THE TOPOGRAPHICAL INCIDENCE OF CANCER IN YORKSHIRE AND THE MIDLAND COUNTIES OF ENGLAND, INCLUDING THE FENLAND.

By MATTHEW YOUNG, M.D.

(National Institute for Medical Research.)

(With 2 Maps.)

THAT the mortality from cancer shows definite variations in different parts of England is now generally believed. Various attempts have been made to ascertain whether any association exists between this variation in mortality and variations in certain features such as elevation and levelness of site, nature of soil and underlying geological formation, proximity to rivers liable to floods, etc., that characterise the several districts comprising different regions, and evidence both for and against the influence of one or other of these factors in predisposing to cancer has been brought forward at different times. An inquiry (1922) into the incidence of cancer in the registration districts in the Severn Valley for the decade 1901–10 seemed to indicate that no definite connexion existed between an excessive mortality rate from cancer and the foregoing factors. It was considered advisable, however, to continue the investigation in another part of the country to determine if the inferences drawn from the analysis of the Severn Valley data were confirmed or if any new features were brought to light. The region chosen included the districts drained by the Yorkshire Ouse, the Trent, the Cambridgeshire Ouse, and those that intervene.

Data used in the Investigation.

The data necessary for the investigation were obtained through the courtesy of the Registrar-General. They comprise the deaths from cancer in the different age-groups in the two sexes separately for the ten years' period 1911–20 in the administrative units comprising the whole area, namely, urban districts, rural districts, municipal boroughs and county boroughs. It was decided to begin the investigation with the data for the year 1911, because, since that date, deaths occurring in persons temporarily removed from their homes to hospitals or other public institutions in other districts have been relegated to the districts to which they belonged. Unfortunately, the ten years' period taken embraces the War years, but this inclusion should not modify the data appreciably as comparatively few men were called up at the ages at which cancer is most prevalent.

By the appropriate summation of the figures for the administrative districts, corresponding figures for the larger registration districts throughout the whole area were obtained, and from these standardised death-rates were calculated for males and females separately from age 25 upwards. Though standardised death-rates may safely be used in comparing with one another the mortalities from cancer in the members of groups of registration districts of a similar character such as rural or town, it has been shown by Brownlee (1922), that the life table death-rate is a better measure for comparing the mortality from this disease in towns with that in rural districts. The use of the standardised death-rate gives the mortality from cancer relatively too low in the rural districts as compared with that in the town districts. As no attempt was to be made, in the present instance, to draw inferences from minute differences but only from relatively wide deviations from the average mortality, it was thought that the fallacy likely to arise from the use of the standardised death-rates could be borne in mind and allowed for in arriving at any general conclusions.

The standardised mortality rates for males and females respectively were grouped into six grades or degrees according to their magnitude, three above and three below the average. For the death-rates in females, the limiting rates per 1000 for the different grades were the following: under 1·3, 1·3 to 1·6, 1·6 to 1·9, 1·9 to 2·2, 2·2 to 2·5, and 2·5 upwards, with an approximate mean value for all districts of fully 1·9 per 1000. For males, the limiting rates per 1000 were: under 1, 1·0 to 1·3, 1·3 to 1·6, 1·6 to 1·9, 1·9 to 2·2 and 2·2 upwards with an approximate mean value for all districts of 1·6 per 1000. This scale of grouping is one chosen quite arbitrarily. Two maps of the region, one for males and one for females, showing registration districts were prepared, and on these by a system of dots and oblique and crossed lines the registration districts with mortality rates falling within the limits of the respective grades were indicated. This made it possible to distinguish readily the districts in which the incidence was most in excess or in defect of the average. The relative distribution of mortality in the different registration districts as shown in the two maps for the separate sexes was studied in relation to their geological formation, altitude, proximity to rivers and certain other factors.

For convenience of description, the whole area to be investigated was divided into two sections:

1. The county of York, *i.e.*, the area in relation to the river Ouse and its tributaries.

2. The group of counties that lie in relation to and between the rivers Humber and Trent to the north and the Great Ouse to the south.

These two regions possess features which render them somewhat suitable for such an investigation as is proposed, as each presents a centrally placed low-lying alluvial area traversed by rivers, with considerable variations in altitude in the country around, and fairly extensive areas belonging to the different geological formations. Within the whole extent of each, there are therefore groups of registration districts which vary considerably in regard to the several factors mentioned above and which may be compared with one another in regard to cancer incidence.

Natural Configuration and Geology of the Region.

Before proceeding with the analysis of the cancer incidence, it may be advisable to give a brief, general account of the configuration and geological formation of each section. Yorkshire falls naturally into a central and two lateral areas. The central area is a broad belt, the Vale of York, running north and south, traversed by the slow-flowing river Ouse and the proximal parts of its tributaries, the Derwent, Swale, Ure, Nidd, Wharfe, Aire and Don. This area is all under 250 feet above sea-level and in the south, around the head of the Humber, resembles somewhat the Fens in character. Geologically, it is a belt of the soft sandstones and marls of the Trias but these are thickly covered, and for the most part concealed by alluvium and glacial drift, including extensive deposits of brick clays. To the east of the central, low-lying area, the land rises up into the great mass of Lias and Oolites forming the East Yorkshire Moors, which attain, at their highest point, a height exceeding 1000 feet above sea-level. To the south of these lies an extensive, elevated chalk area which forms the Yorkshire Wolds, rising to a height exceeding 500 feet above sea-level. The Moors to the north and the Wolds to the south are separated by the Vale of Pickering, which is traversed by the river Derwent. This valley, like the Vale of York, shows extensive alluvial deposits of clay, sand and gravel. South-east of the Wolds, the land is all under 250 feet above sea-level and has a solid chalk formation but this is thickly covered by glacial drift (sand and boulder clay). Passing westwards from the central plain, the land becomes gradually more elevated, rising at length into the Pennine Chain. This part of the county can be demarcated into narrow belts lying at heights above sea-level that increase from 250–500 feet to over 1500 feet. The main part of this western area is formed of carboniferous rocks, including the carboniferous limestone with numerous outliers of millstone grit rising up in high moorlands and fells which are traversed by valleys or dales containing the tributaries of the Ouse, *e.g.*, Swaledale, Nidderdale, etc. This elevated moorland region on the millstone grit (grits, sandstones and shales) forms a belt on the margin of the Yorkshire coal-field to the west of Sheffield and Halifax and extends from Keighley and beyond Leeds northward to near Leyburn and Richmond. The coal-field with the coal-measures of shales and sandstones extends from north of Leeds and Bradford to Sheffield in the south. Intervening between the Vale of York to the east and the coal-measures and millstone grit to the west is a narrow belt of magnesian limestone.

The second section of the area under investigation comprises the counties of Huntingdon, Cambridge, Lincoln, Nottingham, Stafford, Derby, Leicester, Northampton, Bedford, Buckingham and the western parts of Norfolk and Suffolk. This region includes the southern segment of the Great Eastern Plain and is in a large part of its extent under 250 feet above sea-level. To the west of the plain, the country becomes more elevated and forms the Northampton Uplands and the Midland Plateau which lie for the most part between 250 and 500 feet above sea-level but rise in some areas to a height exceeding this. The southern extremity of the Pennine Chain extends into Derbyshire and much of this county lies at a considerable altitude above sea-level. The central part of Lincolnshire is somewhat elevated, forming the Wolds and Heights which rise in some places to a height exceeding 250 feet.

As regards the arrangement of the geological formations in this region, this is comparatively simple and may be briefly described. In the first place, there is an area of considerable extent which encircles the Wash and is named the Fenland. This comprises the southern part of Lincolnshire, the north-eastern parts of Northamptonshire and Huntingdonshire, the northern part of Cambridgeshire (the Isle of Ely) and the western strip of Norfolk and Suffolk. The region embraces the lower parts of the drainage basins of the rivers Great Ouse, Nene, Welland and Witham. It is flat and low-lying and intersected by numerous water-courses. Against flooding by the sea and the rivers it is protected by extensive earthen embankments. The soil of the reclaimed Fens is deep and alluvial but differs somewhat from alluvium elsewhere, as in Yorkshire, in that it is almost everywhere very rich in humus. The Great Ouse forms roughly the limit of the Fenland to the south and east. To the east of this river, in Norfolk, Suffolk and the southern part of Cambridgeshire, lies an extensive cretaceous formation, principally of chalk but showing at its western limit a strip of gault and greensand. Passing westwards through Huntingdon, Northampton and Leicester, strata occur in sequence that belong to the Oolites, the Lias and the Keuper marls and sandstone. In the northern part of Lincolnshire is an extensive chalky area and passing westwards from this we find in succession areas with strata belonging to the Oolitic, Liassic, Triassic, Permian (Magnesian limestone), and Carboniferous formations. The last includes the Coal-measures, the Millstone Grit and Carboniferous limestone in Derbyshire. It must be borne in mind, however, that, though the superficial soil in an area may generally be described as deriving its characters from those of the underlying formations, these strata are frequently covered by glacial drift to an extent and depth which vary considerably in different districts. The nature of the surface soil in a district thus cannot always be gauged accurately from the solid geological formation shown in the maps. Over a considerable part of this region, there is a deposit of boulder clay which is so charged with chalk that it receives the name "chalky boulder clay." It is found in Norfolk as far north as the Wash, in Suffolk, in Cambridgeshire and as far south as Buckinghamshire. It is also described as occurring in East Staffordshire. Its margin runs eastwards through Leicestershire and in Lincolnshire it is found between the Wolds and the Heights. In its whole extent, it covers about 10,000 square miles. Though the deposit is characterised everywhere by the presence of chalk, the matrix of the chalky boulder clay is derived from the subjacent rocks, or from the soft deposits, generally clays, over which it has passed. Thus, in Huntingdonshire and Bedfordshire, the matrix is of Oxford clay; farther east local chalk and gault form the bulk of the deposit.

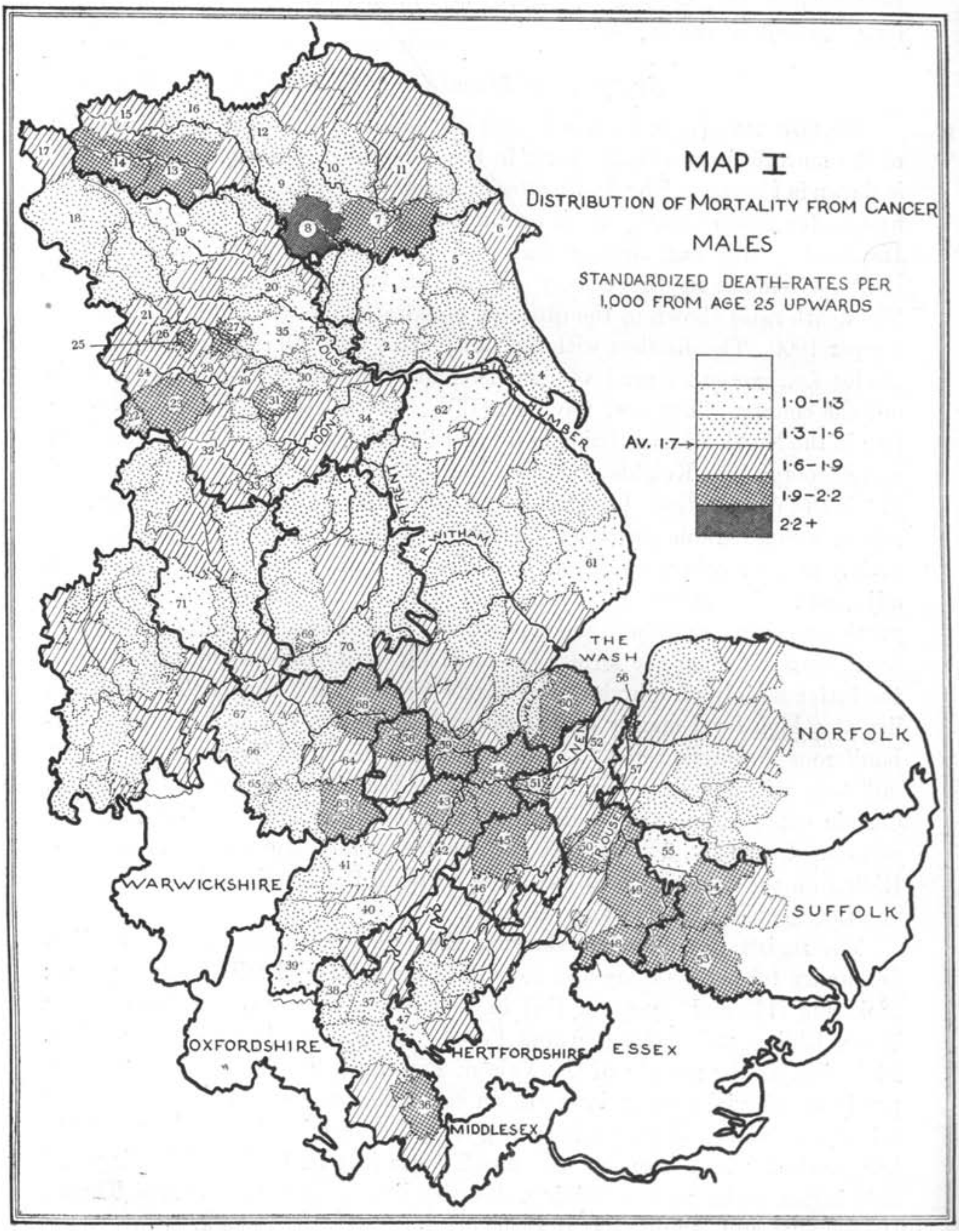
Analysis and Discussion of the Data.

We now come to the analysis and discussion of the relative distribution of the mortality-rates from cancer in the different registration districts, as it is shown in the maps. The death-rates in females in Yorkshire will be considered first as the female death-rate is on the average higher than the male and as Haviland (1875) has already described the distribution of the mortality amongst females in the county for an earlier decade, namely, 1851–60. The death-rates shown in the different registration districts vary from 1·2 to 2·9 per 1000. The districts with mortality-rates that fall into the two highest grades, *i.e.*, exceed 2·2 per 1000, are distributed somewhat irregularly throughout the county. They are: Leyburn (13)[1], Northallerton (12) and Helmsley (10) in the North Riding; Driffield (5) and Pocklington (1) in the East Riding; and Sedbergh (17), Keighley (21), Bradford (25), Dewsbury (28) and Wakefield (29) in the West Riding. Leyburn lies on carboniferous limestone and millstone grit at a considerable elevation; Northallerton is in the central plain and lies mainly on red marls, red sandstone and lias covered by glacial drift; Helmsley, adjacent to Northallerton but somewhat elevated, lies partly on alluvium and partly on oolites (limestone and sandstone). Driffield and Pocklington are two contiguous districts; the former lies on chalk partly covered by glacial drift, the latter mainly on alluvium but partly on red marls and chalk. Sedbergh lies at a high level mainly on the Silurian formation but partly on the carboniferous limestone series. Of the remaining districts, Keighley lies on the millstone grit, and Bradford, Dewsbury and Wakefield on the coal-measures. Certain other districts show death-rates that approximate to the limit just mentioned, namely, 2·2 per 1000. These are mainly aggregated in the West Riding on the coal-measures but some occur in the North and East Ridings on other geological formations (Map II).

The registration districts showing the two lowest grades of mortality, *i.e.*, under 1·6 per 1000 are also somewhat irregularly distributed. They are: Pickering (11) and Aysgarth (14) in the east and west respectively of the North Riding and Settle (18) and Pateley Bridge (19) in the West Riding. Pickering, at the margin of the Vale of Pickering, lies partly on oolitic and partly on alluvial strata; Aysgarth on carboniferous limestone and millstone grit and Pateley Bridge on millstone grit. Other districts that show a notably low mortality are: Wortley (32) and Thorne (34) in the West Riding and Bridlington (6) in the East Riding. Wortley lies on the coal-measures, Thorne on alluvium and Bridlington on glacial drift covering the chalk.

The topographical incidence of cancer in males in Yorkshire (Map I) will now be considered more briefly and compared with that described for females.

[1] The bracketed numbers refer to those given to the districts in the maps that follow.



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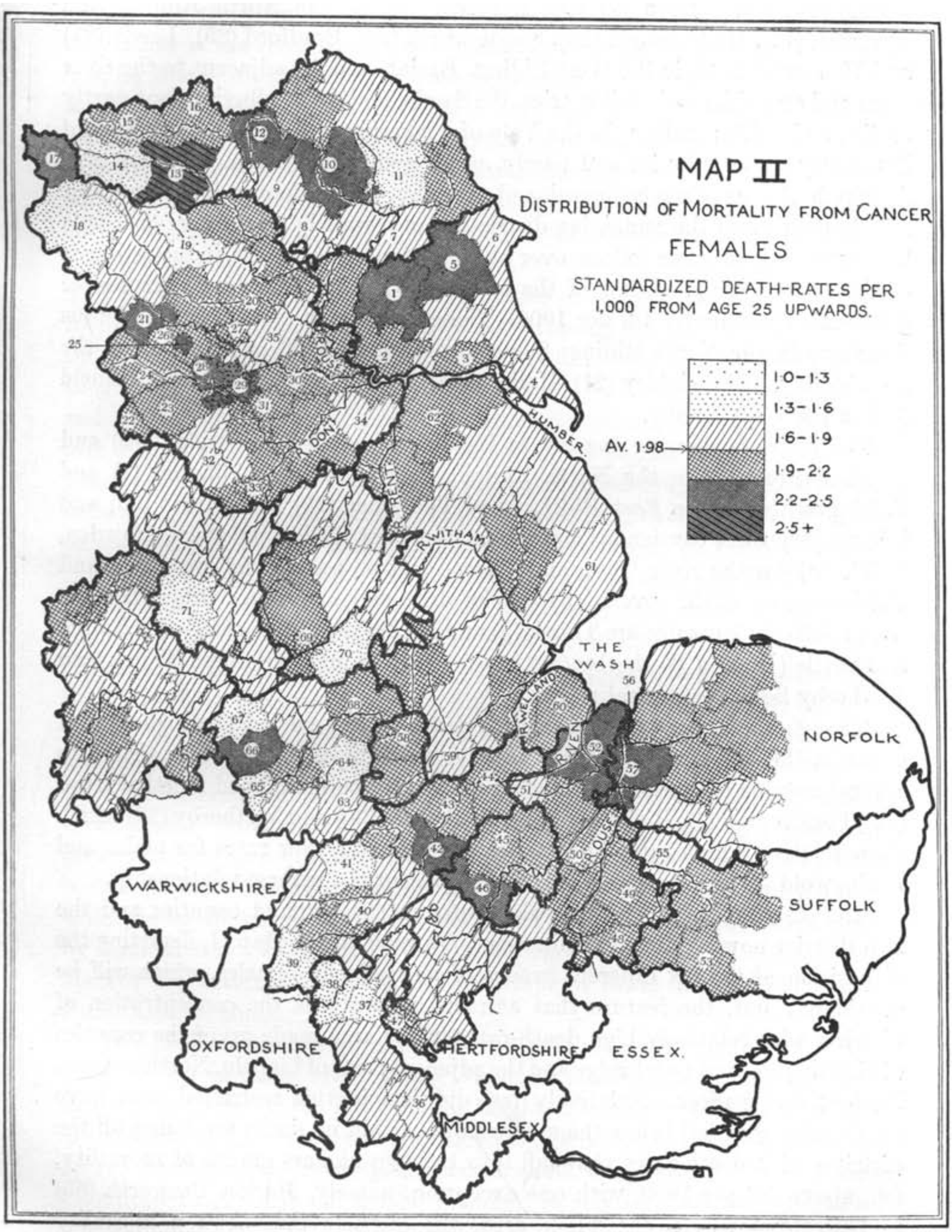

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The registration districts that show the two highest grades of mortality are: Easingwold (8), Malton (7) and Leyburn (13) in the North Riding; and Aysgarth (14), Huddersfield (23), Saddleworth (22), Bradford (25), Leeds (27) and Hemsworth (31) in the West Riding. Easingwold lies adjacent to the river Ouse and one of its main tributaries, the Swale, mainly on alluvium but partly on lias and oolite; Malton, in the Vale of Pickering, adjoins Easingwold and lies partly on an alluvial and partly on an oolitic formation. Leyburn and Aysgarth lie, as already mentioned, on the carboniferous limestone and millstone grit and the remaining districts named mainly on the coal-measures but extending to some extent over the millstone grit, in the industrial area of the West Riding. A few of the other districts in Yorkshire have cancer death-rates just under 1·9 per 1000. These are: Reeth (15) on carboniferous limestone in the North Riding; Sculcoates with Hull (3) on alluvium in the East Riding, and Keighley (21), Halifax (24), North Bierley (26) and Sheffield (33) in the West Riding.

The districts showing the lowest incidence are: Pateley Bridge (19) and Northallerton (12) in the North Riding; Howden (2), Pocklington (1) and Patrington (4) in the East Riding; and Tadcaster (35), Pontefract (30) and Thorne (34), three contiguous districts, in the West Riding. Of these, Howden, which adjoins the river Ouse, and Thorne rest on an alluvial formation and Patrington on chalk covered by glacial drift and alluvium. Other districts with relatively low rates are Thirsk (9) and Richmond (16) in the North Riding and Settle (18) and Wetherby (20) in the West Riding. Of these Thirsk and Wetherby lie in the central plain.

Though a number of districts with death-rates amongst the highest that occur in the one sex also show excessive mortalities in the other there are several notable exceptions. Amongst these may be mentioned Northallerton (12), Pocklington (1), Richmond (16), Pontefract (30) and Wetherby (20) which show relatively high rates for females and relatively low rates for males and Easingwold (8) and Aysgarth (14) which present the reverse relationship.

The distribution of the mortality-rates in the Midland counties and the Fen district now requires examination. On referring to Map II, depicting the disposition of the six different grades of mortality in females, which will be considered first, the feature that attracts attention is the concentration of districts with relatively high death-rates in the area made up of the counties of Huntingdon and Cambridge and the adjacent parts of Lincoln, Northampton, Norfolk and Suffolk. Relatively few districts in this restricted area have death-rates that fall below the average and within its limits are found all the districts with death-rates that fall into the two highest grades of mortality, *i.e.*, above 2·2 per 1000, with one exception, namely, Market Bosworth (66) in Leicestershire. In the whole area, the districts that show a mortality exceeding 2·2 per 1000 are: Wisbech (52) in Cambridgeshire; St Neots (46) in Huntingdonshire; King's Lynn (56) and Downham (57) in Norfolk; Thrapston (42) in Northamptonshire and Market Bosworth (66) in Leicester-

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shire. King's Lynn, Downham and Wisbech lie in the Fenland, the first two adjacent to the river Ouse and the last traversed by the Nene; Thrapston, in relation to the river Nene, on a formation of Oxford clay, lower oolite and lias; St Neots, on the Ouse, on valley gravel, boulder clay and Oxford clay; and Market Bosworth on red marls and sandstone. Amongst the other districts with a cancer mortality exceeding the average are some with death-rates just under 2·2 per 1000. These show some aggregation in the Fen district and that surrounding it but other districts with relatively high death-rates occur irregularly throughout the remainder of the region on dissimilar geological formations.

The districts with the two lowest grades of mortality, *i.e.*, under 1·6 per 1000, are distributed somewhat irregularly throughout the region. They are: Billesdon (64), Hinckley (65) and Ashby-de-la-Zouch (67) in Leicestershire; Bingham (70) in Nottinghamshire; Ashborne (71) in Derbyshire; Brackley (39) and Brixworth (41) in Northamptonshire and Buckingham (38) and Winslow (37) in Buckinghamshire. Of these, Billesdon lies on lias (clay); Hinckley and Bingham mainly on red marls; Ashbourne on red sandstone and carboniferous limestone; Ashby-de-la-Zouch on the coal-measures; Brackley and Brixworth on lias and oolite and Buckingham and Winslow largely on Oxford clay.

In males, the districts with death-rates that attain the highest grades, *i.e.*, above 1·9 per 1000, are: Ely (50), Whittlesey (51) Newmarket (49), and Linton (48) in Cambridgeshire; Huntingdon (45) in Huntingdonshire; Oakham (58) in Rutlandshire; King's Lynn (56) in Norfolk; Oundle (43) and Peterborough (44) in Northamptonshire; Sudbury (53) and Thingoe (54) in Suffolk; Holbeach (60) and Stamford (59) in Lincolnshire; Market Harborough (63) and Melton Mowbray (68) in Leicestershire; Nottingham (69) in Nottinghamshire; and Amersham (36) in Buckinghamshire. Some of these occur amongst those already enumerated as showing the highest mortality in females. The geological formations that are found in these districts have in some cases already been described. Amongst those not already mentioned are: Ely and Whittlesey which lie on alluvium; Linton on chalk and gault; Sudbury on chalk covered by boulder clay; Huntingdon on Oxford clay; Stamford on inferior oolite; Market Harborough and Melton Mowbray on lower and middle lias and Amersham on chalk.

The districts that show the two lowest grades of mortality, *i.e.*, under 1·3 per 1000, in males are: Spilsby (61) and Clandford Brigg (62) in Lincolnshire; Ashbourne (71) in Derbyshire; Leighton Buzzard (47) in Bedfordshire; Mildenhall (55) in Suffolk and Brackley (39), Brixworth (41), and Hardinstone (40) in Northamptonshire. Spilsby lies on gault, Kimeridge clay and alluvium; Clandford Brigg, adjacent to the Humber, largely on chalk but also to some extent on lias and oolites; Mildenhall on chalk and alluvium and Hardinstone on lias and lower oolite. In a few other districts in Lincolnshire, Norfolk and Staffordshire relatively low death-rates are found.

The general distribution of the districts with mortality-rates that exceed the average and those that show the extreme values has now been described for two regions that present a variety of physical features, and the question for discussion is, Has the varying incidence shown in these any relationship to the river system, the character of the soil or underlying geological formation, the elevation or levelness of site or other physical features?

According to Green (1917) the death-rate from cancer is low in districts that are comparatively flat or at most have undulating hills with houses built on their sides or summits, whereas the mortality is high in districts intersected with gulleys and valleys with houses in the hollows. In Haviland's view, the highest incidence should be found in low-lying districts with a deep alluvial or clay soil and traversed by or contiguous to fully-formed rivers liable to overflow their banks, and the lowest incidence in relatively elevated areas with hard rocks or in districts with permeable strata like oolite and chalk.

In Yorkshire comparatively little importance can be attached to the disposition or geological relationship of the districts with the extreme rates of mortality, either high or low, as these are in some cases of small extent or sparsely populated and the mortality-rates are consequently based on relatively small numbers of deaths. The districts in Yorkshire with death-rates above the average in females seem to show, however, a general tendency to a concentration on the coal-measures in the West Riding and to a less extent on the alluvial area in relation to the river Ouse. In males, however, no tendency is shown to a concentration of high mortality districts around the Ouse. In the Midland counties, including the Fenland, the districts with high mortality rates seem to show some aggregation in the Fens and the adjacent region and those with a lighter incidence in Staffordshire and Derbyshire. This is the general impression conveyed by a survey of the maps though registration districts with relatively high rates occur irregularly disposed on different formations throughout the region. Though the distribution in the Fen district and the Midland counties would seem to suggest that there is some reasonable basis for Haviland's view as to the local conditions that predispose to an excessive incidence of cancer, the disposition of the mortality-rates in Yorkshire for the two sexes does not lend much support to it.

With the object of eliminating the districts which might show extreme mortality-rates through being derived from small numbers of deaths occurring in sparsely populated areas, the registration districts were grouped together, (1) into those comprising the counties, (2) into those lying on the most important geological formations, disregarding county limits. This grouping for geological formation also gives in some measure for the whole region, a rough classification for varying altitude as alluvial soils are, and liassic (clay) soils are generally, low-lying; and millstone grit and carboniferous limestone somewhat elevated; oolitic formations may be elevated or low-lying, elevated in Yorkshire and low-lying in the Midland counties.

Taking Yorkshire as three counties and the districts from Norfolk and Suffolk as one county group, the data for 15 county groups in all were available.

Table I.

Showing the Standardised Death-rates per 1000 *from Cancer in Males and Females from age* 25 *upwards in Yorkshire and the Midland Counties of England.*

No. in Map	No. of Reg. District	Counties and Registration Districts	Males	Females
(1)	(2)	(3)	(4)	(5)
—	—	Yorkshire	1·754	2·070
—	516	York	1·526	1·947
1	517	Pocklington	1·188	2·311
2	518	Howden	1·433	1·954
—	519	Beverley	1·529	1·846
3	520	Sculcoates (and Hull)	1·844	2·125
4	522	Patrington	1·422	1·728
—	523	Skirlaugh	1·587	1·769
5	524	Driffield	1·551	2·492
6	525	Bridlington	1·645	1·617
	526	Scarborough	1·572	1·914
7	527	Malton	2·051	1·885
8	528	Easingwold	2·236	1·823
9	529	Thirsk	1·493	1·789
10	530	Helmsley	1·521	2·217
11	531	Pickering	1·730	1·361
—	532	Whitby	1·604	1·831
—	533	Guisborough	1·688	1·752
—	534	Middlesbrough	1·573	1·907
—	535	Stokesley	1·657	2·022
12	536	Northallerton	1·388	2·436
—	537	Bedale	1·763	1·797
13	538	Leyburn	1·969	2·957
14	539	Aysgarth	1·945	1·306
15	540	Reeth	1·814	1·896
16	541	Richmond	1·483	2·012
17	483	Sedbergh	1·763	2·226
18	484	Settle	1·471	1·367
—	485	Skipton	1·528	1·753
19	486	Pateley Bridge	1·111	1·190
—	487	Ripon	1·568	1·914
—	488	Great Ouseburn	1·719	1·968
—	489	Knaresborough	1·760	1·850
20	490	Wetherby	1·485	2·008
—	491	Wharfedale	1·611	1·978
21	492	Keighley	1·837	2·220
—	493	Todmorden	1·706	1·952
22	494	Saddleworth	2·113	2·049
23	495	Huddersfield	2·011	2·186
24	496	Halifax	1·885	2·111
25	497	Bradford	1·940	2·265
26	498	North Bierley	1·838	1·958
—	499	Hunslet	1·444	1·849
27	501	Leeds	1·931	2·128
28	502	Dewsbury	1·680	2·480
29	503	Wakefield	1·788	2·290
30	504	Pontefract	1·346	2·060
31	505	Hemsworth	1·901	2·155
—	506	Barnsley	1·529	2·073
32	507	Wortley	1·617	1·655
33	509	Sheffield	1·838	2·013
—	510	Rotherham	1·586	1·968
—	511	Doncaster	1·642	2·168
34	512	Thorne	1·356	1·622
—	513	Goole	1·813	1·967
—	514	Selby	1·575	2·089

No. in Map	No. of Reg. District	Counties and Registration Districts	Males	Females
(1)	(2)	(3)	(4)	(5)
35	515	Tadcaster	1·269	1·739
—	—	Buckinghamshire	1·690	1·762
36	140	Amersham	2·040	1·736
—	141	Eton	1·744	1·890
—	142	Wycombe	1·646	1·762
—	143	Aylesbury	1·300	1·869
37	144	Winslow	1·510	1·401
—	145	Newport Pagnell	1·830	1·688
38	146	Buckingham	1·515	1·465
—	—	Northamptonshire	1·704	1·959
39	156	Brackley	1·130	1·445
—	157	Towcester	1·528	2·073
—	158	Potterspury	1·604	1·799
40	159	Hardinstone	1·270	1·870
—	160	Northampton	1·722	1·999
—	161	Daventry	1·521	1·715
41	162	Brixworth	1·201	1·518
—	163	Wellingborough	1·724	1·853
—	164	Kettering	1·643	2·114
42	165	Thrapston	1·692	2·259
43	166	Oundle	1·989	2·086
44	167	Peterborough	2·023	2·040
—	—	Huntingdonshire	1·896	2·085
45	168	Huntingdon	2·059	1·909
—	169	St Ives	1·747	2·097
46	170	St Neots	1·859	2·280
—	—	Bedfordshire	1·676	1·856
—	171	Bedford	1·822	1·785
—	172	Biggleswade	1·863	1·855
—	173	Ampthill	1·508	1·882
47	175	Leighton Buzzard	1·149	1·996
—	176	Luton	1·668	1·878
—	—	Cambridgeshire	1·914	2·032
—	177	Caxton	1·867	1·753
—	178	Chesterton	1·847	1·962
—	179	Cambridge	1·887	1·904
48	180	Linton	2·051	1·966
49	181	Newmarket	2·089	2·117
50	182	Ely	2·097	2·094
—	183	North Witchford	1·738	2·164
51	184	Whittlesey	2·191	1·823
52	185	Wisbech	1·738	2·459
—	—	Suffolk (part of)	1·865	2·003
53	203	Sudbury	1·939	1·898
54	204	Thingoe	2·132	2·176
55	207	Mildenhall	1·275	1·848
—	208	Stow	1·632	1·912
—	—	Norfolk (part of)	1·668	2·063
—	232	Wayland	1·401	1·707
—	233	Mitford	1·863	2·053
—	234	Walsingham	1·722	2·026

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Table I (*contd.*).

No. in Map	No. of Reg. District	Counties and Registration Districts	Males	Females
(1)	(2)	(3)	(4)	(5)
		Norfolk (*contd.*)		
—	235	Docking	1·368	1·681
—	236	Freebridge	1·652	1·958
56	237	King's Lynn	2·106	2·800
57	238	Downham	1·717	2·429
—	239	Swaffham	1·431	2·114
—	240	Thetford	1·490	1·666
—	—	Rutlandshire	1·873	2·027
58	411	Oakham	1·928	2·002
—	412	Uppingham	1·795	2·059
—	—	Lincolnshire	1·538	1·927
59	413	Stamford	2·133	1·820
—	414	Bourne	1·658	1·878
—	415	Spalding	1·457	1·984
60	416	Holbeach	1·926	2·078
—	417	Boston	1·662	1·858
—	418	Sleaford	1·434	1·872
—	419	Grantham	1·692	1·952
—	420	Lincoln	1·529	1·829
—	421	Horncastle	1·402	1·992
61	422	Spilsby	1·178	1·826
—	423	Louth	1·436	1·606
—	424	Caistor	1·837	1·683
62	425	Clandford Brigg	1·137	1·921
—	426	Gainsborough	1·357	2·162
—	424*b*	Grimsby	1·704	2·105
—	—	Leicestershire	1·744	1·910
—	400	Lutterworth	1·532	1·651
63	401	MarketHarborough	2·074	1·740
64	402	Billesdon	1·632	1·509
—	403	Blaby	1·516	1·908
65	404	Hinckley	1·595	1·411
66	405	Market Bosworth	1·530	2·446
67	406	Ashby-de-la-Zouch	1·402	1·505
—	407	Loughborough	1·641	1·824
—	408	Barrow-on-Soar	1·572	1·762
—	409	Leicester	1·894	2·062
68	410	Melton Mowbray	1·899	1·955
—	—	Nottinghamshire	1·669	1·960
—	427	East Retford	1·477	1·730

No. in Map	No. of Reg. District	Counties and Registration Districts	Males	Females
(1)	(2)	(3)	(4)	(5)
		Nottinghamshire (*contd.*)		
—	428	Worksop	1·564	1·871
—	429	Mansfield	1·452	1·938
—	430	Basford	1·587	1·939
69	431	Nottingham	1·908	2·086
—	432	Southwell	1·680	1·676
—	433	Newark	1·530	1·822
70	434	Bingham	1·521	1·494
—	—	Derbyshire	1·522	1·856
—	435	Shardlow	1·621	1·818
—	436	Derby	1·618	1·975
—	437	Belper	1·396	1·892
71	438	Ashbourne	1·252	1·419
—	439	Chesterfield	1·493	1·852
—	440	Bakewell	1·655	1·727
—	441	Chapel-en-le-Frith	1·496	1·716
—	442*a*	Glossop	1·475	2·153
—	442*b*	Hayfield	1·446	1·794
—	—	Staffordshire	1·637	1·862
—	359	Stafford	1·509	1·683
—	360	Stone	1·775	1·660
—	361	Newcastle-u.-Lyme	1·842	1·949
—	362	Wolstanton	1·558	1·901
—	363	Stoke-upon-Trent	1·812	1·992
—	364	Leek	1·407	1·950
—	365	Cheadle	1·409	1·758
—	366	Uttoxter	1·433	1·796
—	367	Burton-on-Trent	1·669	1·672
—	368	Tamworth	1·691	2·091
—	369	Lichfield	1·651	1·701
—	370	Cannock	1·422	1·957
—	371	Wolverhampton	1·590	1·890
—	372	Walsall	1·592	1·888
—	373	West Bromwich	1·850	1·745
—	374	Dudley	1·502	1·806
—	375	Stourbridge	1·552	1·899
—	—	Parts of Norfolk and Suffolk together	1·733	2·040
—	—	Total Area	1·700	1·984

The death-rates for these are shown in Table I. In males, the highest mortality occurs in Cambridgeshire, Huntingdonshire and Rutlandshire, as is generally known from the Annual Reports of the Registrar-General, the lowest in Lincolnshire and Derbyshire. In females, though the death-rates in Cambridgeshire and Huntingdonshire are still amongst the highest that are found, the mortality in the East, and West Ridings of Yorkshire is practically equivalent. The lowest mortality-rate is found in Buckinghamshire, but the rates in Bedfordshire, Derbyshire and Staffordshire are also relatively low.

In grouping the registration districts according to their geological formation, a rough classification into 12 types was made. These include the fen, alluvium (excluding fen), coal-measures, millstone grit, carboniferous lime-

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stone, etc. The names of the strata distinguished and the corresponding death-rates are given in Table II. The table shows that in females the mortality-rates are highest and practically equivalent on fen, alluvium, coal-measures and millstone grit and lowest on carboniferous limestone. On chalk, the death-rate is just under the average for all the strata. In males, the highest mortality-rates are found on the fen and the coal-measures, and the lowest on magnesian limestone and carboniferous limestone. Though differences in mortality from cancer thus occur on the different strata, they are not very pronounced and appear of doubtful significance. The best measure of testing this seemed to be to estimate the probability that deviations as great or greater than those found might occur through chance. For the 12 groups in each sex, the actual numbers of deaths corrected for age distribution and the numbers expected on the basis of the mortality for the whole area were calculated. From these figures the values of χ^2 were determined. For

Table II.

Showing the Standardised Death-rates from Cancer per 1000 *from age* 25 *upwards, on the Principal Geological Formations.*

Geological formation	Males	Females
1 Fen	1·800	2·160
2 Alluvium	1·718	2·072
3 Coal-measures	1·771	2·073
4 Millstone Grit	1·656	2·063
5 Chalk	1·659	1·893
6 Marls	1·672	1·921
7 Magnesian Limestone	1·533	1·921
8 Lias (clay)	1·671	1·903
9 Lower Greensand and Gault	1·655	1·891
10 Oxford and Kimeridge Clay	1·737	1·884
11 Oolite and Lias	1·645	1·860
12 Carboniferous Limestone	1·572	1·816
All Strata	1·700	1·984

males it was 6·27 and for females 11·54 which, for $n' = 12$, gives values of $P = 0{\cdot}85$ and $0{\cdot}41$ for the respective sexes. This indicates that out of 100 samples for each sex, in 85 cases in males and 41 cases in females as wide deviations as those found might occur fortuitously and that consequently the deviations from the expected on different soils or formations in the whole region examined are not sufficiently great to indicate any definite association between particular geological strata and excessive or defective mortality from cancer.

It seemed to be of interest to determine whether the cancer incidence in the region where it was most common, namely, in the counties of Huntingdonshire and Cambridgeshire, showed any notable variation in the administrative districts. The standardised death-rates were calculated for the several administrative areas that comprise some of the registration districts already named. The death-rates were taken as a percentage of the death-rates in the corresponding registration districts. What appeared to be striking differences, *i.e.*, as high as 50 per cent., were found in the areas that comprise some districts; in other districts the death-rates in the component areas were practically identical. The figures are so small that it is quite uncertain whether these differences have any significance. On similar but even more unreliable data, however, from still smaller districts, many inferences have already been drawn and published as to the local conditions which predispose to an excessive incidence of cancer.

The relationship of cancer prevalence to local conditions may be discussed from another standpoint. If the physical features pertaining to a place have an important influence in predisposing to or in preventing cancer, then it might be expected that, other things being equal:

1. Districts with a high cancer death-rate in females would on the average have a definite tendency to an excessive mortality in males.

2. The relative distribution of mortality in the area under investigation at one period of time would be somewhat closely analogous to that at a subsequent period.

A comparison of the two maps for males and females seemed to indicate that the association between the relative magnitudes of the death-rates in the two sexes in the corresponding districts was not very marked either in Yorkshire or the Midland Counties, unless in that region of the latter around Cambridgeshire. A relatively high death-rate in females has been seen to be associated in a number of districts with a relatively low death-rate in males and *vice versa*. To ascertain more precisely the degree of association between the mortality-rates in males and females in corresponding districts throughout the area, the coefficient of correlation was calculated. It was found to be $+ 0{\cdot}169 \pm {\cdot}088$ in Yorkshire, $+ 0{\cdot}295 \pm {\cdot}060$ in the Midland Counties and $+ 0{\cdot}257 \pm {\cdot}049$ in the total area. This last coefficient is statistically significant and there thus appears to be in the data for the whole area a tendency for a district that has a high mortality in one sex to have a high mortality in the other. The association is only present to a significant degree in the districts of the Midland Counties; however, it cannot be said to be sensible in the districts of Yorkshire. For the whole region, it does not appear to be so pronounced as might be expected if the local features were very important in determining the incidence of cancer, even making some allowance for the reduction in the correlation that must occur as a result of the organs specially liable to attack in the two sexes not being identical.

With regard to the second point, Haviland gives in his map of England and Wales the mortality-rates for cancer in females in the registration districts of Yorkshire for the decade 1851–60. The distribution of these mortality-rates is very different from that shown in females for the decade 1911–20. As Haviland had used crude death-rates for the earlier period, the standardised rates from age 25 upwards were calculated, but though the relative magnitudes of the mortality-rates as shown by this measure were altered in a few cases, the general topographical distribution remained essentially as described by him. A few of the registration districts given in the data for 1911–20 did not exist in the earlier decade and probably some fairly considerable changes in the limits of others have taken place in the interval that elapsed between the two decades; moreover, there was no transfer of deaths in the earlier decade. The districts that existed at the two periods under the same names and thus may be considered as to some extent comparable, however, numbered 54. The correlation coefficient between the standardised death-rates in corresponding districts in the two decades was calculated and was found to be $-\cdot 034 \pm \cdot 092$. There is thus no association present between the magnitudes of the mortalities in the corresponding districts in the two decades. The coefficient of correlation between the death-rates in females in the corresponding districts in the decennia 1851–60 and 1901–10, in neither of which any transfer of deaths took place, was $+ 0\cdot 123 \pm \cdot 090$ and that between the death-rates in the decennia 1901–10 and 1911–20, $+ 0\cdot 194 \pm \cdot 088$. These last two coefficients also indicate that there is no significant association between the size of the death-rates in corresponding districts in the different decennia. The fact that such a definite change has taken place in the relative distribution of mortality from cancer in the registration districts in the interval of half a century is of considerable interest. It is doubtless partly due to the circumstance that the death-rates in many districts are based on small numbers and are consequently not very stable. Whatever may be the complete explanation of the change, it seems to be opposed to the view that peculiar local conditions are of great importance in determining the local incidence of the disease.

CONCLUSIONS.

In this paper, the topographical variations in the incidence of cancer as shown in the registration districts and groups of districts in Yorkshire and the Midland Counties of England, including the Fenland, and their relationship to variations in certain physical features such as character of soil and underlying geological formation, elevation of site, proximity to slow-flowing rivers liable to floods, etc. have been examined and discussed. From a general review of what has been found the following conclusions may be drawn:

1. The variations that occur in the mortality-rates for both sexes in the different registration districts appear to be considerable, but as some of the extreme values found are based on comparatively small numbers their significance cannot be regarded as certain. This applies to some of the relatively high and relatively low rates which have been noted in adjacent districts on similar geological strata in Yorkshire and to those that have been described as occurring in the administrative areas in the Fen region.

2. The districts with death-rates above the average seem to show in both sexes *some aggregation in the West Riding of Yorkshire on the coal-measures.* In females, some slight tendency is shown to a concentration of high mortality districts on the alluvium around the river Ouse, but no such tendency is present in males. In the Midland counties, the districts that show excessive mortality-rates in both sexes seem to show some aggregation in Huntingdonshire and Cambridgeshire. Though there is a suggestion that in the Fen district

some association exists between an excessive prevalence of cancer and an alluvial or clay soil adjacent to rivers, the disposition of the mortality-rates in Yorkshire cannot be said to lend much support to this view.

3. As the probability that deviations in mortality as great or greater than those shown on the different geological formations would occur in about 85 and 41 instances out of 100 similar samples in males and females respectively, it cannot be said that any definite association between incidence of cancer and geological formation has been established.

4. The correlation shown between the mortality-rates in males and females in corresponding districts is not so pronounced as might be expected if peculiar local physical features were very important in determining the prevalence of cancer.

5. The definite change that has taken place in the relative distribution of cancer mortality in females in the districts of Yorkshire after a lapse of half a century is also in support of the view that local physical features are not important as predisposing causes of the disease.

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