5-1-1937

Abdominal pain

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ABDOMINAL PAIN

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SENIOR THESIS

PRESENTED TO

THE COLLEGE OF MEDICINE,

UNIVERSITY OF NEBRASKA

OMAHA, 1937

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I

INTRODUCTION

Pain is probably the most common symptom which causes an individual to seek medical attention, and in abdominal disease it is perhaps the most important single symptom upon which diagnosis is based. An understanding, therefore, of the origin, nature, and localization of abdominal pain is of prime interest to the physician. When one turns, however, to consider the precise etiology, mechanisms, and interpretation of abdominal pain, he can not fail to be impressed by the great number of theoretical and obscure considerations which still remain unsolved. Clinicians, physiologists, and neurologists, despite the long period of investigation concerning abdominal pain, are still seeking, and with ever renewed diligence, to come to an understanding which will be nearer the truth and which will make interpretation of pain as a symptom of abdominal affections more accurate and practical.

Pain is a symptom which arises from involvement of the nervous system. Consequently, an understanding of pain depends upon a knowledge of the nervous mechanism participating in its reception, conduction, and appreciation. When the various nervous mechanisms for abdominal pain are considered, it appears that there are,

in general, three possibilities. First, stimulation of those nerve fibers which extend from the abdominal viscera to the central nervous system and thence to conscious centers might give rise to a pure visceral pain. Second, nerve fibers which run from the body wall surrounding the viscera might to stimulated by direct contact with diseased viscera and produce somatic pain, as they are known to do when stimulated by external stimuli. Third, it is conceivable that stimuli which arise from visceral organs and are conducted centralward by fibers from the viscera might in some way affect pain fibers from the abdominal soma and produce a referred pain. The consideration of abdominal pain mechanisms in this paper will be grouped under these three headings. The discussion will be limited principally to a consideration of pain mechanisms of the gastrointestinal tract and its accessory organs.

II

PURE VISCERAL PAIN

By pure visceral pain or splanchnic pain is meant pain which arises from an internal organ and is appreciated by the individual as having arisen internally just as a pure somatic pain is one arising as from a cut finger and appreciated as coming from that structure. Is there pure visceral pain? The answer to this question rests upon the demonstration of an afferent pathway for pain from the abdominal viscera to pain centers in the central nervous system and the proof that a pure visceral pain actually arises from the stimulation of this nervous pathway. Incidentally, also the existence of a referred pain mechanism depends in part on the existence of an afferent pathway for some type of visceral impulse even though the pain is not appreciated as arising from internal viscera.

(A) Afferent Visceral Pathway

While the early anatomists had a fair knowledge of the general pattern of nerves and ganglia related to the viscera, it was not until histoligical study of such nerves was begun that any real evidence as to visceral afferent fibers was gained. Bell, in 1844, was probably one of the first to recognize that both sensory and motor

fibers are distributed to the viscera; he also proposed that the posterior roots of the cord contained only afferent sensory fibers and that the anterior roots contained only motor fibers. (3)

Remak, in 1838, noted certain large non-medullated nerve fibers arising from the posterior root ganglia and running in the white rami of the thoracic region. (68) The rami communicantes were recognized as the connecting link between the nerves to the viscera and the cerebrospinal nerves. In 1886 Gaskell confirmed Remak's observations, finding such fibers in the white rami from 2 thoracic to 2 lumbar segments inclusive (in dogs). Gaskell, however, recognized that the white rami and nerves to the viscera were composed mainly of medullated fibers which are mostly small. He named the nerves which pass from the spinal nerve roots through the white rami to the abdominal viscera the visceral splanchnic nerves. Although he recognized that the splanchnic nerves must contain both sensory and motor fibers, it was not possible for him to separate these in their peripheral distribution, but he thought it probable that the afferent visceral fibers ran together with the efferent fibers in the same nerves to reach the respective fiscera. (21)

In 1893, Edgeworth found some large medullated fibers

coming off from 1 dorsal to 3 lumbar roots inclusive and running through splanchnic nerves via the white rami and uninterrupted through the ganglia of the splanchnic nerves, that is, the sympathetic ganglia. He judged these fibers to be sensory, because he could trace them centrally into the posterior roots, and peripherally, he found them connected with the Pacinian corpuscles in the mesentery. (20)

With the evidence at hand, and with additional information gained by his own experiments, Langley, about 1900, concluded that afferent visceral fibers reach the abdominal viscera through the white rami, the pelvic splanchnics and the vagi. He stated that these fibers could not be said to be of any one size since in the white rami, for example, medium and large medullated fibers as well as fine medullated and non-medullated fibers are found. By much more definite proof than Gaskell, Langley demonstrated that the medullated afferent fibers which pass in through the white rami to the posterior roots have their cells of origin in the posterior root ganglia and that the distribution of the afferent visceral fibers of the several white rami to the viscera corresponds very nearly to the efferent distribution. The number of visceral afferent fibers was found to be small in comparison to the number of the efferent visceral fibers. (43),(44) Warrington and Griffiths, in 1904, gave even more proof

of the cells of origin of the visceral afferent fibers being in the spinal ganglia. (86)

Coming down to more recent times, a summary of the most generally accepted conclusions regarding the neuroanatomy of the visceral afferent system in man at the present day may be given. Anatomically the visceral afferent system is closely associated with and distributed through the autonomic nervous system. But the autonomic system is restricted to efferent distribution only, and there is no acceptable proof that histologically or functionally the afferent visceral fibers are a part of the autonomic nervous system. Therefore, the term sensory sympathetics for the visceral afferent fibers is unsatisfactory and misleading. (67)

On the other hand, the afferent visceral fibers cannot be distinguished from the somatic afferent fibers of deep sensibility and protopathic sensibility, and their cells of origin are in the dorsal root ganglia or homologous cranial nerve ganglia. (64) Hence, they are considered as an integral part of these two divisions of the afferent nerve supply of the body. (24),(29),(41),(30)

The large myelinated fibers to the viscera correspond to the fibers of deep sensibility and are mostly connected with the Pacinian bodies found especially in the

base of the mesenteries. (64),(29) Relatively little else is known about the terminations of the finer myelinated and non-myelinated fibers to the viscera. Apparently, they end simply in relation to the smooth muscle fibers and vessels, epithelium and peritoneum of the viscera.

As the afferent visceral fibers from the abdomen are traced centralward various paths of enterance into the central nervous system are found. (1.) The vagi contain afferent fibers, but the distribution of them to the abdominal viscera is indefinite. Apparently some fibers go to the lower esophagus and stomach while below this organ there are very few afferent fibers, but possible some go to the small intestine and descending colon. The vagal afferent fibers have their cells of origin in the ganglion nodosum and the central axons terminate in the nucleus solitarius. (67),(89) It has been shown quite definitely, however, that although the afferent vagal fibers do have to do with certain visceral reflexes, e.g. nausea, they are not known to carry any definite pain sensations. (89),(17) (2.) No white rami exist in the sacral division of the cord, but general visceral afferent fibers do pass out in visceral (nervi erigentes or pelvic nerves) and pudendal nerves of 2,3, and 4 sacral nerves. The cells of origin are in the corresponding ganglia. (89) (3) White rami, all of which contain visceral afferent fibers, are

found from the first thoracic to the second,third or fourth lumbar segments. Most of the abdominal viscera receive visceral afferent fibers from T5 or 6 to L2,3, or 4 through the white rami.(89),(65),(23) Bundles of these fibers from T5 or 6 to and including T9 make up part of the greater splanchnic nerves. The minor splanchnics receive fibers from T9-12. Because of the overlapping and difficulty in tracing of the afferent visceral fibers, the definite anatomical knowledge of the segments supplying afferent fibers to the respective organs is lacking. However, largely from the work of Head (28) on referred pain and other clinical observations the following spinal segments are generally accepted as being related to the viscera listed: pericardium, central tendon of the diaphragm, hepatic ligaments and liver capsule,C4; heart,T1-T5 (mostly on left side,may spread as low as T7); lungs,T1-T5: stomach, T6-T9; small intestine and greater portion of large intestine,T8-T12; appendix T11-L1; sigmoid, colon, L1-L2; rectum, S2-S4; liver, gallbladder and pancreas, T6-T9; spleen T6-T8 (left side); borders of diaphragm, T6-T12; (67)

There is some controversy as to whether the visceral afferent fibers related to the white rami have synapses in the sympathetic ganglia through which they

course in reaching the viscera, but Langley,(44), Ranson (64), and Kuntz (41) are all fairly well convinced that there is no real evidence for such connections. Many have questioned whether some of the visceral afferent fibers after they have reached the spinal roots from the white rami might not enter the spinal cord through the anterior roots. Recently Davis,(17) by a rather complete survey of the literature on this question and his own experiments, comes to the conclusion that impulses (especially painful visceral) enter the central nervous system by way of the posterior roots only. The cells of origin of the afferent visceral fibers related to the white rami and, also, the sacral group are located in the dorsal root ganglia.(41) The central axons of the visceral afferent fibers enter the cord in the posterior roots, but their intraspinal course is difficult to ascertain, and the admission is made by Grinker (24) that their course is not definitely known.

In the first place, probably the majority of the afferent visceral fibers are concerned with various spinal reflexes and never reach conscious centers. The great difficulty of separating these fibers from those that might ascend to conscious centers is obvious.

Apparently the visceral afferent fibers which mediate pain enter the cord mainly through the lateral

division of the posterior roots. The cell column in the cord which marks the first synapse of the visceral fibers is not well circumscribed. The cells may be more or less diffused in the basal region of the dorsal horn. The nucleus dorsalis (Clarke's column) appears to occupy the logical position for this purpose, but this column is regarded as being somatic receptive for deep sensibility. (67) Ranson and Billingsley(64) have presented evidence showing that pain fibers in general are unmyelinated, enter the lateral division of the dorsal roots, synapse immediately upon entrance into the cord and neurons of the second order run in the lateral spinothalamic tract. It would seem that visceral afferent impulses are transmitted within the cord by short fibers with many relays and synapses having a juxtragriseal position. (67),(16) According to Head (29) all pain fibers ascend in the same path in the cord. There is evidence to indicate that visceral afferent fibers for pain do not ascend beyond the thalmus in great numbers.(6)

(B) The Adequate Stimulus for Pure Visceral Pain

Having offered evidence that there is an afferent visceral nerve supply the next consideration will be that of the actual sensitiveness of visceral structures, themselves, especially to pain. Rather naturally much of

the information in this regard has come through observations and deductions of clinical workers mostly on human subjects who are able to give expression to painful sensations.

The fact that the internal organs are not sensitive as compared to the external surface of the body must have impressed some individuals since early times. Haller, in 1752, after various observations and experiments expressed the opinion that the stomach, intestine, liver and certain other abdominal viscera were insensitive to various mechanical stimuli such as the point of a scalpel as well as to ulcers and stones. (25) Bichat in 1812 and Budge in 1862 made some similar observations. Weber found the colon insensitive to a hot iron. (77) Beaumont, in 1833, noted the pains which accompanied spasmodic contractions of the pylorus upon the thermometer introduced into the stomach of St. Martin. (2) Head in 1893 stated that the stomach, intestines, and liver were insensitive to touch, cutting and pinching. (28) Sherrington, 1900, likewise believed that variously applied mechanical, thermal, and chemical stimuli produced no pain or signs of pain. (77)

As abdominal operations became more common and especially with the advent of colostomy these facts became more or less common knowledge. Lennander, after rather

extensive observations in 1907, stated that the protruding colostomy loop was insensitive to cutting, crushing, pricking or burning. He found the rest of the intestines, liver, and gall-bladder likewise devoid of sensibility to electrical, thermal and mechanical stimuli.(46)

So striking was this insensibility of the viscera to the various stimuli mentioned to many of the early observers that some of them were led to believe that the viscera themselves whether normal or diseased were absolutely insensitive to any type of stimuli and were not appreciative of pain. But they could not deny that under certain conditions the viscera were actually the cause of pain, and some explanation had to be offered.

Thus Lange, in 1875, Hilton in 1879, and Mackenzie in 1912 and others explained abdominal pain as a referred type of pain entirely. (42),(33),(49) That is, as Mackenzie explained it, while the viscera were supplied with afferent fibers, these fibers did not carry pain impulses nor give rise to visceral pain, but in the cord impulses from these fibers might stimulate somatic sensory pain fibers and give a referred or reflex pain. (49) Lennander, on the other hand, said that there were no afferent visceral pain fibers and that all abdominal pain was due to a direct stimulation of pain fibers of the cerebrospinal nerves, especially those at the base of the

mesenteries and parietal peritoneum. (see in more detail p. 83). Even the colic pains of bowel obstruction he attributed entirely to a stretching of the mesenteries and consequent stimulation of somatic pain fibers. (46)

Some workers, however, were not entirely satisfied with the above explanations and were aware of the necessity of accounting for certain sensations which quite definitely arose from the visceral organs themselves even though many organs were insensitive to cutting, pinching, etc. Thus Ross in his important work of 1887 although he laid great emphasis on the referred type of pain from the viscera, still made it quite clear that he believed the various organs themselves were capable of appreciating pain and this he named splanchnic (pure visceral) pain. As an example he gave pain over the stomach in dyspepsia, the pain being of splanchnic origin conducted by splanchnic fibers. (72) Similarly Head in 1893 distinguished the splanchnic type of pain as apart from referred pain. He described the pain as frequently felt in the organ itself and as "dull", "heavy", wearing", and not "sharp", "aching", "stabbing" like the referred pain. He stated that only stimuli which were tearing or rending in character, in fact pressure stimuli, seem to act on the viscera to give this type of pain. This

splanchnic pain in certain intestinal conditions was diffuse and ill-defined with no cutaneous tenderness and not referred. He described it as a "rolling", "gripping", "doubling up pain". The production of splanchnic pain only by pressure stimuli and the poor power to localize it he attributed to the fact that in the evolutionary development of the internal organs no opportunity or necessity for the development of a higher or finer sensibility had arisen. (28)

In later studies (1920) on the entire sensory system of the body Head divided all sensibility into: (a) epicritic sense of tactile discrimination of points and finer grades of temperature limited to the skin and of recent evolutionary development, (b) protopathic sense of superficial pain and extremes of heat and cold distributed throughout the body and an older protective sense giving prompt, poorly localized widespread and reflex responses and (c) deep sensibility, the muscle and joint sense of pressure, position, movement, and pain on excessive pressure. Pacinian bodies are associated with this system.

Head thought that probably the viscera had a poorly developed protopathic and deep sensibility. Normally the only visceral responses are a sense of movement of the organs at times and a certain affective sense of well being. But under certain conditions of stimulation by certain

noxious stimuli the high threshold of the protopathic and deep sensibility sense of the viscera is overcome and the pain mechanism which is normally inhibited comes into play and promptly there is a wide-spread, poorly localized pain reaction with protective reflexes and a strong affective reaction of ill-being accompanying. Thus Head conceived of the adequate stimulus for visceral pain and of the sensibility of the viscera as being an integral part of the sensory system of the entire body. (29)

Sherrington, another eminent neurologist, had ideas corresponding quite closely to those of Head. Sherrington recognized that the adequate stimulus for the afferent nerves of the hollow viscera was distensile in nature. He included hunger pains as possibly being due to tension on the stomach wall. Sherrington's classification of the afferent division of the nervous system was somewhat different than that of Head. He named the nerve supply to the viscera interoceptive; that to the surface of the body, exteroceptive. Normally the interoceptive system contributed sensory impressions which did not reach consciousness (common sensation and spinal reflexes), but when visceral sensations became strong, the fibers which ordinarily were involved in common sensation mediated pain. The high resistence of

the central paths for visceral pain was overcome and a protective type of reaction with pain, affective displeasure, and a "spread" of reactions occurred. (77),(78)

Head's and Sherrington's work still stands as essentially correct in neurological circles. (30),(89) But it remained for a clinician, Hurst, in 1911 to demonstrate beyond a doubt to the medical world in general that the viscera were not absolutely insensible and that pain in them could be produced by a certain adequate stimulus. Credit must also go to Neumann, 1910-11 and Kast and Meltzer, 1909. (17) Hurst confirmed again that from the upper esophagus to the inner end of the anal canal the gut was insensitive to heat and cold and that HCl or organic acid in abnormal strengths had no effect. The only adequate stimulus for the production of true visceral pain is increased tension. To quote Hurst, "abnormal tension on the muscle fibers and perhaps, also, the connective tissue fibers of the muscular coat are probably the only adequate stimulus for the production of pain in the stomach as well as of pain in all other hollow viscera". If intragastric pressure, for example, is increased rapidly or beyond a certain degree a sense of fullness which is merely uncomfortable is replaced by actual pain. He believed that intestinal colic as

another example was a visceral pain due to exaggerated peristalsis vaguely localized in the center of the abdomen. (35)

It is interesting to note that although as late as 1920, Mackenzie still clung to his theory that all visceral pain was referred, finally in 1922 he acknowledged that there was probably a pure visceral pain in connection with certain obstructive lesions of the gut where increased tension comes into play. (74)

Finally, to quote from Morley, 1931, (51) as an example of the generally accepted belief today, he says, "I am firmly convinced that true visceral pain exists, and that as Hurst has pointed out, it is usually the result of abnormal tension on the splanchnic nerve endings in the muscular walls of the hollow viscera. It is in no sense referred to the superficial structures of the abdominal wall, and is a deep-seated central pain, not accurately localized. When pure visceral pain occurs, as in early intestinal obstruction, or in the early hours of an attack of acute obstructive appendicitis it is entirely unassociated with any tenderness, superficial or deep, or with any reflex muscular rigidity of the abdominal wall."

The question has come up from time to time as to whether or not inflammation and disease of the viscera

alter the adequate stimulus for visceral pain. Undoubtedly in inflammatory lesions and disease the viscera are more susceptible and sensitive to the usually adequate stimulus for splanchnic pain. It is a controversial point, however, as to whether or not certain lesions of the viscera render them sensitive to stimuli other than those of tension. Lennander, Hurst in 1911, Mackenzie, Morley and others have said that whether normal or inflamed, ulcerated, or infected the only adequate stimulus for visceral pain is increased tension in the viscus. Thus Lennander cited the fact that the loop of a colostomy became infected in a few days but that it was still insensitive to cutting, thermal and chemical stimuli. By observations at operation he concluded the same to be true in inflammations of the intestines and gall-bladder, a gangrenous loop of bowel, etc. Mackenzie confirmed these observations. Morley, in 1931, claimed that the whole gastro-intestinal tract even when inflamed, was insensitive to direct mechanical stimuli. (51),(46),(49) For example, in two crucial experiments he found that ulcers which showed tenderness on palpation previous to operation were absolutely insensitive both to digital pinching and squeezing of the ulcer at the time of operation under local novocain infiltration of the abdominal wall.

Some men on the other hand such as Hertzler, have contended that it is only when the peritoneal surface of the viscus becomes inflamed that the sensitiveness becomes so heightened that it is painful to contact. As evidence Hertzler found that inflammatory adhesions when separated caused acute pain, the clamping of inflamed gut caused pain as did packing of an inflamed area.(31)

Hurst, in 1929, altered his original contention of 1911 that tension was the only adequate stimulus for visceral pain because of the demonstration in recent years by radiological studies that the localized tenderness in certain visceral conditions such as peptic ulcer, appendicitis, and cholecystitis is directly over the lesion. Also the shifting of the point of tenderness with the alteration of the position of the lesion by palpation and by change of posture convinced Hurst that when the subserosa of the visceral peritoneum of an organ became inflamed that a localized spontaneous continuous pain and tenderness resulted.(36)

Kinsella expressed a very similar opinion in 1928 except that he believed it was the local tissue congestion at the site of the lesion which was the adequate stimulus.(38) Both Hurst and Kinsella, it must be remembered, still believe that tension is also an adequate stimulus.

(C) Localization of Visceral Pain

As has been stated, visceral pain is characteristically poorly localized; nevertheless, it is in accord with both neurological and clinical evidence that there is, in general, a certain degree of localization of splanchnic pain. In direct contrast to somatic pain, pure visceral pain is perceived as being deep within and in the general position where the organ producing the pain was located embrologically. Thus, splanchnic pain of the esophagus, stomach, and intestines are localized as being in or near the mid-line since the gut developmentally is a mid-line structure. Likewise, the biliary system, pancreas, and appendix are derivatives of the gut, and, therefore, the pain from them also, is near the mid-line. On the other hand the upper genito-urinary system develops laterally and so its pain is to one side or the other. Furthermore, the splanchnic pain of structures most caudad embrologically are localized as being higher than structures more caudad.

As a general rule, it may be said that the pure visceral pain of the esophagus is felt in the region of the episternal notch, the stomach, duodenum pancreas and biliary system to the upper epigastrium, the small intestine, appendix and caecum to the lower epigastrium and umbilicus, the large intestine to the

hypogastrium and umbilicus, the kidney to the loin, ureter to the groin, and bladder to the suprapubic region in the mid-line.(29),(49),(56). Any attempt to localize splanchnic pain more definitely than this is not usually possible or accurate. Bruning ascribed the pure visceral pain arising from the small intestine asbeing localized in the superior mesenteric ganglion, while visceral pain originating in the colon were said to be localized in the inferior mesenteric ganglion. There is no physiological evidence for such a supposition.(51)

Hurst and Kinsella. Ryle and others have expressed the belief that in certain inflammatory lesions of a viscus there may be an accurately localized pain and tenderness in addition to the poorly localized pain.(38), (38),(74) As will be shown later, there is considerable controversy as to whether or not these actually are pure visceral phenomena and they may be omitted from the immediate discussion.

(D) Occurrence of Pure Visceral Pain

The next consideration is that of the diseases and organs especially of the gastrointestinal tract in which splanchnic pain is found. In many instances this visceral pain is associated with and perhaps even greatly dominated by the so-called somatic or referred type of pain as well as hyperesthesia and rigidity of somatic

tissues. Although it is difficult to separate and consider visceral pain apart from these other sensory manifestations, still something is to be gained in the clearer understanding of abdominal pain by considering only the pure visceral pain of various organs. This will be attempted even at the expense of perhaps some repetition in the later consideration of other types of abdominal pain.

(1)Esophagus

Under certain conditions the lower portion of the esophagus may give rise to pure visceral pain appreciated as being deep in the upper epigastrium in or near the midline or subzyphoid. Consistent with the previous facts mentioned as to the adequate stimulus for splanchnic pain, it has been shown quite conclusively by numerous workers but more recently by Payne and Poulton,1927 (61) by experiments with inflations of balloons in the esophagus that tension produced pain. They considered that the pain was produced by a stretching of the wall which in turn produces a stretching and deformation of the nerve endings in the wall of the viscus. In addition, they observed that the pain from ballooning of the esophagus was often relieved by peristaltic contractions which overcame the stretching or by an alteration in the postural tone of the viscus which increased its capacity.

Peristaltic contractions which failed to overcome the stretching resulted in more intense pain; also, after a peristaltic wave, when the stretching of the relaxed esophagus was again resumed, pain occurred.

Such pain, therefore, might be caused by any number of conditions in which a stretching of the lower esophagus occurs. Foreign bodies, stricture tumors, etc. There is some radiographic evidence that in cardiospasm there is a dilitation of the lower esophagus which may be a factor in the pain.(61)

Another sensation related to the lower end of the esophagus is heart burn. While not having the typical characteristics of a pure visceral pain still heart burn is undoubtedly a type of splanchnic pain. Hurst (1929) (36) contended that the burning sensation that occurred in chronic dyspepsia and was often but not necessarily, associated with hyperchlorhydria such as in duodenal ulcer and was relieved by the taking of soda, was caused by muscle tension in the lower esophagus. He showed that fairly strong solutions of HCl were not felt in the lower end of the esophagus. Payne and Poulton in their experiments showed that continuous stretching of the esophagus gave rise to the burning pain characteristic of heart burn. (61) It may be concluded, therefore, that heart burn is produced when, for some reason, regurgitation of

chyme from the stomach into the lower esophagus occurs, the chyme whether with above normal or normal or even subnormal acidity is sufficient to stimulate the esoph- mucosa and to cause changes in esophageal tension which lead to pain and discomfort. (90). Some men, however, contend that in certain highly sensitive persons it is probably the irritating effect of the acid itself which causes the sensation. Apparently the relief afford- ed by alkalies is due to a quieting of peristalsis, as well as neutralizing the acid and creating a large amount of gas.(34)

(2) Cardia

The principal condition to be considered here is cardiospasm. On some occasions a cardiospasm may give rise to a deep seated high epigastric or subzyphoid pain which is undoubtedly splanchnic in character. Epigastric pain was a symptom of cardiospasm in about half of a series of 400 cases reported by Horsley (34), and when found the mechanism was apparently that of the increased tension of the sphincter muscle. Hurst contended that the tension was not due to an active contraction of the sphincter but rather that it was a failure of the muscle to relax(achlasia). (36) Sturtevant gave a rather complete review of the mechanism of cardiospasm and included among the causes numerous psychic, reflex, and endocrine factors.(81)

Alvarez stated that mild degrees of cardiospasm may be associated with gall-bladder disease. The mechanism may act either by a reflex stimulation of the cardia or by raising in some way the tone of the whole digestive tract; more rarely cardiospasm is due to ulcerations of the upper portion of the stomach which stimulate the afferent fibers in the neighborhood of the cardia which produces cardiospasm. (1)

(3) Stomach

(a) Hunger pains: While usually readily distinguishable from other types of pain in the deep epigastrium, hunger pains are a form of pure visceral pain of the stomach. The work of Carlson, in 1916, (12) and of Cannon and Washburn,1912, (8) has stood as authoratative on this subject. According to Carlson the only pains arising from the stomach under normal physiological conditions were the pangs of hunger. The sensation of hunger arose from stimulation of nerves in the submucosa or muscularis by a certain type of contraction of the stomach in a condition of emptiness or near emptiness. Cannon and Washburn showed that during the periods of emptiness when hunger was experienced the hunger pangs were synchronous with stomach contractions. They also gave evidence that the esophagus contracted and was involved in producing the hunger pains. Carlson reported cases of

neurasthenia with epigastric pain in which hypertonicity and contractility of the stomach was noted. He attributed the condition to a hyperexcitability of gastric hunger nerves so that normal contractions actually give rise to abnormally strong impulses or else the normal impulses from the stomach become exaggerated in consciousness through perverted attention.

(b) Dilitation of the stomach: Sudden and rapid dilitation of the stomach is known to produce a deep epigastric pain in some cases.(34) It has been shown that gastric distension by a balloon in dogs can produce all the morphological and functional disturbances observed in the usual clinical case of acute dilitation.(7) The fact that pain is not an outstanding symptom of acute dilitation and especially of a chronic dilitation may be explained on the basis of a lack of strong tone and contraction of the stomach. Nevertheless, there may be an epigastric discomfort in even an atonic dilitation, and in hypertonic dilitation often found in ulcer, pyloric obstruction, gastric adhesions, and gastroptosis.(34) The dilitation which occurs at times postoperatively is apparently due to a reflex inhibition of gastric tone and motility. (1)

(c) Gastritis: It is a matter of common experience as well as experiment that in acute gastritis, due to

chemical irritants or infection, may, cause a burning or dull pain in the epigastrium. Substances such as pepper, mustard, strongalcohol or acid (5-20 per cent HCl) etc., introduced into the stomach in sufficient concentration will cause a warm burning or pain sensation.(10),(40),(36) While the pain of gastritis is pure visceral in type,it is difficult to ascertain the exact mechanism of its production because of the variety of local and functional changes which occur. It would seem that the immediate injury to the mucosa and the nerve endings near the surface and the severe inflammatory reaction might produce the pain.(59). However, even such gastric "colic" or gripping pains as occur in acute indigestion, may be due to a hypertonus and pylorospasm, according to Ryle. (74) Carlson, on the other hand, reported an absence of gastric contractions and atony during an acute gastritis.(12) The exact mechanism of pain production, therefore, remains obscure.

(d)Dyspepsia: As a matter of fact dyspepsia does not as a rule produce actual pain, but rather epigastric discomfort; actual pain may occur,however. Whenever gastric symptoms are inconstant and intermittent and no evidence of a gastric lesion is present and when somatic reflex symptoms are absent, dyspepsia must be considered. The dyspepsias being considered here are the so-called functional disturbances in digestive activity of a motor,secretory or sensory nature.

The so-called primary dyspepsia is due to a functional abnormality of hyperacidity or subacidity or increased or decreased motor activity brought on by chronic irritation of the stomach.

The reflex dyspepsias are a very important group producing epigastric pain by a reflex alteration in gastric function from a primary lesion somewhere else in the body. However, as a general rule the nearer the lesion to the stomach the more likely gastric reflex symptoms are to occur. The appendix, gallbladder, colon, herniae, acute infections and intoxications, cardiac decompensation, renal and pelvic disorders as well as almost any other condition may be the offender.

There are a group of dyspepsias due to nervous gastric disorders the classification of which is difficult. One group includes the so-called gastric neuroses which in turn includes two types. The one tends to occur in persons with the gastric ulcer or hyposthenic diatheses who become neurasthenic. This usually is found in thin, run-down older women with poor stomach tone and relaxed abdominal wall and a tendancy to gastroptosis. A mild pyloric obstruction and the orthostatic hour-glass stomach may be present. There is as a rule a tendancy to hyposecretion, sluggish peristalsis and decreased gastric irritability. Pain is not a prominent symptom and the gastric stasis appears to have the most

to do with the symptoms. Relief on lying down is characteristic. The second type occurs in the person who becomes neurasthenic on top of a duodenal ulcer or hypersthenic diathesis. There is a tendancy to hyperperistalsis and hypersecretion and gastric hyperesthesia due to the exaggerated irritability of the nervous system. There is considerable evidence that the hyperacidity, or better hypersecretion, in itself does not produce the distress or pain but that the disturbed motor functions of the stomach are directly responsible. Occassionally there are hysterical gastric pains.

The other important type of nervous gastric pain is the gastric crisis of tabes characterized by very severe pains with sudden onset and cessation with perhaps mild dyspeptic symptoms in the intervals. While due to an organic lesion in the dorsal region of the paterior nerve roots and posterior columns of the cord, the precise mechanism of the pain is not known. It would appear to be more in the nature of a reflex dyspepsia. Not all the pain is pure visceral, since there may, also, be pains radiating around the chest and to the shoulder-tip.(14),(40),(51),(36)

(d) Pylorospasm and pyloric stenosis: The primary concern here is not the various causes of pyloric obstruction but the matter in which visceral pain is caused by this condition.

Elsesser, 1910,(1) by experiments on dogs in which

a partial pyloric stenosis was produced and then gastric function studied it was concluded that partial pyloric stenosis produces hypertonicity, hypermotility, and hyperperistalsis of the empty stomach, which phenomena were similar to those seen in the filled stomach of man with partial obstruction of the pylorus. The same motor activities were seen in the filled stomach as well, and consequently the inference was drawn that partial pyloric stenosis appeared to produce a hyperactivity independent of the presence of food in the stomach.

Carlson in a study of cases of congenital pyloric stenosis and of pylorospasm in infants demonstrated a condition of hypertonus and hypermotility of the entire stomach which was either primary or secondary to the excessive pyloric contraction. The latter he thought might be an expression of the general hypermotility. He stated that in the adult those gastric contractions would cause intense hunger pains, and it seemed probable that such pains were, also, experienced by the infant.(11)

Alvarez pointed out that the muscle fibers in the pyloric sphincter actually were more irritable than those of the pyloric antrum and gastrointestinal tract (this holds true also for the cardiac, ileocecal and anal sphincters).(1) As was mentioned in the case of the cardia Hurst emphasised that the failure of the pyloric sphincter to relax as being

the mechanism of a pylorospasm.

This data would indicate that a closed or partially closed pylorus increases tone, and motility of the stomach, and obviously the emptying time of the stomach is delayed. The combined effect of these two factors causes and increased intragastric tension, especially in the prepyloric antrum and the resultant stretching of the stomach wall serves as the adequate stimulus for the distress and pain. Peristalsis exaggerates the pain, but a more or less continuous pain may be present due to the persistent ballooning of the pyloric antrum.(36)

(e) Gastric and Duodenal Ulcer: Much has been written about the splanchnic pain of peptic ulcer and only some of the essential points can be touched upon here. Undoubtedly peptic ulcer is one of the commonest, if not the commonest, cause of "gastric" pain. The characteristic features of ulcer pain have been known for a long time, but perhaps the most classical description of the clinical features are to be found in Lord Moynihan's works. The pain of ulcer is described as "aching", "boring", or "gnawing" in character. It is a steady continuous pain as a rule, though it may be intermittent or spasmodic. The pure visceral pain of ulcer is localized more or less vaguely in the "pit of the stomach" or mid-epigastrium. Tenderness, rigidity or referred pain are, in the uncomplicated ulcer, usually not found accompany-

ing the splanchnic pain. The most striking features of the pain of ulcer are as follows. First, there is the interval between the time of eating and the onset of pain, the general rule being that the lower the ulcer in the gastro-duodenal tract the later the onset of pain following the taking of food. The period of relief after food and the onset of pain when peptic digestion begins to reach its height is characteristic. Second, there is a periodicity of the pain, that is, in an uncomplicated case the pain occurs in attacks of several days or weeks especially in fall and spring with intervals of freedom between such attacks. Third, there is relief of pain by food, alkalies, vomiting (principally in gastric ulcer) and hemorrhage. (52),(36)

The problem in the consideration of the ulcer pain mechanism is to give a satisfactory explaination of the above features, and as will be pointed out no explaination that completely fills the requirements has yet been forthcoming. The various exceptions to the rules of ulcer pain make any one mechanism not wholly consistent and the advocates of each theory must make certain concessions to the others.

(1) The Mechanical Theory:

To be consistent with the adequate stimulus for the production of pain of pure visceral type ulcer pain should be explained on the basis of increased tension on

the wall of a hollow viscus. Many workers including Hurst have supported such a mechanism as the cause of ulcer pain.(36)

In 1916, Ginsberg, and also Teinpowsky and Hamburger reported experiments showing the muscle tension factor in gastric ulcer pains.(22) Carlson, 1918,(13) by balloons and tambours showed the intermittent ulcer pain as being synchronous with gastric contractions and concluded that the pain was due to the tension of the muscle of the stomach wall and not due to any direct effect of stomach acidity. Hardt drew similar conclusions and Poulton reported that distress of gastric ulcer could be initiated by increasing gastric tension and relieved by its reduction.(26),(62) Ryle likewise states, "given an irritative focus (ulcer) the ingestion of food, or the readiness for it, even in the absence of acid secretion, is an adequate stimulus for the initiation of the exaggerated tonic and peristaltic action upon which the pain depends."(73)

The chief exponent of the mechanical theory is Hurst (36); the essence of his contentions is as follows. Normally as each peristaltic wave approaches the pylorus, active relaxation occurs. When an ulcer of the duodenum or prepyloric region is present there is a protective reflex called forth probably by the irritation of the surface of the ulcer by the chyme as it comes into the duodenum

especially if it is very acid. This protective reflex acts by inhibiting the normal relaxation of the pylorus which is called achalasia by Hurst. The achalasia delays the emptying of the stomach since stomach emptying in this situation can only be produced by increased pressure upon the pylorus. This increased pressure in the pyloric vestibule, especially, is the cause of the pain. Hurst has answered the objection of some that according to this mechanism the pain would be intermittent, by saying that the pyloric antrum acts as a separate chamber from the stomach and that the tension in it remains high even between peristaltic contractions. If a prepyloric or duodenal ulcer invades the pyloric ring and the element of actual pylorospasm enters in or if actual stenosis occurs, the tension mechanism still holds. Other gastric ulcers may produce pain by the mechanism of pylocic achalasia or by a spasmodic ring of the stomach wall with increased tension above the constriction ring. Hurst considered the evidence that relaxation of the pylorus by alkalies as seen radiologically was supportive of his theory.(36)

Carlson laid more stress upon actual peristalsis as being the exciting factor in pain production. The so-called "hunger pains" he described as being very typical of ulcer.(13) Horsley in a series of peptic ulcers found hunger pains in 50 per cent. However, the hunger pains are

not pathognomonic of peptic ulcer being found in chronic cholecystitis, chronic appendicitis and even with no demonstrable lesion in the alimentary tract.(34)

Wilson considered that the sustained contraction in the duodenal bulb was the inciting factor in the pain of duodenal ulcer.(91)

(2) Chemical Theory

Certain difficulties arise if all ulcer pain is explained upon the basis of increased tension or peristalsis, the principal one being that the closed pylorus and exaggerated peristalsis in the prepyloric region are often not associated with pain and that pain may occur with an open pylorus. Reynolds and M'clure (70) and numerous others by radiological studies have demonstrated these facts.

The advocates of the alternate theory that the pain is primarily due to some chemical irritation of pain bearing fibers at the ulcer site are numerous, but Palmer is probably the chief advocate. In a series of articles (19)(57) (58),(59) he has given a very complete review of the literature and the most convincing arguments for the acid stimulus as initiating the pain. He has shown that ulcer pain may be produced by introducing 0.5 per cent HCl into the stomach of an ulcer patient; that the pain was relieved by the neutralization or evacuation of the acid or chyle; that the pain was resumed by reintroducing the acid or chyle; that

the pain was resumed by reintroducing the acid or chyle; that pylorospasm, gastric motility or intragastric pressure were not necessarily associated with pain; and that the ulcer pain arose by acid irritation at the site of the lesion. The mechanism may be described, therefore, as follows. Given an ulcer of the mucosa, the presence and continued action of acid gastric juice exerts a direct effect on nerves in and about the ulcer site rendering them hyperirritable by the local inflamation which is set up. With this irritable pain producing mechanism present an adequate stimulus acting in or adjacent to the lesion produces the pain. The usual adequate stimulus is the free hydrochloric acid of thegastric content. In the cases of a quite sensitive mechanism, peristaltic action or local spasm are undoubtedly adequate stimuli, also. Hardy (27) is one who confirmed Palmer's results.

(3) Theory of Local Tissue Congestion

The principal advocate of this theory is Kinsella who contended that the pain was due to compression of nerve fibers in the neighborhood of the ulcer by vascular congestion, increased volume of tissue fluids, cellular infiltration and rigid fibrosis although he admitted that increased motility and tension were also, adequate stimuli. However, it is difficult to reconcile this theory with prompt relief of ulcer pain by alkalies and pain similar to that of ulcer produced reflexly from the infected gall-

bladder or appendix. (38), (39)

Ivy, according to Alvarez, supported this congestion theory. (1)

(f) Carcinoma of the Stomach: The pain of malignancy of the stomach is quite variable and may simulate other types of gastric pain, more especially ulcer pain. Cancer of the body of the stomach rarely produces a true visceral pain, not at least, until very late. Cancer of the pylorus on the other hand if it gives a certain degree of obstruction may produce pain by the mechanism of increased tension previously described. (51) Palmer stated that various visceral pain producing mechanisms may occur in carcinoma of the stomach including acid stimulation of the malignant ulceration, muscle tension and carcinomatous infiltration of the sensory nerve fibers. Clinically the pain may closely resemble that of ulcer at times. (58)

(4) Intestines

The occurence of pure visceral pain in the intestinal tract is relatively frequent and it is an important symptom in the diagnosis of intestinal ailments. Being a typical hollow viscus, and quite an actively functioning one, there are numerous possibilities for the production of the adequate stimulus for the pain.

Some type of disturbed motility or obstruction is almost always the cause of pure visceral pain arising from the intestines. Certain principles of bowel motility

and irritability are so closely linked with obstruction it will be well to consider a few of them. In regard to the bowel as a whole, Alvarez thought that there was a "gradient" of irritability down the bowel. The jejunum was thought to be very sensitive to food or a balloon, while the ileum did not respond with peristaltic action nearly so readily. The ileum, however, was more sensitive than the colon; the ileocecal valve and anal ring were exceptionally irritable points and, therefore likely to be points of obstruction; the sigmoid and descending colon also appeared to have a higher degree of irritability than the rest of the colon. Alvarez stated another principle of bowel motility, namely, that stimulation at any point tended to hold back the progress of material coming down from above. (1) In this connection it was Starling who first described the myenteric reflex by which a stimulation of the intestine at any point caused a reflex contraction above the point and a reflex inhibition or dilitation below. (80)

Evidence has already been cited showing the bowel insensitive to pricking and to chemical, thermal, and strong faradic stimulation. Mechanical stimulation of ulcers of the colon and inflamed bowel is, also, painless. (46), (49), (35)

The only adequate stimulus known, therefore, is of

the distensile type, but as in the previous discussion on gastric pain certain finer mechanisms are postulated. Hurst (36) suggested that the downward peristalsis caused a ballooning against a point of obstruction and the tension of the wall proximally caused the pain. Cannon's work of 1912, also suggested that this might be the mechanism. (8) Carlson and Cannon and Washburn and others would postulated the contraction itself as the cause of the pain. (12),(8) Mackenzie's observation (49) of painful peristalsis noted at the time of operation, the physical finding of peristaltic movements across the abdomen accompanying colic etc. might be given as additional evidence. Alvarez stated that colic was due probably to an incoordinated type of peristalsis which resulted in pressure being put on a segment of bowel by contractions above and below. In intestinal obstruction in animals tonus waves and slowly moving deep peristaltic waves of unusual type have been observed. (1) Poulton (63) arguing from analogy from his work on esophageal dilitation postulated tension as the mechanism; he suggested that a successful peristaltic contraction relieved the pain and the pain appeared again as tension increased during relaxation. Mackenzie found that a dilitation of the colon with air caused pain. (49) Also the expelling of gas and relief of pressure by perforation led to the relief

of colicky pains. Kinsella, by evidence that after the injection of saline solution into the wall of the bowel, peristalsis caused pain, suggested the congestion theory. (38)

Although there are numerous causes and types of bowel obstruction, the mechanism of the pain may be thought of as being essentially the same in each. In general a high obstruction, that is one in the small intestine and caecum, gives a pain at and just above the umbilicus while an obstruction lower down in the large intestine gives pain in the hypogastrium. There, is, however, rather vague localization in each case. In acute and complete obstruction the pains are typically those of a severe colic, being intermittent spasms with perhaps no pain between the regularly recurring short severe bouts.(51) In a chronic, incomplete obstruction the pains are more irregular and intermittent, are apt to be related indirectly to the taking of food and bowel movements. Whether the obstruction or ileus is of a mechanical, reflex, inflammatory, atonic or hypertonic type, when colicky pains occur they may be considered as being due to an altered metabolism and peristalic activity and unusual tension upon the wall of the viscus. (14),(1)

(5) Appendix

That the epigastric pain of inflammatory lesions

of the appendix is a pure visceral pain is quite generally accepted at present. Typically the pain is located in the center of the abdomen perhaps a little above the umbilicus. It is vague, deep and may be described as extending across the mid-abdomen. The pain has all the characteristics of an intestinal colic, or as the patient describes it, "like a severe belly-ache". At times it may be heavy, dull, aching or boring. In the acute attack the pain increases in severity usually coming in spasmodic attacks until the paroxysms are more or less constant and cause great restlessness and agony. This so-called initial pain in the acute attack lasts for a matter of several hours and overlaps the second or localized pain but tends gradually or suddenly to disappear. (51), (15)

A chronic or subacute appendix may cause this colicky type of pain alone with no symptoms or findings directly referable to the appendix, itself. Since the initial pain in the early stage of an acute appendicitis or the pain of a chronic obstructive appendicitis is usually of the pure visceral type alone referred pain, tenderness and rigidity will be lacking.

Until more recent years the importance of so-called appendicular colic in the early diagnosis of appendicitis was not fully appreciated. Murphy (53) must be given credit for emphasizing this epigastric or umbilical pain

as the first symptom of appendicitis followed by nausea and vomiting, local iliac tenderness and pain, fever, and leukocytosis.

The debate as to the exact mechanism of the true visceral or central pain of appendicitis has been a long and unending one. Four possible mechanisms may be mentioned.

(1) Mackenzie mentioned the appendicular colic noted in chronic appendicitis especially. Although he admitted not understanding the cause of the attacks, he had noticed in some cases that there was a stenosis and distension of the appendix, and using Sherrington's experimental evidence of such a mechanism for biliary colic he said that the stenosis would cause the spasm of smooth muscle of the appendix wall, sympathetic afferent nerves would be stimulated and conduct impulses to the cord and by referred pain mechanism give rise to the pain; he, also, suggested that in some cases the pain might be due to violent intestinal peristalsis above the inflamed appendix. The fact that the pain was in the mid-line he attributed to the appendix being derived from the digestive tube, a mid-line structure. (48),(49) Cope, likewise called this diffused pain of a referred type and thought it might be due to exaggerated peristalsis in the obstructed lumen which bouts of pain might also cause painful peristalsis of the caecum. (15) Undoubtedly these two men were correct in their conception of the local

mechanism and the reason for its being a mid-line pain, but the evidence previously presented and the present day understanding as to pure visceral pain certainly eliminates the possibility of the pain being a referred one.

(2) Lennander, because he denied the existence of splanchnic pain proposed that this type of pain was due in part at least to irritation of somatic nerves at the base of that portion of the mesentery which contained the lymphatics draining the inflamed appendix. (46) This theory likewise apparently may be discarded because the pain occurs often where there is no such inflamation and too early for such a spread to have occurred. (50)

(3) Unquestionably the pain is often due to an obstruction of the lumen of the appendix, especially near its base. The consequent dilitation probably serves as the stimulus for contractions and the stretching gives the adequate stimulus for a pure visceral pain of a colicky nature. Morley thought this obstrusctive mechanism was the most common one and stated that since the lower ileum and appendix have the same segmental innervation the appendicular colic was localized in the same area as colic of the ileum, namely at and just above the umbilicus. (51) Occassionally if the appendicitis not of the obstructive type the umbilical pain may be slight or absent. The "appendicular colic" met with in children is frequently due to obstruction

by a fecolith or thread worms, offering additional evidence for the obstructive mechanism.

(4) Many clinicians make the mistake of calling the central pain referred even though they themselves may realize that it is not in the nature of a viscero-sensory reflex but is due to pain arising from some other part of the gastrointestinal tract which is reflexely affected from the inflammed appendix. It is better not to use the term referred, when inferring that the central pain is due to a reflex effect upon some other organ. There is considerable experimental and clinical evidence to support the theory that much of the diffuse epigastric pain of appendicitis is due to increased or altered peristalsis of the small bowel andto pyloric and ileocecal spasm.(1),(36), (74),(51) Quite often a chronic appendicitis produces a reflex dyspepsia with the symptoms of epigastric fulness and distress and heart burn. (14)

(6) Liver and Biliary System

(a) Liver Pain: The emmitence of pure visceral pain from the liver substance is very questionable. There is no opportunity for the stretching mechanism and practically all pain referable to the liver is explained on a somatic or referred pain basis. (51) The surface of the liver is not sensitive to any type of stimulation. (40)

(b) Biliary dyspepsia: The so-called reflex dyspepsia of

gallbladder disease gives a pure visceral pain arising from the stomach and duodenum, the close "neighbors" of the gallbladder.. The symptoms are difficult to estimate and relate to the gallbladder but they are of great importance. The dyspeptic symptoms often accompany a chronic cholecystitis with or without stones. The symptoms of fulness, distress, and dull pain are vaguely localized in the epigastrium, usually come on a short time after meals and, also, include distention and belching. Frequently these dyspeptic symptoms are the only symptoms of gallbladder disease or they may be the residual symptoms between attacks of biliary colic.

The mechanism of the pain production is a debatable one and some of the possibilities have been suggested previously. The inflammation, the irritation of stones, and the dysfunction of the biliary system in general apparently produces certain reflex motor phenomena via the vagi and splanchnics in the stomach, cardia, pylorus and duodenum, which in turn are productive of the pain. (69) The possibilities as to distension of the esophagus, cardiospasm, pylorospasm, achalasia and increased tension in the pyloric antrum, and the general hypertonicity and hypermotility of the stomach have all been mentioned as being factors. (60),(63),(1),(51) There may be a hyperchlorhydria which contributes some to the distress

and fulness and suggests that it is the stomach itself which is principally responsible for the shymptoms. The occurrence of hyperchlorhydria suggests why relief of symptoms from alkalies is sometimes noticed. The hyperchlorhydria occurs in about 21-23 per cent of the cases of reflex irritation of the stomach associated with gall-bladder disease. Adhesions to the stomach or other parts of the bowel as a result of ballbladder disease may give rise to a visceral pain. In acute cholecystitis or during an attack of biliary colic it is difficult to estimate the part played by reflex dyspepsia as to the cause of pain, but indoubtedly it at least contributes some.

(c) Biliary Colic: While clinically biliary colic may cause "referred" and somatic symptoms, only the true visceral pain element is being considered here. This pain is located in the epigastrium in or near the mid-line but is diffusely localized and may extend all across the epigastrium. The pain is a heavy boring one and usually increases rapidly in severity, sometimes with slight wave-like exacerbations. This pain is usually discernable early in an attack before actual tenderness, rigidity and localized pain over the gallbladder and elsewhere appears. While masked somewhat as the attack progresses it is probably present through to some degree. (51),(71)

The pain of biliary colic is generally recognized

as being due to an obstructive mechanism, in favor of which there is a great deal of proof both experimentally and clinically. Sherrington in 1900 reported that he caused evidences of pain in animals by the distention of the gallbladder with saline solution. (77) Hurst's work in 1911 on the adequate stimulus for visceral pain naturally was applied to biliary colic. (35) It was assumed the obstructing element served to distend the gallbladder or ducts causing as increased tension which in turn stimulated splanchnic fibers in the wall. Much work has been done on the various detailed variations of the mechanism.

The most common obstructing mechanism is stone, of course, but other mechanisms may be stenosis of the ducts from inflammation and edema of the walls, tumors of the wall or adjacent tissues, scar tissue and adhesions, and spasm.

The obstruction may be at the neck of the gallbladder or in the cystic duct and cause pain. In this type of obstruction one of the mechanisms is dilitation of the gallbladder which has been shown to be painful. (56), (75),(71) Rolleston referred to the possibility of a valve like action of a stone in the neck of the bladder causing intermittent attacks of painful spasm and distension. The presence of some increased amount of muscle tissue at the

neck of the gallblader fits in with this. There is some evidence that the pain may be induced by some unusual contractions of the gallbladder forcing a stone into the cystic duct. It is also contended that the presence of a stone in the cystic duct stimulates more forceful gallbladder contractions which serve to cause pain. (71) However against the contention that contractions of the gallbladder play any great part is the fact that the muscle of its wall is so thin and sluggish. (71),(1)

Cystic duct colic may arise possibly from the local duct spasm and the associated spasm and dilitation of the gallbladder or possibly by reflex gastric phenomena. Experimentally, Schrager, Ivy and Davis have produced pain by dilitation of cystic duct. (75),(17)

Common duct obstruction may be the cause of either continuous or intermittent or paroxysmal pain. The cause is usually a stone or stones in the lower end of the common duct or at the ampulla of Vater. (71) The most common and likely explaination of the pain in this case is that the stone either by virtue of its size or shape or descent or turning so irritates or stretches the duct wall that there is a severe spasm produced, especially at the lower end of the duct and sphincter of Oddi where smooth muscle is more abundant and pain is produced by the usual pressure mechanism. (51) The part played by

dilitation and contraction of the ducts or gallbladder above the obstruction and reflex stomach and duodenal effects is difficult to estimate but is undoubtedly of considerable importance. (1),(71),(69) That the spasm and dilitation of the common duct are effective pain producing mechanisms is witnessed by the relief of pain by the removal of the obstruction and by pain being produced by experimental dilitation of the common duct. (75),(55),(85),(32)

The importance of pains of biliary colic being due to an obstruction of the sphincter of Oddi has only been emphasized in recent years. Obstruction at this point in addition to stone may be due to an inflamation of the sphincter, a sphincteritis or to a spastic contraction of the sphincter or rather a failure of the sphincter to relax, a choledochal dyssynergia. (55),(4)

III

REFERRED PAIN

(A) Referred Pain Mechanisms

Obviously the poorly localized, deep-seated pure visceral pain that has been described as being mediated only by a visceral afferent pathway and as being typically unassociated with any somatic sensory or motor phenomena only accounts for part of abdominal pains. The sharp finger point pain of an acute appendicitis or the scapular pain of a gallbladder colic, etc, require an explaination that must involve more than just a pure visceral pain set-up by an adequate pressure stimulus and mediated only by visceral afferent fibers. Furthermore the somatic phenomena of superficial and deep tenderness and muscular rigidity seen in various conditions of visceral involvement require an explaination.

Historically the names of Traube, Quincke, Hilton,(33) Brown-Sequard, Dana and Sturge, Muller and Lange (42) should be mentioned as having suggested the possibility that in certain visceral diseases there was an associated or reflex type of pain, and "illusion of pain", on the surface of the body. (77),(17) However all these men who worked before 1886 had had relatively little appreciation of either somatic or visceral nerve supply especially as to segmental innervation or distribution. It was only after

Gaskell in 1886 (21) worked out the splanchnic innervation of the viscera that the first definite theory of referred pain was proposed by the English physician, Ross, in 1887. In addition to the splanchnic pain felt over an organ (see P.13) Ross postulated that in certain conditions there was an associated or referred somatic pain, that was felt in the distribution of the cerebrospinal nerves of the body wall that came out from the same segment of the cord as the afferent splanchnic nerves innervating the affected viscus. As an example of the mechanism he referred to the pain between the shoulders and just below the mid-sternum in disease of the stomach. To quote Ross' explaination; "The splanchnic nerves of the stomach are derived from the 4th and 5th and probably the 6th dorsal nerves, and when the splanchnic peripheral terminations of these nerves are irritated, the irritation is conducted to the posterior roots of the nerves, and on reaching the grey matter of the posterior horns it diffuses to the roots of the corresponding somatic nerves, and this causes an associated pain in the territory of distribution of these nerves which may appropriately be named the somatic pain." (72)

The logic and the utility of Ross' theory of referred pain in explaining certain abdominal as well as other visceral pains was such that its support and amplification by the clinical and research worker alike from Ross' time

to the present has been almost universal.

Henry Head did much to put the theory of referred pain on a somewhat firmer scientific foundation. In 1893 he presented evidence from three sources which seemed to establish more specifically the segmental relationship between the innervation of the viscera and the corresponding somatic segments. As one argument he used the fact that in certain diseases of the viscera he had noted areas corresponding to somatic nerve distribution of skin which were hyperalgesic. Within there areas the referred pain and the tenderness from the same viscera which were productive of the hyperalgesia. These areas of hyperalgesia have come to be known as Head's zones although Mackenzie observed them about the same time. Also, Head found areas of tenderness associated with many abdominal diseases, and he found that the somatic pain of a certain organ was always located within the corresponding area of tenderness. The tenderness was purely superficial and was more intense at certain "maxima" to which the pain was referred. These "maxima" he found to be fixed points and from them and the position of the referred pain he could predict the probable diseased viscus. Mackenzie likewise confirmed these findings. As the third piece of evidence Head found that in many cases of herpes zoster the pain and herpes often had a distribution similar to the areas of tenderness and hyperalgesia just

described. From this evidence Head was able to map out fairly accurately the segmental pattern of the cerebro-spinal nerve innervation and futhermore since Ross had proposed that referred pain was produced by a diffusion of impulses from splanchnic to somatic nerves of the same segment, Head could say what was the segmental splanchnic nerve supply to the particular affected organ. (See list page 8). (28),(47)

Head's later work (1920) on the protopathic and deep sensibility of the viscera and the common spinal path for both somatic and visceral pain fibers fit in quite consistently with the referred phenomena of pain, tenderness and rigidity. Thus in a cord segment a painful stimulus from the viscera came into close connection with the somatic pain fibers, and since the sensory and localizing power of the surface of the body was greatly in excess of that of the viscera, there was by what might be called a psychical error of judgment, an acceptance of the intra-spinal diffusion area by consciousness and pain was referred to the surface of the body instead of the organ actually affected. Also, within the segmental diffusion area there was a tendency for over-reaction of a protective nature in the whole segment so that ordinary superficial pressure gave tenderness, light touch gave "hyperalgesia", superficial reflexes, including pilomotor

response, were exaggerated. and the motor reflexes acting as a protective mechanism gave the tonic muscle contraction, or rigidity. (29)

While the work of Head served to give to the concept of referred pain a considerable scientific backing, it was the promulgation of the theory in the fields of practical medicine and surgery by the celebrated English physician, James Mackenzie, which gave the concept such a prominent part in diagnostic symptoms and signs of recent years.

Mackenzie's work ran more or less parallel with that of Head. Both of these men placed considerable emphasis on the mapping out of the areas of hyperalgesia and tenderness, the location of the referred pain, and the importance in diagnosis of all these reflex phenomena. Unlike Head, however, Mackenzie could not accept Ross' concept of splanchnic pain as probably existing. His reasons were as follows: first, the viscera were insensitive to local artificial stimuli; second, in his experience in a laparotomy in which he observed that contractions of the bowel produced pain the patient referred the pain precisely to an area ten or twelve inches away from the contracting bowel; third, after keeping notes as to the position of pain in a variety of diseases, he believed that the situation of the pain did not as a rule directly afford any clue to the situation of the lesion; fourth, even when

the situation of the pain was immediately over the lesion, other evidences showed that the pain was not felt in the organ but was referred to the sensory nerves in the external body wall. In support of the latter he gave his finding that in gastric ulcer, while the stomach might be moved by palpation or respiration, still the pain remained fixed (this has since been disproved). Thus Mackenzie believed all pain and other phenomena of visceral disease to be reflex in nature. To quote him: "If, however, a morbid process in a viscus gives rise to an increased stimulus of the nerves passing from the viscus to the spinal cord this increased stimulation affects neighbouring centres, and so stimulates sensory, motor and other nerves that issue from this part of the cord. Such stimulation of a sensory nerve will result in the production of pain referred to the peripheral distribution of the nerve whose spinal centre is stimulated, so that visceral pain is really a viscero-sensory reflex. If the increased stimulus affects a motor centre, then a contraction of the skeletal muscle results, and thus is produced the viscero-motor reflex." (49) It was unfortunate that Mackenzie made the error of not recognizing pure visceral pain, because it created a wrong impression and in reading his works at present allowance must be made for this error.

With the pain of a true visceral nature deducted from Mackenzie's work, however, his theory of viscero-sensory and viscero-motor reflexes as an explanation of many somatic phenomena in visceral disease is still generally accepted to-day by both physiologists and clinicians. Certain modifications, nevertheless, have been imposed upon the theory and it is by no means as inclusive to-day as formerly. The principal points of controversy are as to the determination of the inclusiveness of and the boundary line between pure visceral pain, and tenderness, referred phenomena, and true somatic responses. Some of the more recent views will serve to show the present status of a question which is as yet unsettled.

Ryle, 1926, one of the chief supporters of the referred pain theory gave quite a workable hypothesis. He was convinced that non-inflammatory visceral lesions rarely gave rise to referred pain or somatic hyperalgesia unless of the severe visceral crises. Thus in a "stomach-ache" due to extra-gastric causes or most other solely functional disturbances of the organs, cutaneous soreness or muscular guarding was not found. Such conditions produced a pure visceral pain and tenderness without or with accompanying referred phenomena. He believed the visceral pain and tenderness

could be accurately localized by the patient. On the other hand, referred somatic pain and tenderness and rigidity, i.e. the viscero-sensory reflexes and viscero-motor reflexes, although they might accompany a severe visceral crisis of mechanical origin were more frequently, Ryle believed, to be the expression of an inflammatory lesion of the viscus. He claimed that referred somatic pain or tenderness in inflammatory lesions might occur in the absense of local visceral pain, thus suggesting a different causation for each. Thus a cholecystitis might cause a subscapular pain and local rigidity and tenderness in the absence of stone; but, also, since biliary colic was such a severe visceral pain it might cause in addition to visceral pain, referred somatic phenomena such as subscapular pain, etc. In acute appendicitis and in chronic gastric ulcer the localized cutaneous hyperalgesia and muscular rigidity in the corresponding areas of the abdominal wall are examples of reflex phenomena associated with inflammatory lesions of the wall of the viscus. (74),(40) And so Ryle's views corresponded quite closely with those of Head and, also, With those of Mackenzie except for the recognition of pure visceral pain by Ryle.

Kinsella (38) was able to agree with Mackenzie's theory of reflex viscero-sensory and viscero-motor

phenomena on the basis of an irritable focus in the cord up to a certain point, that is, the shoulder pain in gallbladder disease and the radiating pain of renal colic as well as much of the hyperalgesia of skin and muscles could be explained. But the point that was difficult to account for was how the unilateral symptoms and signs of appendicular and cholecystic disease as well as ulcer could be explained on a reflex basis since these structures are all developmentally part of the digestive tube and should have bilateral innervation which should produce referred pain and other reflex signs in or near the midline. While not denying a referred component to abdominal pain, Kinsella did express the belief that the localized pain, whether spontaneous or produced by pressure over the organ in an ulcer, appendix, or gallbladder, was not reffered but was due to an actual sensitiveness of the viscus itself, the pain being caused by compression of the congested area either by peristalsis or by palpation.

Hurst (1929) (36) as has been described previously, adhered to the belief that there was a pure visceral pain due to tension, but that in addition, when the subserous layer of the visceral peritoneum became involved there was also a pure visceral pain and pure visceral tenderness produced which was accurately localized over the viscus.

In this way he explained some of the localizing signs of ulcer, appendicitis, and gallbladder disease. But in addition, Hurst believed that there were viscero-sensory and viscero-motor reflexes in visceral disease and believed in the theory of an irritable focus in the cord. He attempted to account for the localization of the reflex signs (as well as the visceral pain and tenderness) on the basis of a preponderance of afferent visceral fibers being stimulated at different levels and more on one side of the cord than the other; thus, in a gastric ulcer more fibers on the left were stimulated while in duodenal ulcer the reverse was true. The unilateral signs of gallbladder and appendicular disease he ascribed to the same reason. There might, however, if the afferent visceral stimuli were strong, be a spread to segments above and below and across the cord. Hurst found that while an ulcer was being treated, spontaneous pain generally disappeared first, then muscular tenderness, and lastly, rigidity, the rigidity perhaps persisting in intervals when pain and reflex tenderness were absent. In the intervals between attacks the x-ray showed the ulcer crater was still present and not healed, but it was assumed that the ulcer was not "active", no inflammatory reaction being present, and, consequently, the patient was free from symptoms. To quote Hurst: "This fact has led

Ryle to suggest that rigidity and other reflex symptoms depend upon direct reflexes from the lesion itself; ---- It is thus not, as I had at one time thought, a reflex result of the increased tension, which I have shown is the cause of the pain of ulcers, and which may be in a part of the stomach remote from the ulcer. The investigations already described prove that irritation of the ulcer does not lead directly to pain, which like rigidity, is a reflex symptom. ----Ryle has clearly summed up this distinction in the statement that 'The somatic phenomena of visceral disease are not a reflection of the visceral pain, but are symptomatic of the lesion, which, also by reflex mechanisms, causes the visceral pain.' This explains why the reflex signs, such as muscular tenderness and rigidity, and increased abdominal pilomotor, and vasomotor reflexes are generally unilateral or at any rate more marked on one side or the other, whereas, spontaneous pain is much more frequently central."

It had been suggested by several other workers previously (77), but more recently by Lemaire, (45), that the point of "transfer" from visceral to somatic fibers was not intraspinal, as has usually been thought, but through certain bipolar cells in the spinal cord. His reasons for coming to this conclusion may be cited. He produced local anesthesia of the entire abdominal wall

and abolished the pain, tenderness, and muscular rigidity of gastric ulcer, tuberculous peritonitis, chronic constipation with pain in the left iliac fossa. But he realized that a complete anesthetizing of the wall did not prove whether the pain was from the parietal peritoneum or from the viscera and so he anesthetized only the subcutaneous tissues and still claimed that the pain, tenderness, and rigidity in patients suffering from various intraabdominal diseases was relieved. He found that even in peritonitis the spontaneous pain and the tenderness and hyperalgesia were relieved by contaneous anesthesia.

Lemaire believed strictly in Mackenzie's views of a viscero-sensory reflex even to the point of the parietal peritoneal irritation causing viscero-sensory reflexes. But his experiments led him to believe that the reason the subcutaneous anesthesia was effective was because the cerebrospinal neurones to which the pain was referred, were decreased in irritability and that the visceral stimulus must be referred not through the posterior horn cells of the cord, but through bipolar cells of the posterior root ganglia.

Weiss and David in experiments similar to those of Lemaire anesthetized the skin into which localized pain was referred in twenty-five patients with pain

from pleuritis, carcinoma of the esophagus, gastric ulcer, cholecystitis, nephrolithiasis, acute appendicitis, salpingitis and pyelitis with either complete or almost entire relief of pain. They, also, were able to prevent the occurrence of pain due to distention of the esophagus or doudenum by a balloon, including that referred to the back. Hence, it would seem that their experiments would afford direct proof of the truth of Mackenzie's theory of a viscero-sensory reflex, since, if the pain were purely visceral, it should persist even after cutaneous anesthesia. These men admitted, however, that they were unable to relieve a dull unpleasant sensation, but not a true pain, which they could not deny being a true visceral sensation. Nevertheless, they claimed relief from many sensations "felt inside."

Apparently the manner in which the cutaneous anesthesia acts is to cut off cutaneous afferent sensations which by the ordinary referred pain mechanism (irritable focus in the cord) become abnormally exaggerated and produced the localized pain and other viscero-sensory as well as viscero-motor phenomena. (87)

(B) Viscero-cutaneous and -motor Reflexes in Referred Pain

It has been noted that somatic hyperalgesic areas from visceral disease often exhibit vasoconstriction, contraction of the erector pili muscles, activity of the sweat glands as well as the well-known muscular guarding

or rigidity. Wernoe, who studied these phenomena quite extensively both clinically and experimentally, was led to believe that they played considerable part in producing an area of cutaneous hyperalgesia. He found that zones of cutaneous ischemia were bilateral if the lesion was in an unpaired organ such as the intestine, but unilateral if in a paired organ. He produced the viscero-cutaneous reflexed experimentally by visceral stimulation even after destruction of the cord in the corresponding segments; these effects he interpreted as being in the nature of axon reflexes mediated through a single sympathetic neuron which sent processes both to a visceral organ and the skin. Wernoe concluded that cutaneous hyperalgesia probably had its origin in changes brought about in the skin through viscero-cutaneous reflexes; that is, the ischemia and also the erector pili muscle reflex might stimulate cuatneous pain receptors. (88) It was also pointed out that the reflex muscular guarding or rigidity as it occurred in acute appendicitis or gastric ulcer, for example, might contribute to the production of associated hyperalgesia and muscular tenderness and pain. That is, the spastic contraction or increased tonus of skeletal muscles might give rise to pain by its stimulating effect of sensory receptors in the muscle; in turn, the painful stimuli giving the tender muscles,

tended to keep the muscle in a spastic state even after the exaggerated visceral stimulation had subsided. (40)

Verger (84),(18) proposed a different path for viscero-cutaneous reflexes. He traced the impulses of referred pain as going by way of the afferent sympathetic fibers from the viscera through the posterior roots to the anterolateral column, then by way of the sympathetic efferents running antidromically in the posterior roots to the skin where a sensory impulse set up there was conducted to consciousness by way of the cerebrospinal system.

Spameni and Lunedei (79),(17) proposed another pathway, namely, that the visceral impulses that reached the lateral columns of the cord by afferent visceral pathways, stimulated centrifugal unmyelinated fibers, which terminated in the sensory corpuscles (of the skin). Physicochemical changes were thus produced which stimulated the sensory organs from which impulses travelled over the cerebrospinal nerves.

Davis and Pollock (18) by their more recent expermiments of the referred shoulder-tip pain from stimulation of the diaphragm have given the pathway proposed by Spameni and Lunedei considerable support. They believed that impulses of referred pain travelled from the viscera

along with autonomic or spinal sensory fibers to the spinal cord by way of the posterior roots. After passing over the synapse with cells in the anterolateral column the impulses travelled over preganglionic efferent fibers to the autonomic ganglia. A postganglionic fiber then carried the impulses to the skin where the sensory end organs are stimulated. Thus an ordinary somatic painful impulse was produced which travelled over the spinal sensory nerves, entered the cord by way of the posterior roots and ascended in the lateral spinothalamic tract to a cortical level. They have shown this path to have a fairly sound anatomical basis and claimed it did not call into play any hypothetical radiation, irritable foci, lowering of threshold or diffusion, as do other theories of referred pain. They believed referred pain to be a real entity and that viscero-sensory and viscero-motor reflexes should not be considered as nothing more than peritoneosensory and peritoneomotor reflexes as Morley would have it. (see page 89)

Take for example pain produced by distention of the gallbladder which was found to be unaffected by section of the thoracic posterior roots but relieved by section of the splanchnic nerve. This would indicate that there is a pain of both referred and true visceral nature, since

it is also known that when the skin overlying the gallbladder in man is anesthetized, the pain of biliary colic may be abolished.

Davis also considered that the shoulder-tip pain of diaphragmatic stimulation was a typical referred pain, since anesthetization of the skin or section of the phrenic abolished the pain while section of the thoracic intercostals had no effect. He considered the diaphragm a visceral organ (unlike Morley) and believed that since section of the cord or thoracic posterior roots left the shoulder-tip pain unaffected that the pain was not a peritoneo-cutaneous reflex from stimulation of parietal peritoneum as Morley would have it. However, Davis did not deny the possibility that Morley's peritoneo-sensory and peritoneo-motor reflexes (see page 89) might not exist in addition to viscero-sensory and viscero-motor reflexes and splanchnic pain. (18),(51) Capps, like Davis has expressed the opinion that the phrenic shoulder-tip pain was a typical referred pain. (9)

(C)Examples of Referred Phenomena:

In the following considerations of some examples in which referred pain is thought to occur, it is well to keep in mind that the dogmatic acceptance of them is a mistake because of the uncertain status of referred pain. Referred pain, in general, is described as sharp, stabbing,

superificial, and localized. It is accentuated by movement, pressure or other sensory stimuli. For practical purposes the spontaneous referred pain may be considered as the subjective manifestation of the objective sign of tenderness.

(1) Stomach:

The functional disturbances where there is no organic pathology of the stomach or duodenal wall rarely give somatic symptoms except perhaps in the severe gastric crises. Simple gastritis rarely produces somatic signs because the lesion is so superficial and does not involve the muscular layer; also, uncomplicated carcinoma, while it does invade the wall, does not erode the muscle fibers in which most of the nerve fibers are found and so does not, as a rule, give referred symptoms. When reflex signs are present in cancer, they are usually bilateral and are probably due to a direct irritation of somatic nerves. The chief condition in which reflex phenomena are of most interest in relation to the stomach and duodenum is that of ulcer.(74),(51)

(a) Cutaneous Hyperalgesia of Ulcer: In a small proportion of cases of gastric ulcer there is a superficial hyperalgesia or soreness of the skin present during an attack and perhaps persisting for some time after spontaneous pain has subsided. (74) Hurst said that the

symptom was of no importance diagnostically because it was so infrequent, actually but was too often demonstrated by its being suggested especially to a neurotic patient. (36) Ryle and Morley agreed on this point also and all but Morley would put it, when it does occur, on a viscero-sensory reflex basis. (51)

(b) Muscular Tenderness of Ulcer: Hurst's conception of true visceral tenderness has already been given. He also believed that there was a reflex muscular tenderness which was distinguished by its greater extent, its fixed position even when the stomach was moved. The extent was also more widespread the greater the amount of spontaneous pain. It was generally situated higher and to the left in the rectus muscle with ulcers near the cardia and along the lesser curvature while with prepyloric ulcers it was more often present on the right side or bilateral and with duodenal ulcers it was almost invariably right-sided or most marked on the right side. (36)

Hilton and Boas (33),(5) were among the first to mention the areas of sub-and inter-scapular tenderness with diseases of the upper alimentary tract, especially in connection with ulcer and gallbladder disease. The area was quite well localized over the lower ribs in gastric ulcer being located to the left of the twelfth dorsal vertebra but occasionally it is in the region of the 11D

or 1L vertebra or even on the right side, but in prepyloric and duodenal ulcer it was often on the right side only. This back pain occurs particularly in cases of posterior excavating ulcers adherent to or eroding the pancreas. (51),(74) Morley (51) would explain this back pain on the basis of a radiation to the superficial branches of the same cerebrospinal nerves deep in the retroperitoneal tissue just as he would explain the anterior abdominal wall tenderness on the basis of his peritoneo-cutaneous reflex, but most men believe it to be a referred pain.

(c) Deep (non-muscular) Reflex Tenderness: Mackenzie was the first to emphasize the fact that in the absence of superficial or muscular tenderness or by palpation between the two recti that a reflex tenderness of the sensitive subperitoneal tissue could be elicited.(49) Hurst also mentioned this type of tenderness in connection with ulcers as shown by the frequent existence of mid-line epigastric tenderness in patients with widely separated recti, the tenderness being localized some distance from the actual ulcer. Hurst himself admitted, however, that this tenderness could be the same as the visceral tenderness, while Morley would classify it as a tenderness due to parietal peritoneal irritation.(51),(36)

(d) Rigidity: The reflex rigidity of ulcer is explained on the basis of the hypersensitiveness of the spinal cord segment which is present when an ulcer gives rise to pain or when a somewhat exaggerated form of deep tenderness is present. There is a spasmodic contraction of the muscles which is augmented by pressure on them. There is also an exaggeration of the abdominal reflexes. The rigidity is most marked at the time pain is most severe but rigidity may persist after the spontaneous pain has subsided. There is usually considerable inflammatory reaction around the ulcer when rigidity occurs and the rigidity is related more to the continuous flow of impulses from this inflammatory site than the spontaneous pain from tension. In general the rigidity is greater or only present on the left side of the rectus muscle in gastric ulcer and in duodenal ulcer on the right side, although there are many exceptions. When the pain is very great, the area of muscular rigidity is increased and rigidity as well as unilateral tenderness and exaggerated abdominal reflexes may become bilateral. (74), (51), (36)

(e) Pilomotor and Vasomotor Reflexes: The occurrence of these reflexes in ulcer was first noted by Mackenzie. (47),(49) Ryle, Hurst, and Ruhman and Spiegel have noted them also in ulcer usually elicited by gently stroking the skin in the hypersensitive zone. (36),(40)

(2.)Intestines:

It is generally conceded that disease of the intestines rarely gives rise to reflex signs unless the parietal peritoneum becomes involved. Mechanical obstruction or cancer which are uncomplicated by infection, ulceration or necrosis or extension beyond the gut wall as a rule do give rise to reflex phenomena. Ryle, Hurst, Kinsella, and others, however, hold to the belief that with inflammatory or ulcerative lesions of the intestine, such as deeper involvment of the wall and subserosa by tuberculosis of the ileum or a diverticulitis, for example, may produce tenderness, soreness, and muscular rigidity of a reflex nature. Hurst accounted for the unilateral localizing signs of a diverticulitis of the pelvic colon, for example, as of reflex origin from the inflamed viscus.(74),(36),(38)

(3) Appendix:

(a) Cutaneous Hyperalgesia: It was Mackenzie who first laid emphasis upon the mapping out of the areas of cutaneous hyperalgesia especially in appendicitis. He claimed that it was quite a constant and helpful finding, explainable on a viscero-sensory reflex basis.(49) Head agreed and his work showed it to be in the distribution of the 9-12 dorsal nerves. (28) Sherren found a tri-

angular area of hyperalgesia over the right iliac fossa in thirty-two per cent of a series of 124 cases of acute appendicitis. He pointed out that hyperalgesia depended largely on the degree of distention of the appendix, and that when gangrene or perforation occurred, it tended to disappear. Cope agreed with Sherren and believed it to be present in over fifty per cent of the cases of appendicitis even in some cases of gangrenous or perforated appendix. (76),(15)

Most of the more recent workers, however, are inclined to place relatively little diagnostic value on the inconstant finding of hyperalgesia. Ogilvie,(56) believed that in some few cases as an early sign even of an uninflamed appendix, it might be fourd; hence, he believed it to be a reflex phenomena, but as he states, "brought up on the Mackenzie tradition, I spent many years in the routine search from areas of hyperaesthesia seldom rewarded by any findings at all and never that I can remember by any of real value". Hurst was of the same opinion.(36) Ryle (74) believed that cutaneous hyperalgesia developed much more frequently and early along with other reflex signs in the "inflammatory" type of appendicitis than in the gangrenous type, its absence in the latter type being perhaps accounted for by the lace of early inflammation and the later ischemia of

gangrene. Morley has stated that this physical sign, which varies in its frequency from 20-59 per cent can be of little aid in diagnosis. However, when it did occur, he was the only one apparently who believed that it was produced only by an irritation of the parietal peritoneum, that is a peritoneo-cutaneous reflex. (51)

(b) Tenderness: The finding of increased sensitiveness of the muscles over the right iliac fossa and erector spinae muscles in appendicitis has long been recognized. Mackenzie of course put it entirely on the basis of a viscero-sensory reflex. However, he did admit that it was difficult to tell when the tenderness due to the viscero-sensory reflex from the irritation of the "insensitive" peritoneum (both visceral and parietal) was superimposed by a tenderness and rigidity due to an involvement of the subserous layer of the parietal peritoneum with its sensitive cerebrospinal nerves. (49) With few exceptions, the general consensus of opinion among practitioners is that the deep tenderness of early acute of chronic appendicitis without parietal peritoneal involvement and the local spontaneous pain which is subjective expression of the tenderness is due to a viscero-sensory reflex. Cope, Ryle, Lemaire, Kinsella, Hurst (15),(74),(45),(38),(36) and others are included in this group. However, as previously described, Hurst,

Kinsella, and Ryle believed that with inflammatory involvement of the wall deeply, resulted in a true local tenderness in the organ itself. As evidence for this Hurst used the facts that the right iliac tenderness, especially in chronic appendicitis which could be shown by x-ray to be directly over the appendix even when the appendix was removed by palpation; also Bastedo's test (inflation of the colon with air) gives rise to pain and tenderness in the right iliac fossa if there is an acute appendicitis.(56) Morley, standing somewhat alone, has proposed placing all the local reflex signs on the basis of a parietal peritoneal irritation which results in peritoneo-sensory radiation and peritoneo-motor reflexes. (51)

(c) Rigidity: Another of the objective signs of localized pain in appendicitis especially of the acute type is rigidity. Mackenzie postulated the muscular contraction of the transversalis abdominis, the oblique and psoas muscles as being due to a viscero-motor reflex. (49) Ryle expressed the belief that in the "inflammatory" type of acute appendicitis the reflex rigidity was usually present, even in the mildest and earliest cases where they constituted an important diagnostic sign. In the gangrenous type, on the other hand, it might be entirely absent. (74)

(4) Gallbladder and Biliary Ducts:

(a) Cutaneous hyperalgesia: This sign was found in gallbladder affections by Mackenzie as early as 1891.(47) The area was usually found extending somewhat above and below the right costal margin over the upper portion of the right rectus, although it might extend downward. The hyperalgesia in a great many cases persisted after the sub-sidence of a gallbladder "attack". Ryle (74) likewise included superficial soreness in the upper right quadrant as one of the viscero-sensory accompaniments of cholecystitis with or without gall stones. He was in doubt how much of the hyperalgesia and other referred phenomena should be attributed to cholecystitis and how much to the mechanical distension of the ducts. Hurst (36) did not deny that cutaneous hyperalgesia of a reflex origin might exist but thought it was too rare to be of any diagnostic value.

(b) Tenderness: Mackenzie (49) said that the muscular tenderness in gallbladder disease was most common on the right side and upper right rectus. The tenderness was the objective manifestation of the spontaneous referred pain which was localized over the gallbladder area. The tenderness became apparent especially after the spontaneous pain subsided due to the irritable focus remaining in the cord. Tenderness and referred pain in gallbladder

disease occur quite frequently over the middle dorsal spines and along the course of the eleventh right rib. (74) The same arguments in regard to an actual tenderness of the gallbladder itself, a viscero-sensory tenderness or a peritoneo-sensory tenderness arise here the same as has been discussed under the appendix and ulcer.

(c) Rigidity and Exaggerated Superficial Abdominal Reflexes: The rigidity more or less parallels the tenderness according to Mackenzie. It is found usually in the upper right rectus but may spread down in the right abdominal wall (as may the other reflex symptoms). Sometimes, after an acute attack, there may be rigidity of the lower right intercostals muscles. (49) Ryle described the reflex muscular guarding in acute cases amounting to actual rigidity often times and in subacute cases exaggeration of the abdominal reflex on the right side might be present. (74)

IV

SOMATIC PAIN

(A) Innervation of the Parietal Peritoneum

Somatic pain in abdominal disease has to do with stimulation of somatic afferent fibers in the abdominal wall; therefore, some consideration of the sensory innervation of the parietal wall is in order. Probably earliest mention of the nerve supply of the parietal peritoneum was made by Haller in 1766. He believed that the peritoneum had no nerves; those nerves found underlying it he thought belonged to the abdominal wall muscles. (25) Bourgery, 1845, recognized the fact that there were nerves in the peritoneum and which were derived from the intercostal nerves. (31) It was not until Ranstrom in 1908 made a careful histological study of the abdominal wall, however, that the nerve supply was fully appreciated. He showed that there was a rich supply of nerves in the subserous layers of the parietal peritoneum derived from the lower intercostal nerves which supplied the muscles of the abdominal wall. He also found some intercostal fibers running into the peritoneum of the outer border of the diaphragm.(66)

It is now known that fibers from the lower six intercostal nerves and some fibers from the ileoinguinal

and ileohypogastric nerves supply the visceral peritoneum. The nerves innervating the muscles of the abdominal wall give off branches which turn inward and form a plexus in the subperitoneal tissues and within the peritoneum itself. The distribution of the nerves in the peritoneum corresponds more or less closely with those in the overlying muscles and skin. (31)

Both medullated and non-medullated fibers are found in the peritoneum but the latter type predominate. The non-medullated fibers end in fine meshes about the blood vessels; the varied sized medullated fibers end in the serous and subserous layers in special end-organs, the larger ones in relation to the Pacinian bodies, which are quite numerous, especially near the anterior mid-line and the finer fibers terminate as free nerve endings just beneath the endothelium and in the subperitoneal tissue.(31)

There are unquestionably some cerebrospinal fibers closely related to the base of the mesenteries to points where the dorsal mesentery has become obliterated and to the posterior parietal peritoneum in general; apparently, however, the innervation is more sparce than in the anterior parietal peritoneum. Pacinian bodies are found in comparative abundance at the base of the mesenteries.(66) Morley expressed the belief that the small or gastro-

hepatic omentum, transverse mesocolon and pelvic mesocolon were supplied with somatic nerves.

The general opinion has been that the parietal peritoneum ended at the root of the mesenteries and that the somatic innervation did not extend into the mesenteries beyond that point. Morley, however, believed that somatic nerves ran in the mesenteries to within about one to two inches of the gut as did the parietal peritoneum. The sensory innervation of the remainder of the mesenteries, and the greater omentum, he conceded to be of afferent visceral innervation the same as the intestines. There is some question as to the sensory innervation of the mesenteric vessels. The splanchnic nerves are known to parallel the vessels as they run out into the mesenteries. Some contend that the afferent splanchnic fibers innervate the vessels, but others think that somatic afferent fibers are especially related to the vessels near the base of the mesenteries. (51),(46)

(B) Sensitiveness of the Parietal Peritoneum

The first significant work on the sensitiveness of the peritoneum was done by Lennander. He, in conjunction with Ranstrom who had demonstrated the Pacinian bodies in the parietal peritoneum, tested the sensibility of these supposedly specialized endings for "pressure sense". (46)

It was found that light touch produced no sensation; strong pressure set up a cramp-like pain; cutting the parietal peritoneum caused stitch-like pain. The sense of heat and cold was not demonstrable. They concluded that the parietal peritoneum was devoid of pressure sense, but was very sensitive to pain. Hertzler in 1919 gave very similar conclusions. Light touch was not felt, but when contact either by pressure or traction reached a certain degree, pain was produced. He did believe that there was some ability to recognize movement of abdominal organs against the parietes as during peristalsis or movements of tumors, etc. Pricking the parietal peritoneum with a fine needle caused no pain but when traction in suturing existed pain resulted. (31)

Hertzler, like Mackenzie and Lemaire, believed the serosa of the parietal peritoneum to have a sympathetic sensory innervation like the visceral peritoneum which became sensitive only when inflamed and which produced referred phenomena. (49),(45)

Capps, in 1932, confirmed the conclusions of Ranstrom and Lennander that the parietal peritoneum was devoid of pressure sense. It was also found that all the anterior median and lateral areas of the peritoneum were sensitive to pain from strong pressure of a smooth object or light pressure or lateral movement of a rough

point. He concluded that this pain had all the characteristics of peripheral nerve pain especially since it was localized directly over the site of irritation. It was a direct somatic pain. (9)

Lennander was the first to emphasize the sensitiveness of the posterior parietal peritoneum along the base of the mesenteries. He found that traction on the mesenteries produced pain. This fact has been demonstrated time and time again since in abdominal operations done under local anaesthesia. For example, Kappis (37) found the small omentum, messentery of the small intestine and mesocolon highly sensitive to mechanical stimuli. Tyrrel-Gray (82) likewise emphasized the great sensibility to traction on the posterior attachments of the gallbladder, stomach and intestines. Morley found that dragging on the mesentery of the jejunum and stomach, transverse mesocolon was painful at operation. He stated that he could not agree with Cope and Lennander that the posterior peritoneum was insensitive to mechanical stimuli over the vertebra. He was of the opinion that the posterior parietal peritoneum with the mesocolon and the mesentery up to one to two inches of the small intestine was sensitive to mechanical stimuli although less so than the anterior parietal peritoneum and with a poorer power to localize. The remainder of the mesenteries and the greater

omentum were said to be insensitive to mechanical stimulation like the gut. (51)

(C) Part of the Diseased Parietal Peritoneum in Abdominal Pain

(1) Historical

Discerning workers could not fail to be impressed by the prominent part irritation of the parietal peritoneum played in pain from disease of the abdominal organs. Hilton in 1879 recognized that in peritonitis the nerves supplying the abdominal muscles and peritoneum were irritated causing pain and contraction of the muscles. He recognized that as peritonitis subsided the abdomen softened; if there was pain with rigidity he took it to indicate a peritonitis. (33) Head, 1893,(28) believed that when the peritoneum became involved that there was local pain and tenderness produced along the lines of peripheral nerves supplying the area of peritoneum involved.

It was Lennander, however, who first gave great emphasis to the role of the parietal peritoneum and mesenteries in visceral pain. As previously described, he believed that the abdominal organs were insensitive whether normal or inflamed; also, he, in association with Ranstrom,had demonstrated the rich cerebrospinal nerve supply in the parietal peritoneal subserous layer. He contended, therefore, that all visceral pain was due to

an irritation of the somatic pain fibers either at the base of the mesenteries or in the subserous layer of the parietal peritoneum or both. While a good part of Lennander's contentions remain true, still, there are certain very definite modifications that had to be made.

(2) Mesenteries

Lennander believed that all colicky pain from the gut, gallbladder, etc. were due either to a stretching of the base of the mesentery or a displacement of the parietal peritoneum on the sensitive subserosa by the violent peristaltic action. It has been shown previously in this paper that these contentions were incorrect in many respects. His contentions may apply at times where there are adhesions between the visceral and parietal peritoneum or where an exceptionally large piece of bowel and mesentery, for example, especially if it is inflamed, may cause painful traction on somatic nerves. Tyrrel-Gray (82) and also Kappis (37) supported Lennander's ideas that an inflamed mesentery especially was sensitive, that many colicky pains of the gut, appendix, and gallbladder were due to traction on the mesenteries. Tyrrel-Gray emphasized this mechanism as being especially important in visceroptosis. It has been stated that the pain of a mesenteric embolism may be due to traction on the mesentery due to the violent intestinal peristalis set up.(83)

Despite all these contentions, however, the factor of tension on the mesenteries should not be over emphasized. It does not seem likely that in most obstructive lesions as, for example, the knuckle of bowel in a strangulated hernia or gall stone, that the exaggerated peristalsis could affect Pacinian corpuscles or somatic nerves at the base of the mesenteries. But in the event of a large intussusception, a good sized intestinal or mesenteric strangulation, umbilical hernia, etc. the heavy dull aching pain of a constant character may be related to a tension on the mesenteries. Also, in regard to carcinoma of the colon when the growth is situated in a fixed part of the colon, i.e. the ascending, descending or iliac colon but not in the transverse or pelvic colon, there may be fair localization of the pain to the side of the lesion, in which case it would appear that perhaps exaggerated peristalsis above the obstruction may cause a drag upon the sensitive parietal peritoneum to which the bowel is closely adherent and thus giving rise to a unilateral somatic pain.(51)

Lennander emphasized that in inflammatory lesions of the gut and in appendicitis, cholecystitis, etc, the lymphatic drainage was to the base of the mesentery. He believed this inflammatory process rendere the cerebrospinal nerves endings at the base of the mesentery

irritable and more sensitive to traction and was an important factor in pain production.(46) There may be a deep epigastric tenderness in ulcer at times due to inflamed lymph glands situated near the lesser curvature of the stomach. (36) It cannot be denied that this is not infrequently a factor, in certain cases of deep tenderness on either side of the mid-line and pain and tenderness in the back in certain visceral inflammatory lesions, but certainly it does not deserve the emphasis that Lennander first put upon it.

(3) Adhesions

The part played by adhesions in abdominal pain has been a point of controversy for some time, and like many ideas in medicine, was marked for a time by a period of over enthusiasm as to its importance. Lennander believed that adhesions, by displacing the parietal peritoneum upon the sensitive subserous peritoneal plexus of nerves was capable of producing somatic pain and frequently did so. He believed that many of the colicky pains in biliary and intestinal disease were due to the pulling on ahdesions by increased peristalsis. (46) Mackenzie found that cutting and breaking adhesions alone was insensitive, but that when they were pulled so as to irritate the subperitoneal nerves, pain was produced. He attributed much of the pain and tenderness, often found as

a residual from laparotomies as due to adhesions.(49)

In later years, however, the repeated finding of an abdomen full of adhesions and still the absence of any previous history of pain has caused most men to believe that actually adhesions play little part in causing pain. Of course, adhesions may secondarily cause bowel obstruction and pain or bind a piece of bowel to the parietal peritoneum so that when it becomes obstructed,pain is produced by dragging on the adhesions. (31)

(4) Peritonitis

The causes and types of pain from peritoneal irritation are so numerous and complex that only a few of the more pertinent considerations can be mentioned. Experimental evidence has already been cited which showed that the parietal peritoneum even when normal had an acute appreciation of pain which was localized to the point of irritation. It is only natural that inflammation should serve to cause or to heighten the pain sensibility.

Again referring to Lennander, it was his belief that inflammation of the parietal peritoneum greatly increased the sensitiveness of the cerebrospinal nerve fibers in the parietal peritoneum and neighboring serosa; however, later in an inflammatory process, he believed the sensitiveness might become decreased. He also correctly postulated that chemically different substances such as of

the stomach, gallbladder, intestine of abscesses gave rise to pain when they contacted normal or hyperemic parietal peritoneum. He explained rigidity in peritonitis as a characteristic reflex response of the abdominal muscles to the pain originating in the peritoneum or subserous tissue. It was a protective response to limit motion of the abdominal organs and thus decrease painful irritation of the sensitive peritoneum. Lennander minimmized the importance of local tenderness, rigidity and hyperesthesia in abdominal disease before the onset of actual peritonitis in contrast to Mackenzie and Head. (46),(49),(28) In the light of present knowledge it would appear that Lennander was not far from being the more correct.

Mackenzie, recognized the great sensibility of the subserous layer of the parietal peritoneum and the possibility of a peritonitis producing great pain and tenderness by the involvement of this layer. But he observed that peritonitis produced hyperalgesia and tenderness and rigidity so readily that he thought these were due to viscero-sensory and viscero-motor reflexes arising from the "sensory sympathetics" in the serous layer of the peritoneum and produced through an irritable focus in the cord. He did admit, however, the great difficulty in distinguishing between the referred signs

and those due to the direct invasion of the external body wall; thus, in appendicitis when the inflammation extended from the serous parietal peritoneum to the abdominal wall another series of symptoms might arise produced by a different mechanism. In the immediate region of the inflammation very similar pain and associated responses would occur. Lemaire and Hertzler, it would appear, agreed with Mackenzie in regard to the insensibility of the parietal peritoneal serosa and the possibility of viscero-sensory and -motor reflexes arising from it. (45),(31)

In the light of present knowledge in regard to sensory distribution there is no reason for believing that there are any afferent sympathetic fibers in the parietal peritoneum or any place else in the body; the sensory supply to the parietal peritoneum must be through the muscular branches of cerebrospinal nerves. (9)

The usual explanation at present, therefore, as to the pain, tenderness and rigidity of a parietal peritoneal irritation is that they result from a direct involvement of the sensitive cerebrospinal nerves in the peritoneum especially in the subserosa. There is a spontaneous pain from the area of irritation in the peritoneum. There is pain on pressure, the severity of which depends upon the intensity and extent of the irritation. There

may be a bypersensibility of the skin due to an irritation of the nerve trunks in continuity with the inflamed area and consequently hyperirritability of the end-organs in the skin. Or there may only be tenderness on deeper pressure due to hypersensibility of nerve trunks near the area or by actually increasing the pressure upon nerve endings of the parietal peritoneum. Rigidity is explained as a reflex contraction of the muscles over the area involved and its extent, as well as the extent of the tenderness, gives a rather accurate estimation of the extent of the parietal peritoneal irritation. Rigidity as a reflex results from painful impulses arising from the irritated area in order to give protection from pressure and movement. The rigidity tends to be most severe at the point of initial and maximum irritation and is often found in segments of muscles, as, for example, between inscriptiones tendenial of the rectus. (15),(9),(31),(51)

Morley, in 1931, (51) elaborated considerably upon the nervous mechanism for pain, tenderness and rigidity arising from parietal peritoneal irritation, and proposed an alternate theory in place of reflex viscero-sensory and viscero-motor phenomena. His arguments were based principally upon the belief that the pain produced by stimulation of the parietal peritoneal surface

of the diaphragm was "referred" or radiated in precisely the same manner as that from the parietal peritoneum of the abdominal wall. It was his belief that the central portion of the diaphragm was of somatic and not visceral derivation as usually thought and that it was covered by typical parietal peritoneum and that its nerve supply from the phrenic consisted of "deep" somatic afferent fibers similar to those in the parietal peritoneum elsewhere. Irritation of the diaphragmatic peritoneum produced pain not in the diaphragm but in an area over the shoulder-tip innervated by the superficial distribution of the 4C nerve. Similarly he believed the irritation of the peritoneum of the abdominal wall produced a pain not felt in the peritoneum but in the superficial distribution of the nerve supplying the area of peritoneum stimulated. The only difference between the shoulder-tip pain and that of the anterior abdominal wall produced by peritoneal irritation was that in the former in the process of descent of the diaphragm the portion innervated by the deep fibers of the 4C nerve became serarated from the superficial area but in the abdominal wall the deep fibers innervating an area of parietal peritoneum directly over an area of skin and subcutaneous tissue innervated by superficial fibers of the same segment produce pain over the site of irritation. Obviously

a mechanism for this radiated pain had to be postulated; he believed it took place through the afferent somatic fibers to the peritoneum which set up an irritable focus probably in the posterior horn of the cord or posterior ganglia cells and a radiation takes place to the superficial afferent fibers. This he called a peritoneo-cutaneous radiation. The muscular rigidity from peritoneal irritation he believed to be in the nature of a peritoneo-muscular reflex via somatic afferent fibers from the peritoneum to the irritable focus and stimulation of motor fibers to the muscles of the corresponding area. Morley believed that the localized pain, the deep and superficial tenderness and muscular rigidity so commonly observed in association with inflammatory disorders of the abdomen were accounted for much more correctly and simply by his theory than by the viscero-sensory and viscero-motor reflexes.(51)

Only the test of time and further observation and experimentation will tell whether Morley's theory, which is convincing in many respects, is entirely or in part true. Davis (18) and Ogilvie (56) have spoken favorable words for it but would not deny the possibility of viscero-sensory reflexes, also.

(D) Examples of Parietal Peritoneal Irritation

(1) Stomach

The controversy brought up by Morley's contention that the local tenderness and rigidity of a peptic ulcer might be due to a parietal irritation produced by the contact of the inflamed ulcer area with the anterior parietal peritoneum, is open for considerable debate. The principal objection to the universaal application of his theory for local ulcer signs is that it does not seem quite likely that in every ulcer with localized signs, especially tenderness over the ulcer site, that there is an actual contact of the inflammatory ulcer site with the parietal peritoneum. It can not be denied, however, that often an ulcer which is perforating may not at times set up an irritation in the nature of a local peritonitis involving the anterior parietal peritoneum which is prodictive of pain, tenderness and rigidity over the area involved.

The principal peritoneal reaction in connection with ulcer is that from perforation. The pain of the primary stage of shock in a perforation is quite characteristic. It begins very suddenly and is immediately exceedingly severe and prostrating; it quickly extends over the entire abdomen, but is most marked about the ulcer site. The tenderness is also extreme and universal but generally most marked over the ulcer site. There is a continuous intense rigidity throughout. These symptoms

which may last from a few minutes to two or three hours are undoubtedly due to the pouring out of gastric contents into the peritoneum. (15) Hertzler found that a drop of the escaped fluid produced severe pain when placed on the conjunctiva; he found that dilute HCl placed on the parietal peritoneum produced pain. (31) It would seem, therefore, that it is the direct effect of the acid in the escaped contents which is the principal irritant to the peritoneal nerves. The so-called stage of reaction in perforation is marked by some lessening of the pain but despite the relief of prostration the rigidity and tenderness remain the same. The pain in this stage is probably due to the continued acid irritation and the development of peritoneal inflammation. The stage of actual peritonitis is marked by pain and tenderness which is still intense, but there is apt to be a more definite localization over the point where the maximum infection is located. In perforated duodenal ulcer it is often in the dependent right iliac fossa. The rigidity is usually less marked and there is distension of the abdomen. Terminally, the pain may disappear due to the failure of nerves to be irritable and the rigidity may disappear due to the lack of pain and to the paralysis from excessive stretching of the muscles. The pain in the inflammatory stage is apparently

mostly due to pressure and irritation of inflammatory exudate pressing on nerve terminals. (15),(36),(31)

(2)Intestines

Perforation of the intestine acts somewhat similarly to that of the stomach except that the initial period of pain and shock may not be so marked. A bacterial peritonitis, however, is the usual result. Apparently the toxicity of the material poured out into the peritoneal cavity does not have a great deal to do with the painful symptoms since a very virulent and rapidly fatal peritonitis may produce very few symptoms.(31)

Probably the principal cause of parietal peritoneal irritation and somatic pain so far as the intestines (including the omentum and mesenteries) is that resulting from obstructive lesions especially those in which the blood supply to a portion of tissue is cut off. In mesenteric thrombosis there is usually a sudden severe pain probably due to atonic or hypertonic obstruction of the affected portion of gut.Almost immediately, however, the process of necrosis begins in the mesentery and gut, and it is the irritating effects of these dying tissues which give the signs of local pain, tenderness and rigidity when they come into contact with the parietal peritoneum. Of course, later bacterial infection becomes a factor.

The less sudden shutting off of the blood supply as in a strangulated hernia of gut or omentum, or in volvulus has, however, the same effect of starting the process of necrosis. It is when there is contact of exudates from the necrosing tissues with the parietal peritoneum that pronounced localizing pain and tenderness are found over the site of the affected viscus. The pain of gangrene may subside after a period of time, probably due to death or lack of irritability of pain receptors. The advent of local abscess formation or of spreading of bacterial or necrotic material onto additional peritoneum is productive of renewed symptoms. The important point to be emphasized is that when localizing pain, tenderness, and rigidity arise in such obstructive lesions as hernia, volvulus, intussusception, tumor, etc. a peritoneal irritation must be suspected. (51),(15),(51)

(3) Appendix

The usual localizing signs of pain, tenderness and rigidity of a typical acute appendicitis which usually appear six to twenty-four hours after the epigastric pains have lessened or ceased, need not be described here. It is only when the localized spontaneous pain appears, or perhaps a short time before it appears in coms cases, that pain on pressure and muscular rigidity are found in the area over the appendix. These localizing signs of ap-

pendicitis are due to the extension of an inflammatory or necrosing process to the visceral peritoneal surface of the appendix and a dissemination of irritating toxins of the process to the sensitive parietal peritoneal surface. This is a localized peritonitis in the strict sense of the word or what has been called a periappendicitis. (31) No abscess formation or perforation has as yet taken place.

In the majority of cases these localizing reactions due to somatic nerve irritation are to be found in the right ilica fossa; often the point of maximum pain and tenderness will be found at McBurney's point. However, McBurney himself (54) stated that the point of maximum tenderness might vary from this point, and despite the mistaken idea of some that the tenderness must be at a certain point, the significant fact is that the localizing signs are not where the appendix is supposed to be but where the periappendicitis is located. Thus, if the appendix and periappendicitis are located high on the right side, if there is a left-sided appendix, if the appendix hangs low in the pelvis, the localizing signs will appear where the lesion is, that is, providing there is parietal peritoneal irritation. An inflamed pelvic appendix which has not ruptured often gives no anterior abdominal rigidity or pain and tenderness but a tenderness

by rectum may often be elicited. (15) A retrocecal appendix, as a rule, gives less pain, tenderness and rigidity and these are likely to be found posteriorly over the iliacus and quadratus lumborum muscles. (15)

There are numerous possibilities as to the subsequent course of appendicular disease after the stage of periappendicitis. Theomentum may so quickly and effectively protect the inflamed organ that even few, if any, signs of periappendicitis may appear. Or a local abscess often forms as the result of perforation and if parietal peritoneum is involved in the abscess cavity, irritation and pressure are produced and somatic signs are likely to be found.(31) The perforation of an appendix often times or the rupture of a local abscess cavity is quite often marked by a lull in the symptoms including pain due to the relief of pressure, but soon the somatic signs of a diffused peritoneal involvement appear.

(4)Gallbladder

In some respects the gallbladder and cystic duct are analogous to the appendix in that each is a tubal out-pouching from the intestine and each is subject to occlusion of its lumen and subsequent infection. Of course, stone is the common cause of biliary obstruction but cholecystitis may occur with or without the presence

of stone. (15) All degrees of cholecystitis from a simple hyperemia of the wall to gangrene and perforation may occur and the symptoms vary addordingly. It may be stated as a general rule that with the probable exception of a certain degree of deep tenderness over the gallbladder, the remainder of the localized signs of pain, tenderness and rigidity of biliary desease are due to some degree of cholecystitis.

As Morley stressed (51) it is probable that even a certain degree of local tenderness and pain may result from the mere contact of the fundus of a slightly inflamed gallbladder wall with the normal parietal peritoneum. With a somewhat more intensive inflammation of the wall and peritoneum of the gallbladder, a reaction in the peritoneal surfaces, a pericholecystitis, near the gallbladder including a local area of parietal peritoneum, especially at its point of contact with the fundus of the gallbladder. This parietal peritoneal irritation is a chemical one at this stage from the non-infectious exudate from the gallbladder wall and is productive of upper right rectus rigidity and a delimited area of tenderness in the right hypochondrium. (15),(31)

At times, the reaction jus described will be seen to progress by a gradual creeping downward of the tenderness and rigidity toward the right iliac fossa and

perhaps toward the mid-line. This indicates a spreading of the peritoneal reaction, probably bacterial in nature. (51),(15) A perforation of the gallbladder while not common, is a condition that is occasionally met with. If the perforation has been rather slow, a localized peritonitis with symptoms localized to the hepatic region occurs. (31) But on some occasions, a perforation into the general peritoneal cavity occurs with the symptoms of a generalized peritonitis resulting. Usually it is not as severe as that from ulcer and the history often serves to differentiate the two. Unchanged bile and mucus apparently produce at most only a limited degree of chemical peritonitis, but stagnant bile with infectious exudate is capable of producing intense parietal peritoneal pain, tenderness and rigidity. (31)

V

CONCLUSION

So numerous and scattered are the facts in regard to abdominal pain and its related signs and so much remains theoretical in the knowledge of the exact causation and mechanisms, that the reaction of many is one of despair amidst confusion. If, however, a more practical scheme for the evaluation of pain as a sympton is to be obtained and if progress is to be made in the more accurate scientific understanding of it, then the two principles which have led to the present understanding must be adhered to. The first is the careful observation of the facts, both objective and subjective, which have served as the basis for the remarkable deductions of the earlier workers and which must be the starting point for the present and future practical and progressive understanding of pain. Then, second, it is the intelligent interpretation of the facts in regard to pain, perhaps with the aid of some such scheme as proposed in this paper clearly in mind, that confusion will be replaced by a more practical appreciation of pain as a symptom and by forward steps in the knowledge of the anatomy and physiology of pain mechanisms.

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VI

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