversed almost completely by water, less by alcohol and still less by glycerin.

Results similar to those obtained on the effect of liquids on oak sapwood have been obtained on blocks of Elberta peach wood and on blocks of the sapwood of Sassafras variifolium (Salisbury) O. Kuntz (Lauraceæ). (*To be continued.*)