THE MULTIMEDIA APPROACH TO CONTENT:
A TEACHING UNIT

by

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A FIELD STUDY

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CHAPTER I

INTRODUCTION

As the trend toward greater specialization and the extension of nursing's traditional role develops, an increasing number of nurses are looking toward graduate education to prepare them for the new responsibilities nurses are being asked to assume. (6,18,29,34,45,51) In a recent publication Brown reports that "studies indicate that the demand for nurses with advanced preparation is so critical that universities are being urged to increase provision for such preparation as rapidly as possible." (13,42,43)

It is believed by many that the answer to this discrepancy of supply and demand in the educational market lies partially in the multimedia approach to learning. (5,14,16,19,21,46) This approach achieves greater efficiency in transmitting information to students, leaving instructors more time to spend on the individual learning problems of their students. When applied to individualized self-learning situations, there is general agreement that the multimedia approach increases the effectiveness of learning by allowing the student to retain interest in the content, and to learn at his own pace. (20,23,25,32,35,57,60) A number of papers have been published on the use of multimedia and self-directed learning in the field of nursing. Several groups of nursing educators (30, 53,55) have obtained results which indicated that undergraduate nursing students showed a definite preference for the self-directed multimedia approach over the traditional lecture method of instruction. However, there was no appreciable difference in achievement between students in the lecture and multimedia groups. Students in the self-directed multimedia groups were seen to vary individually as to the amount of time required to complete designated objectives. (55) In two of these studies (30,55), it was found that a given number of faculty could instruct a larger number of students through the use of multimedia, but this was not true in a third study (53). Another nursing study (58) compared the lecture method with the use of videotapes in an introductory nursing course. They found that the students in the videotape group had higher achievement scores in nine of twelve quizzes, and no significant difference from the lecture group in two of the twelve quizzes given. Both methods of instruction were well received by the students, as indicated by a subjective response questionnaire. However, caution must be used when applying conclusions obtained from testing undergraduate students to the instruction of graduate students in nursing.

In An Abstract for Action, the National Commission for the Study of Nursing and Nursing Education made the following recommendation to nursing's educational community:

> . . . we urge the exploration of new educational technologies that can enhance learning effectiveness and efficiency. . . Without any denigration of the quality of traditional instruction, there is abudant evidence that new media and technology can be effectively applied to the teaching of the health sciences in general and to nursing in particular. . . In addition, computer-aided instruction, simulation, multimedia presentations, and technological systems can probably have a profound effect on the current lack of qualified faculty. (42)

The very nature of graduate education dictates that flexibility of the instructional program must be present so that the student can pursue his area of interest. (7) Nursing students return to graduate school with diverse experiential bases and widely varied educational backgrounds. In institutions such as the University of Oregon School of Nursing, there are too few graduate students in each special interest group of medical-surgical nursing to warrant formal instruction in these areas of emphasis. In the past, in addition to the basic graduate nursing courses, the varied educational needs of each student have been partially met (a) by encouraging non-credit independent study, (b) by advising students to audit specific medical school classes (for which nursing credit is given in special cases), (c) by permitting students to register for credit in conjoint and basic science courses in the medical school, or (d) by arranging a preceptorship with a physician for the student. In the latter case, the physician then taught the student bits and pieces of his unique skills, concepts, and knowledge. This flexibility, which is necessary in graduate nursing education, could be magnified by increasing the availability of individualized multimedia teaching programs in selected subjects. (6,10,16,19,21,23,57)

Specialization and extension of the nurse's role require that the graduate nurse gain mastery of numerous content areas not previously learned. Many of these subjects were not stressed in undergraduate education or were traditionally out of the realm of nursing, such as electrocardiography, or the skills of comprehensive physical assessment of the patient. Furthermore, the courses needed to prepare nurses to assume these responsibilities require more depth and complexity than ever before. For example, unless a nurse has had extensive clinical experience with cardiac patients, as well as coursework in cardiovascular physiology and pathophysiology, she is ill-equipped to assume responsibility for the health care management of stable cardiac patients. Nurses in innovative roles must be able to assume accountability for independent decisions and actions. An important key to competence in clinical nursing lies in an increased emphasis on the physical and biological sciences. Nurses must recognize that there will be no extended role, nor will there be excellence in nursing, without adequate knowledge and clinical experience to support them. (6,49,59) In the quote which follows, Nahm describes the present status of the basic sciences in graduate nursing programs:

> Currently, the curricula of the majority of master's and higher degree programs in nursing provide opportunities for students to broaden their background in social and behavioral sciences and to work closely with specialists in these areas. However, opportunities to broaden their background in physical and biological sciences and to work closely with specialists in these areas may be entirely lacking. The question of how best to develop courses in physical and biological sciences for nurses enrolled in graduate programs in nursing presents special difficulties. A major difficulty arises from the fact that the majority of graduates of baccalaureate programs in nursing have had only beginning courses in the physical and biological sciences, and, therefore, do not meet the requirements ordinarily considered essential for enrollment in graduate courses in these fields. Furthermore, the majority of teachers in clinical nursing areas are themselves not well prepared in physical and biological sciences and, consequently, cannot provide the science content that students need. . . Nurse faculty members, however . . . should also consider how and to what extent the large number of highly prepared scientists associated with medical and health centers could contribute to the teaching of sciences in schools of nursing. (41)

Nursing educators must look to the resources available to provide this high level of education. (54) A highly feasible resource, mentioned previously, is medical education, whenever it is readily available and proximally located. Many of the largest gaps in graduate nursing education can be filled by collaborating with physicians and medical educators in planning educational programs. (4,22,34,40,42,44,46,59) Also, multimedia teaching programs could be utilized to teach these content areas, which are basic to both medical and graduate nursing education.

At present, the cost savings which accompany the use of multimedia instructional programs in an institution, much less in a single course, are negligible. In future years, however, it is speculated that media may become relatively less costly. (60) With the predicted increase in utilization of multimedia materials, the cost per student hour should decline. Due to mass reproduction and more efficient production, media prices should decline. In addition, since faculty salaries are rising, the comparative cost advantage of multimedia instruction may increase. The cost of student time should be considered when one contemplates the cost of education. If student time is valued, then improvements in the efficiency of instruction, although more expensive, may be more effective for the cost. That is, if the multimedia approach is more efficient, the students will simply learn more for the financial input. (60)

However, in this age of increased use of multimedia as an approach to learning, there is also an inadequate supply of high quality multimedia materials being produced for the health professions by the large communications companies. (48) According to Zeckhauser (60), insufficient time, money and manpower lie behind this inadequate supply of high quality multimedia software, such as film, audiotape, videotape, etc. There is a lack of standardization in multimedia equipment (hardware). (31) As a result, software cannot be used interchangeably on all brands of hardware. Commercial software manufacturers have felt it unwise to commit large amounts of money and labor to the development of materials which will be incompatible with many brands of hardware, possibly even becoming obsolete. These conditions generally result in the production of software with limited usefulness. (60) There is no current data available to document the quality of software on the market at advanced content levels. However, software is so often produced with low budgets and sub-professional crews that it is understandable that instructional ineffectiveness, technical shortcomings, and inadequacy of content may result. (60) Some believe it will be necessary to institute standards for multimedia equipment and materials, so that an acceptable level of quality can be insured. (31)

In addition, since these teaching programs, while possibly accurate, were not developed to meet the specific needs of graduate nursing education, the purchase of these programs cannot be justified. One educator in the health sciences states, "A major limitation of most commercial materials is that they are generally of poor educational quality and designed as teaching aids rather than as instructional materials from which students can learn on their own." (48)

Educators recognize another alternative to the acceptance of the below standard or inadequate program. (2,48) That alternative is to produce multimedia instructional materials themselves, to suit the students, and thus, their own needs. In order that the full benefit be realized, these teaching programs should be adaptable to varied groups of learners, from undergraduate to graduate nursing levels, in hospital staff-development, for use by medical students, or, in some cases, in patient teaching. For example, an instructional program on the content, cardiodynamics, might begin with a unit on basic anatomy and physiology of the cardiovascular system. At this level the material could be used beneficially by all of the groups mentioned. As the content of the units became more difficult and specific, their use would naturally be more limited in scope to those students interested in learning the content in greater depth. However, that does not mean that, at advanced levels, these units would have less use by students.

As previously stated, there is a dearth of high quality, in-depth multimedia instructional materials necessary for graduate instruction. Therefore, educators must learn to make use of their own talents, creativity, and initiative to develop multimedia teaching programs which can be used in their own, and possibly other, institutions.

Statement of the Problem

There is a lack of multimedia teaching programs at the advanced content levels required for the instruction of graduate nursing students. By using the talents and the resources available in the local educational community, nursing educators can produce quality multimedia learning materials in their own institutions. In this way the problem may be partially alleviated.

Definition of Terms

The term instructional media refers to any means which an instructor may utilize to communicate with a learner. This may consist of realistic models, books, or the voice of the instructor; or it may include a variety of technological advances, such as videotapes, audiotapes, or films.

The technological media may be divided into two parts, the hardware and the software. The hardware consists of the electronic and mechanical equipment, such as the projector or tape recorder, which provides the means and energy source for the material which is presented. The slides, audiotapes, films, or videotapes that are played on this equipment are called the software.

Multimedia instruction occurs when two or more different instructional media are employed concurrently.

A multimedia teaching program implies that a certain sequence of content is presented, using a variety of instructional media. Frequently, the program will be composed of a series of units, each of which present an important concept or part of the larger program.

A storyboard is used in the creation of audiovisual materials. In this technique, the rough draft visuals and corresponding narrative are displayed together in sequence, so that they may be critiqued.

Purpose of the Study

The purposes of this study are as follows:

1. To demonstrate a procedure by which a unit of a multimedia teaching program is developed. This is to be shown by creation of an audio-visual slide presentation at an advanced content level. The slide presentation will be augmented by the use of additional media.

2. To show the adaptation of a complex concept to the multimedia learning approach.

3. To add teaching materials to the software library in the graduate division of the University of Oregon School of Nursing.

4. To provide data for a cost analysis of an institution produced teaching program.

5. To provide a unit of multimedia instruction which may be used for self-instruction by students, so that the effectiveness of this learning approach may be evaluated in a later study.

CHAPTER II

PROCEDURE

Materials and Equipment Used in This Study

The development of 35 mm slides to be used with synchronized audiotape requires the following materials and equipment:

1. Construction paper
2. Tracing paper
3. Colored pens
4. Acetate sheets- 14 inch x 17 inch
5. Press-on lettering in a variety of sizes
6. Rubber cement glue
7. Flex tape in a variety of widths and colors
8. Cutting tool- scalpel with #11 blade may be used
9. Burnishing tool
10. Large ruler
11. Paper cutter
12. Large artist's portfolio
13. Access to Xerox machine
14. Audiotape
15. Audiotape recorder
16. 35 mm color film
17. Camera and slide mounting facilities

Assessment of an Educational Need

In the introduction to this study, the graduate students at the University of Oregon School of Nursing were identified as a target group who might benefit from the multimedia approach to instruction. These students have diverse educational and experiential backgrounds, widely varied interests, and, in many cases, changing role identities. For these reasons, they exhibit a particular need for the educational flexibility which access to a multimedia teaching program would provide. In addition, it is assumed that graduate students, in general, have a relatively high level of intrinsic motivation, increasing the chance that the fullest potential might be obtained from the multimedia program to be offered. For these reasons, it was believed that these students might use this approach with favorable results.

Since the writer was a graduate student in the school of nursing, she was in a position to be aware of many of the learning needs of this target group. Therefore, it was relatively easy to ascertain a number of content areas in which instruction could be provided or improved upon by the use of multimedia materials. The most difficult task was to choose a single content area from the many which were noted, such as the genetic basis of disease processes, patient management in chronic disease, renal transport mechanisms, or regulation of cardiac output. Suggested criteria for this choice may be that an area of content has previously been difficult for the majority of students to grasp, or that the efficiency of instruction may be increased with a multimedia approach. (50)

For this study, the physiological topic, hemodynamics was chosen as the target content area. Hemodynamics is a complex topic which is difficult for graduate students to master. Furthermore, the use of multimedia appears to have the greatest value in courses which are highly organized, depend a great deal on visual presentation, contain content which is relatively inflexible, and involve minimal student participation, such as lectures in the physical or biological sciences. (60) The topic, hemodynamics, meets each of these requirements.

Determination of Local Resources

The next step was to discover the resources, materials, and equipment available at the University of Oregon Health Sciences Center. The writer felt basically equipped to guide in the method of presentation of content, and the application of the content material to clinical situations in nursing. However, expert assistance was needed in two additional areas, that of physiological content, and the use and production of multimedia materials.

Fortunately, the School of Nursing recently opened a Learning Resources Center. This center has twelve learning carrels with facilities for videotape, audiotape, 8 and 16 mm movies, slides, or filmstrips, as well as computer-assisted instruction terminals. Also, there is a sound studio with provision for videotaping and facilities for the reproduction of software. The Learning Resources Center is directed by a faculty member with a Ph. D. in educational psychology who is readily accessible to students and faculty. At present, the center is being utilized chiefly by undergraduate and graduate nursing students.

In addition to the resource just described, there is a medical graphics department, which offers a variety of services. This department has a team of artists, headed by a medical illustrator who is knowledgeable in the field of communications and the use of media. The medical graphics department has facilities, talent, and materials which may be utilized in the preparation of a multimedia teaching program.

Obviously, there are a number of specialists in the physical, biological and health sciences available in this educational community. Fortunately, the writer enlisted the cooperation of the professor of physiology who is presently responsible for the instruction of both the graduate and undergraduate nursing students in physiology. As an added advantage, this professor had been awarded a grant for the purpose of increasing the use of multimedia in the instruction of physiology for nursing students. As a result, since our objectives coincided, it was proposed and accepted that this field study be underwritten by the funds from this grant. Therefore, with the assistance of the expert in physiology and the help of the medical illustrator, the writer felt prepared to carry out the project.

Selection of the Media

In order to select the media to be used in the multimedia teaching unit, the nature of the content, the learning audience to be taught, and the means for production of the multimedia materials must be considered. As previously mentioned, hemodynamics is a complex, highly organized and abstract topic, the comprehension of which relies to some extent upon the use of mathematical relationships. The students for whom this unit was designed are generally at an advanced level of comprehension. However, there was a need for the unit to be easily adapted to a more basic level of comprehension to accommodate undergraduate students who may show an interest, or graduate students who are returning to school after a long absence. In order to be available to students at both levels of comprehension, the multimedia teaching unit has a format which is amenable to use in self-directed study. The media chosen was of a type which can be created by an amateur in the production of media. The necessary materials were easily accessible, and the production did not require the skill of an expert artist.

It was generally agreed that a sequence of 35 mm color slides synchronized with an audiotape narrative would effectively meet the requirements just described. This combination of media is easily produced by an amateur, is readily adapted to various comprehension levels, and is easily revised. After the finished product has been empirically tested and revised, the slides may then be used to transfer content to other media, such as filmstrips and videotape.

To complement the slide-tape presentation these additional media will be available for student use:

1. A written handout, which includes an overview of the areas to be covered, definitions, basic equations and diagrams pertinent to the unit.
2. A booklist of references for further study, so that the information may be clarified or expanded.
3. A typed transcript of the content will be available to the students for the purpose of review during the program.
4. A seminar is planned to include a group of students who have completed the slide-tape presentation. Clinical application of principles of hemodynamics will be stressed.
5. For many students, the slide-tape presentation will be used as an adjunct to lecture material in the required physiology courses.

Statement of the Behavioral Objectives

After the content area and the method of presentation were chosen, the behavioral objectives were formulated. It was the intention of the writer to create the multimedia teaching unit so that it could be adapted to varied levels of comprehension. There are two ways which this goal may be accomplished. The nature of the chosen media allows certain slides to be omitted for a student group from whom you expect a different level of comprehension. Or, after seeing the same unit on hemodynamics, a lower level of achievement may be required of the undergraduate student. For this reason, two sets of behavioral objectives were formulated; one for advanced comprehension and one for a basic comprehension level (see Appendix).

Formulation of Content

Keeping in mind the behavioral objectives and the nature of the media to be used, the content was outlined and compiled. It was imperative that the writer comprehend the content area completely, even though the consultation services of an expert in physiology were available. Numerous revisions were required at each stage of composition, since it was necessary that the content be correct and not misleading to the student. In this instance, it was to the advantage of the writer that she had recently learned the content material herself. For this reason, she could recall the areas which were most difficult for her to grasp. As a result, several problem areas were circumvented by providing for added examples or more detailed explanations.

The unit began at the most basic level, the definition of key terms, and built toward the application of the principles of hemodynamics in vivo. The narrative was written in full, as it would be presented in manual form. In this way, no step or transition would be omitted. Also, it was necessary to see the quantity and quality of information that could be presented in visual form before the script could be written for audiotape.

Creation of the Software

As the content narrative was being written, ideas for visuals which were immediately obvious to the writer were jotted down in the margin of the narrative text. Later, with the impetus from these impromptu visual ideas, efforts were concentrated upon converting the content of the narrative into visual form that would supplement, interpret, or replace the narrative presentation.

Several general guidelines from the research on media were applied in the design and production of the instructional materials:

1. Active learner response: Learning of content material is increased when student activity or response is required during presentation of that material. (3)
2. Repetition: The learning of concepts, facts, or single stimulus elements will be enhanced if they are repeated one or more times. (3)
3. Directing attention and cueing: By building in cues

which will cause the learner to attend to certain features, or which direct the student's attention to specific learning materials, learning may be increased. (3) Examples of this design element are arrows, underlining, color-cueing, or statements which organize materials in advance.

4. Use of color: The use of color in media design is an area which has been widely researched. There is a lack of support for the use of color to increase learning of content. (26,28,37) However, students have a tendency to respond more favorably to color material, so it is theorized that color may have the effect of added impact on the affective domain. (28,37)

5. Simplicity: It is contended that too many cues may be distracting to the student, possibly evoking competitive responses, which would reduce rather than facilitate learning. (15,38) This is believed to be of particular importance when the students have no control over the amount of time they may spend with each visual. (24)

The storyboard stage followed. In this stage, a rough draft of each slide was made, using colored ink on tracing paper. The content was divided into several sections. In sequence, these sections were presented to the expert consultants for their advice and approval. Initially, the writer received conflicting, and sometimes frustrating advice from the two specialists. This was due to a difference of opinion on how best to communicate the content material. These problems were alleviated by holding frequent conference meetings with both consultants and the writer present. In this way, each member of the team began to understand the rationale for action by the other team members. Therefore, an integration of purposes resulted.

As each group of visuals was approved, the actual layout of the slide was created on a larger sheet of construction paper. All visuals to be photographed were created within a work area which corresponded to the proportions of the actual slide. These layouts were made on a twelve inch by eight and one-fourth inch format, surrounded by a two and one-half inch border.

The visuals were prepared using materials which were readily obtained and easily used by the amateur to produce quality slides. In this way it was shown that any interested educator, who has the time, can create slides for a multi-media teaching program. Needless to say, the writer of this study gained valuable experience, which will be helpful in future teaching situations.

When all the visual layouts were completed, a final evaluation session was held with the consultants. The visual layouts were then photographed in sequence. To insure proper sequencing of the visuals the writer was present during filming. It must be emphasized that the creation of this multimedia teaching unit required constant evaluation. Changes may even be necessary in the completed slides, if the format is not accurate, or evaluations show that the slide does not convey the intended message.

In the next step, which is yet to be completed, the narrative must be edited for audiotaping. The audio portion should complement, not just duplicate, the slide presentation. Therefore, in general, the student's reading ability should not be questioned by duplicate wording on the audiotape. However, since each viewer sees a visual in his own unique way, if the visual is to convey the intended meaning, the narrator must take responsibility for insuring that interpretation. The audiotape narrative interprets, emphasizes, explains, and gives audio cues to the student.

Provision for Evaluation of Student Progress

It was necessary to formulate plans for the evaluation of student response, so that the effectiveness of this multimedia teaching program could be discerned in further study. It is recommended that evaluation be carried out at three levels. Prior to beginning the hemodynamics teaching unit, diagnostic evaluation of each student should be done. Notation could be made of the student's experiential and educational background, such as Graduate Record Examination scores, grade point average, previous courses in mathematics or physical and biological sciences. At this time a brief pretest, covering the basic concepts of hemodynamics, could be administered. When the diagnostic evaluation has been completed, the student may begin section I of the program, which describes the general principles governing blood flow.

The next type of evaluation to be employed, formative evaluation, is useful in guiding the student through the learning sequence. It enables the learner to evaluate himself as he progresses through the program. A brief recall quiz is built into section I, directly following the presentation of the symbols and definitions of key terms in hemodynamics. The students are given a slide, which shows the symbols only, and are asked to try to recall the definition and term which corresponds to each symbol. If they are unable to recall these facts, they are advised to refer to their handout before continuing with the lesson. In addition, at the end of section I a short break is provided for the students. At this time it is advised that a brief quiz be administered to evaluate comprehension of the general principles which determine blood flow. It is important that these relationships be understood before the student progresses to the next section of study.

When section II also has been completed, the student should be given ample time for review of the handout, for additional study from the references provided, and, if the student requests, an opportunity to see the slide-tape presentation again. When the student is fully satisfied that he has completed the multimedia unit in hemodynamics, summative evaluation may be done. This will consist of an examination covering the behavioral objectives previously outlined by the writer, as well as a subjective response to obtain student impressions of the unit. As stated, different behavioral objectives will be required of students at different levels of entry into the program, either graduate or undergraduate nursing students. If possible, a test for retention of content material should be given the student at a later date.

CHAPTER III

THE TEACHING UNIT

Included in the teaching unit are the content narrative, Hemodynamics, and a set of slides. In addition, each student will be given two handouts, a study guide and a list of references for further study.

The Content Narrative

HEMODYNAMICS

The Study of the Movement of Blood

(Slide 1)

The efficiency of cellular metabolism depends upon an adequate rate of blood flow throughout the tissues of the body. For this reason, hemodynamics, the study of the physical aspects of blood flow, assumes vital importance for the practicioner. In order to appreciate the effects of various disease processes on the cardiovascular system, the concepts of hemodynamics must be mastered. (Slide 2)

In order to understand hemodynamics, which is the study of the physical aspects of blood flow, it is necessary to learn some principles of simple fluid dynamics.

Fluid dynamics, the science of the forces involved in producing the motion of liquids, uses mathematical equations to describe how simple fluid systems behave under specific conditions. These mathematical relationships apply when the following criteria are met: (Slide 3)

1. Steady flow: The flow of fluid is continuous, non-pulsatile, and does not vary with time.
2. Newtonian fluid: The fluid is a simple homogenous liquid, such as water, which exhibits laminar flow and a constant viscosity.

3. Rigid container: The vessels or tubes are rigid with dimensions which do not vary.

Blood flow in the human circulatory system does not meet these special conditions, for the following reasons: (Slide 4)

1. Pulsatile flow: As a result of the heart's pumping action, blood flow is pulsatile, not steady.
2. Complex suspension: Blood is not a simple Newtonian fluid. Instead, it is a complex suspension of platelets, red and white blood cells, proteins, and lipids, suspended in a salt solution.
3. Compliant container: The blood vessels of the body are compliant tubes with varying dimensions, not the rigid tubes required in the equations which describe simple fluid movement.

(Slide 5) Despite these apparent discrepancies, the laws of blood flow approximate the simpler laws of fluid dynamics well enough for us to apply them to hemodynamics. Therefore, the principles of fluid dynamics which follow will provide insight into the mechanics of blood flow in the more complex human circulatory system.

Definitions (Slide 6)

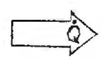
Before proceeding any further, it is necessary to clarify the meaning of certain terms which will be referred to repeatedly in this lesson.

1. Proportion (Slide 7) describes a relationship of

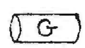
numbers. The symbol $\propto$ is used to indicate proportionality. Numbers may be proportional in two different ways:

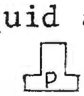
a. <u>Directly</u>: as x increases, y increases; as indicated by $x \propto y$ or $y \propto x$.

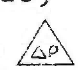
b. <u>Inversely</u>: as x increases, y decreases; as indicated by $x \propto 1/y$ or $y \propto 1/x$.

2. <u>Flow</u> (Slide 8) is the change in volume per unit time. The symbol  or $\dot{Q}$ is used for blood flow.

3. <u>Resistance</u> (Slide 9) is the impediment to blood flow ($\dot{Q}$) through a vessel. The symbol  or R is used to indicate resistance.

4. <u>Conductance</u> (Slide 10) is the measure of the amount of blood volume that can pass through a vessel in a given time ($\dot{Q}$) for a given pressure difference. The symbol  or G is used for conductance. It is the reciprocal of resistance, so $G = 1/R$. In other words, as resistance increases, conductance decreases; or as resistance decreases, conductance increases.

5. <u>Pressure</u> (Slide 11) is defined as force per unit area and is usually expressed in terms of a height of a column of liquid above an arbitrary reference point. The symbol  or P is used for pressure.

6. <u>Difference</u> (Slide 12) between two quantities is indicated by the sign $\triangle$. For example, (Slide 13) <u>pressure difference</u> is $\triangle P$, and is symbolized by .

7. <u>Velocity</u> (Slide 14) is the distance that a particle moves in a given period of time. The symbol  or V is used for velocity.

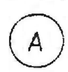
8. <u>Viscosity</u> (Slide 15), or fluid friction, is the internal resistance to motion of fluid itself. Viscosity tends to retard flow ($\dot{Q}$), and thus, is one of the components of resistance. The symbol  or η, the Greek letter eta, is used for viscosity.

9. <u>Compliance</u> (Slide 16), or capacitance, is the volume change produced by a unit of pressure change. The symbol  or C is used for compliance. The explanations in this lesson deal mainly with rigid tubes which have no compliance. However, in vivo, this variable is very important. The arteries of an aged person or the patient with arteriosclerosis will exhibit a low compliance, when compared to those of the young, healthy adult.

10. In the diagrams which follow (Slide 17), the physical dimensions of vessels will be indicated by these corresponding symbols. You are already familiar with the definitions of these terms:

    a. <u>Radius</u> is  or r.

    b. <u>Length</u> is  or L.

    c. <u>Area</u> is  or A.

To summarize (Slide 18), we will briefly review the symbols.

Before going on with the lesson, let's see if you can match the terms we just discussed with their symbols. Here are the symbols (Slide 19). See if you can remember which term corresponds with each symbol, and if you can recall the meaning of the terms.

And here are the matched terms (Slide 20). If you are unsure of any of the symbols or definitions for these terms, please review the definition section of this lesson or the handout before proceeding to the next section.

Relationships Between
Pressure, Flow, and Resistance

To begin (Slide 21), we will look at the basic relationships between pressure, flow, and resistance. Flow ($\dot{Q}$) through a blood vessel is determined by two factors: (Slide 22)

1. The pressure difference ($\triangle P$) tending to push blood through the vessel.
2. The resistance (R), or impediment to blood flow ($\dot{Q}$) through the vessel.

As an illustration, consider the vessel in this diagram (Slide 23). P_{in} represents the pressure at the origin of the vessel. P_{out} is the pressure at the other end of the tube. P_{in} is greater than P_{out}, so a pressure difference ($\triangle P$) is present. This pressure difference between the two ends of the vessel causes fluid to flow from the high pressure area to the low pressure area, while the resistance (R), within the fluid itself (viscosity) and along the walls of the vessel (friction), impedes the flow ($\dot{Q}$) of blood.

It is important to emphasize that it is the *difference* in pressure (ΔP) between the two ends of the vessel that determines the flow ($\dot{Q}$), and it is *not* the absolute pressure in the vessel. For example, (Slide 24) here are three vessels, all with an equal amount of resistance. In the top vessel, if the pressure at both ends were 150 mm Hg, and no difference in pressure existed between the ends, there would be no flow, despite the presence of a pressure of 150 mm Hg in the vessel. Likewise, if you had two identical tubes filled with the same fluid, as in the middle and bottom vessels shown here, one with a P_{in} of 200 mm Hg and a P_{out} of 150 mm Hg, and the second with a P_{in} of 400 mm Hg and a P_{out} of 350 mm Hg, the flow ($\dot{Q}$) would be the same in both tubes, since the pressure difference (ΔP) in each is 50 mm Hg.

Several general statements can be made to describe the basic relationships between pressure difference (ΔP), flow ($\dot{Q}$), and resistance (R).

1. (Slide 25) When resistance (R) is held constant, if the pressure difference (ΔP) is increased, the blood flow ($\dot{Q}$) increases. Conversely, if the pressure difference (ΔP) is decreased, the blood flow ($\dot{Q}$) decreases also. So, blood flow ($\dot{Q}$) is directly proportional to pressure difference (ΔP).

$$\text{Blood Flow} \propto \text{Pressure Difference} \quad \text{or} \quad \dot{Q} \propto \Delta P$$

2. (Slide 26) At a constant pressure difference, as the resistance (R) increases (and therefore the conductance, G, decreases), the blood flow ($\dot{Q}$) decreases. Conversely, as the resistance (R) decreases (conductance, G, increases), the blood flow ($\dot{Q}$) increases. Therefore, (Slide 27) blood flow ($\dot{Q}$) is inversely proportional to resistance (R).

$$\text{Blood Flow} \propto \frac{1}{\text{Resistance}} \quad \text{or} \quad \dot{Q} \propto \frac{1}{R}$$

However, blood flow ($\dot{Q}$) is directly proportional to conductance (G).

$$\text{Blood Flow} \propto \text{Conductance} \quad \text{or} \quad \dot{Q} \propto G$$

3. In summary, (Slide 28) blood flow ($\dot{Q}$) increases as pressure difference (ΔP) increases, as resistance (R) decreases, or as conductance (G) increases. These important relationships between pressure, flow, and resistance are expressed mathematically as follows: (Slide 29)

$$\text{Blood Flow } (\dot{Q}) = \frac{\text{Pressure Difference } (\Delta P)}{\text{Resistance (R)}}$$

or

$$\text{Blood Flow } (\dot{Q}) = \text{Pressure Difference } (\Delta P) \times \text{Conductance (G)}$$

Pressure Difference and Flow

Now (Slide 30) we will more closely examine the relationship between <u>pressure difference</u> (ΔP) and flow ($\dot{Q}$), putting resistance (R) aside for a moment by keeping it constant throughout the illustrations which follow. As previously stated, pressure difference (ΔP) is a principal determinant of blood flow ($\dot{Q}$), (Slide 31) since flow is directly proportional to the difference between inflow and outflow pressures.

$$\dot{Q} \propto P_{in} - P_{out}$$

In the vascular bed, P_{in} is the mean arterial pressure and P_{out} is the central venous pressure. Blood flow through the living system is directly proportional to this pressure difference.

Please remember that pressure (P) is often expressed as the height of a column of fluid above an arbitrary reference point. It is usually measured in mm Hg or cm H_2O.

To understand this concept more clearly, we will watch what happens to the flow ($\dot{Q}$) in the tubes connecting the reservoirs in several examples.

1. In the first example (Slide 32), reservoir A is filled to height 1, so the inflow pressure to the tube, P_{in}, equals 1. Reservoir B is empty so the pressure at the outflow end of the tube, P_{out}, is zero. Under these circumstances, let's assume that the flow ($\dot{Q}$) through the tube is 5 ml/sec.
2. In the second example (Slide 33), if reservoir B remains empty and the pressure at the outflow end of the tube, P_{out}, stays zero, but the height (and therefore, pressure at P_{in}) of reservoir A is

doubled to level 2, the flow ($\dot{Q}$) will be twice as great, 10 ml/sec. So, when reservoir B is empty and P_{out} is zero, the flow is directly proportional to the inflow pressure, P_{in} (which, under these circumstances, is also the difference in pressure). In other words, as the P_{in} was doubled, the flow ($\dot{Q}$) also doubled.

3. In example three (Slide 34), if the fluid level in A remains at 2, but the level in reservoir B is increased from zero to 1, the flow ($\dot{Q}$) will again be 5 ml/sec, since the pressure difference ($\triangle P$) between P_{in} and P_{out} is identical to that in the first example. Comparison of examples two and three also shows that flow ($\dot{Q}$) is directly proportional to the difference between inflow and outflow pressures. That is, when the difference between the two pressures decreased, the flow ($\dot{Q}$) decreased.
4. In the final example (Slide 35), when the fluid level of reservoir B rises to the height of reservoir A, flow ($\dot{Q}$) will cease, since there is no difference in pressure ($\triangle P$) between P_{in} and P_{out}.

Resistance

Now we will look at <u>resistance</u> (R) in more detail. (Slide 36) The resistance term is composed of:

1. The physical dimensions of the resistance vessel or tube, which are the length (L) and the radius (r);

2. The viscosity (η) of the fluid.

To begin the discussion (Slide 37) we will hold both pressure difference (ΔP) and viscosity (η) constant. We will concentrate on how changes in the physical dimensions of resistance vessels affect flow ($\dot{Q}$).

1. (Slide 38) First we will discuss the <u>length</u> (L) of the tube. In the top figure, the tube connected to the reservoir has a length of 1 unit and a radius of 1 unit. With these dimensions suppose the flow ($\dot{Q}$) from the tube is 10 ml/sec.

   In the bottom figure, the tube has the same radius, but is twice as long as the tube shown in the top figure. The flow from the tube in the bottom figure is only 5 ml/sec, which is one half as much as that shown for the top figure.

   So, (Slide 39) as the length (L) of the resistance vessel increases, flow ($\dot{Q}$) decreases. Conversely, as the length (L) decreases, flow ($\dot{Q}$) increases. Thus, flow ($\dot{Q}$) is inversely proportional to the length (L) of the resistance vessel.

$$\dot{Q} \propto \frac{1}{L}$$

2. <u>Radius</u> (r) of the tube (Slide 40) also affects resistance (R), and thus, flow. In this example, the length of the tube in the bottom figure is the same as that in the top figure, but the radius (r) is twice as large. Doubling the radius causes the

flow to increase from 10 ml/sec to 160 ml/sec, or sixteen times.

So, (Slide 41) as the radius (r) is increased, the flow ($\dot{Q}$) is increased. Conversely, as the radius (r) is decreased, the flow ($\dot{Q}$) is decreased. To be more precise, flow ($\dot{Q}$) varies directly as the fourth power of the radius (r^4) of the resistance vessel.

$$\dot{Q} \propto r^4$$

For example, (Slide 42) for a radius increase from 1 unit to 2 units, $r^4 = 2 \times 2 \times 2 \times 2 = 16$, which is sixteen times greater than 1, the r^4 value if the radius is 1 unit. Carried further, if the radius is then increased to 4 units from 2 units, the $r^4 = 4 \times 4 \times 4 \times 4 = 256$, which is sixteen times greater than 16, the previous r^4 value. Thus, changing the radius (r) of a blood vessel has a profound effect on blood flow ($\dot{Q}$). From this example, it is obvious why the patient with an iliac artery which is partially occluded due to intravascular clotting may have a greatly reduced flow of blood to his extremity.

(Slide 43) The second variable affecting resistance to flow is the <u>viscosity</u> (η) of the fluid. For any given pressure difference (ΔP) and tube dimensions, flow ($\dot{Q}$) will vary according to the nature of the fluid itself. (Slide 44) Under these conditions, as viscosity (η) increases, flow ($\dot{Q}$)

decreases. Conversely, as viscosity (η) decreases, flow ($\dot{Q}$) increases. So, viscosity (η) is inversely proportional to flow ($\dot{Q}$).

$$\dot{Q} \propto \frac{1}{\eta}$$

As a simple illustration of this relationship, consider the common-sense example seen when the flow of water is compared to the flow of honey, or the very viscous fluid, vaseline. Clearly, flow decreases as the viscosity of a fluid increases, as long as pressure difference and the physical dimensions of the vessel are held constant. Therefore, the greater the viscosity (η), the slower the flow ($\dot{Q}$).

Poiseuille's Law

The factors which affect flow may be summarized in one descriptive equation, called Poiseuille's Law. (Slide 45) We have previously shown that flow ($\dot{Q}$) is directly proportional to radius to the fourth power (r^4) and pressure difference ($\triangle P$), and is inversely proportional to viscosity (η) and length (L) of the resistance vessel.

$$\dot{Q} \propto r^4 \text{ and } \triangle P$$

$$\dot{Q} \propto \frac{1}{\eta} \text{ and } \frac{1}{L}$$

Hence, this knowledge may be combined to read: (Slide 46)

$$\dot{Q} \propto \frac{r^4}{\eta} \times \frac{\triangle P}{L}$$

In order to replace the proportionality sign with an equal sign, we must insert a proportionality constant, K. (Slide 47)

$$\dot{Q} = K \times \frac{r^4}{\eta} \times \frac{\Delta P}{L}$$

In this case the constant, K, equals $\frac{\pi}{8}$. Therefore, Poiseuille's Law states: (Slide 48)

$$\dot{Q} = \frac{\pi}{8} \times \frac{r^4}{\eta} \times \frac{\Delta P}{L}$$

This final equation (Slide 49) is the mathematical expression of Poiseuille's Law without the familiar symbols.

In review: (Slide 50)

1. Flow ($\dot{Q}$) varies directly with pressure difference (ΔP) and the fourth power of the radius (r^4) of the tube. Flow increases as the pressure difference or radius of the tube increases. Flow decreases as the pressure difference or the radius of the tube decreases.
2. Flow ($\dot{Q}$) varies inversely with the length (L) of the tube and the viscosity (η) of the fluid. So flow decreases as the length of the tube or the viscosity of the fluid increases; and flow increases as the length of the tube or the viscosity of the fluid decreases.

Relationships of Velocity, Flow, and Area

Now we will discuss the relationships of velocity, flow and area. (Slide 51) What happens when the cross-sectional <u>area</u> of flow is increased or decreased? A new variable, <u>velocity</u> (V), is introduced. The initial definitions told us that:

1. Flow ($\dot{Q}$) (Slide 52) is a change in volume per unit time and is expressed in terms such as ml/sec.
2. Velocity (V) (Slide 53) is the distance that a particle moves per unit time. Velocity is expressed in terms such as cm/sec, or the familiar, mi/hr.

Stated mathematically, the relationship of velocity (V) to flow ($\dot{Q}$) is as follows: (Slide 54)

$$\text{Velocity} = \frac{\text{Flow}}{\text{Area}} \quad \text{or} \quad V = \frac{\dot{Q}}{A}$$

It may also be written as:

$$\text{Flow} = \text{Velocity} \times \text{Area} \quad \text{or} \quad \dot{Q} = V \times A$$

To explain further, (Slide 55) when flow is kept steady in a rigid tube, such as the one shown here, the volume of fluid passing by a certain point in that tube will stay constant. If the area (A) through which that flow ($\dot{Q}$) is passing is increased, the velocity (V) of the fluid decreases. Therefore, it can be said that velocity is slowest where the cross-sectional area of the tube is the greatest. Conversely, velocity is greatest where the cross-sectional area of the tube is smallest. This means that velocity (V) varies inversely to the cross-sectional area (A) of flow.

$$V \propto \frac{1}{A}$$

The next slide (Slide 56) illustrates this principle in more detail. When the same volume of fluid per second (flow) passes from section a to section b, where the cross-sectional area is five times greater, the velocity of flow decreases to one-fifth that of the previous value. Proceeding to c, where the area is one-tenth as great, the velocity of the fluid must increase tenfold to provide the same flow.

How does this principle affect blood flow in the body? (Slide 57) In the body there are large variations in total cross-sectional area of the vascular bed. This graph (Slide 58) shows these variations as the total cross-sectional area of flow gradually increases from the aorta to the capillary beds and then decreases again on the return to the right side of the heart.

(Slide 59) At a constant mean blood flow through the vascular tree the velocity of flow gradually decreases to a minimum in the capillary beds, where the total cross-sectional area is greatest, and increases in the veins as the cross-sectional area decreases. This change in velocity is illustrated by the dark blue curve in the graph.

An equation (Slide 60), called the Continuity Equation, summarizes the relationship between velocity (V) and cross-sectional area (A) when the flow ($\dot{Q}$), or cardiac output is constant. The Continuity Equation states that, at constant cardiac output, the velocity of flow multiplied by the cross-sectional area of flow is at all points the same.

For example (Slide 61), at a given cardiac output the flow ($\dot{Q}$) through the aortic valve must equal the flow through the systemic capillary bed, as well as the flow through the veins. Therefore, the product of the velocity (V) of blood flow and the cross-sectional area (A) through the aortic valve must equal the product of the velocity of blood flow and cross-sectional area in the capillary beds, and the product of the velocity of flow and cross-sectional area of the veins, as follows:

$$\text{Since; } \dot{Q} = V \times A$$

$$\text{And since; } \dot{Q}_{\text{Aortic valve}} = \dot{Q}_{\text{Capillary beds}} = \dot{Q}_{\text{Veins}}$$

$$\text{Then; } V_{AV} \times A_{AV} = V_{CB} \times A_{CB} = V_V \times A_V$$

Resistance to Flow in Vivo (Slide 62)

We will now look at how resistance affects blood flow in the living body. In a previous section we examined basic principles of blood flow, concluding that flow ($\dot{Q}$) is directly proportional to the fourth power of the radius (r^4) and the pressure difference (ΔP), and is inversely proportional to viscosity (η) of the fluid and the length (L) of the resistance vessel. (Slide 63)

$$\dot{Q} \propto \left\{ r^4 \text{ and } \Delta P \right.$$

$$\dot{Q} \propto \left\{ \frac{1}{\eta} \text{ and } \frac{1}{L} \right.$$

These principles were summarized by Poiseuille's Law in this way: (Slide 64)

$$\dot{Q} = \frac{\pi r^4 \Delta P}{8 \eta L}$$

In order to isolate the factors which create resistance (R) to flow, we will break down the components of Poiseuille's

Law.

Flow (Q) also equals the conductance (G) multiplied by the pressure difference (ΔP): (Slide 65)

$$\dot{Q} = G \times \Delta P$$

Therefore; (Slide 66) $G \times \Delta P = \frac{\pi r^4 \Delta P}{8 \eta L}$

Since both sides of the equation contain the term, pressure difference (ΔP), it may be cancelled out to yield: (Slide 67)

$$G = \frac{\pi r^4}{8 \eta L}$$

Since conductance (G) is the reciprocal of resistance (R), G = 1/R, the following equation shows the factors affecting resistance: (Slide 68)

$$R = \frac{8 \eta L}{\pi r^4}$$

The constant $\frac{8}{\pi}$ can be removed to yield: (Slide 69)

$$R \propto \frac{\eta L}{r^4}$$

This last equation may be broken down further to show that the resistance (R) of a vessel is directly proportional to the blood viscosity (η) and the length (L) of the vessel, but inversely proportional to the fourth power of the radius (r^4) of the vessel. (Slide 70)

$$R \propto \eta \qquad R \propto L$$

$$R \propto \frac{1}{r^4}$$

However, in vivo in the cardiovascular system the length (L) of the blood vessels and viscosity (η) of the blood stay relatively constant, so resistance (R) is altered chiefly by variations in the radius (r) of the blood vessels in the body. (Slide 71)

All blood vessels in the body have a certain amount of resistance. (Slide 72) However, the arterioles offer the major resistance in the vascular bed, and thus, are called the main resistance vessels.

The blood vessels of the cardiovascular system are arranged so that their resistances are both in series and parallel to one another. What do we mean by these two terms, series and parallel?

1. (Slide 73) In a series route, the blood flows through several resistances (R) in sequence, one after the other. There is no alternate route of flow. For example (Slide 74), the various types of vessels, which are pictured in cross-section, from the aorta, to arteries, arterioles, capillaries, venules, veins, and then vena cava are connected in series with one another. Hence, blood flows through each in sequence.

   Note (Slide 75) the variation in radius of the vessel lumen (indicated by green circle), and, thus, variation in the amount of resistance to flow that each type of vessel exhibits since:

$$R \propto \frac{1}{r^4}$$

2. (Slide 76) The second type of resistance in the vascular bed is parallel resistance, in which blood may flow through any one of two or more vessels simultaneously. In a single circulation through the body a given red blood cell can flow through any one parallel pathway, but not all at the same time.

In vivo the many blood vessels are arranged in both series and parallel circuits. (Slide 77) This diagram illustrates this relationship. Blood is pumped from the left ventricle through the aorta to a number of parallel circuits. Blood may flow in these circuits to either the head, trunk, arms, the pelvic organs, or to other parallel routes. In addition, although the splenic and mesenteric beds are in parallel with one another, both are in series with the portal bed. Notice that in the kidney there are two capillary beds in series with one another. Remember, also, that each set of parallel vessels includes a set of series vessels, namely the artery, arteriole, capillary, venule and vein. Blood flow through the lungs is in series with all other capillary beds of the body.

The amount of resistance (R), or impediment to blood flow, varies greatly as the blood makes its circuit through the body. This resistance cannot be measured by any direct means, but must be calculated using the mathematical relationships between pressure difference (ΔP) and flow ($\dot{Q}$). First, we must go back to the familiar equation for flow: (Slide 78)

$$\dot{Q} = \frac{\Delta P}{R}$$

And note that it may be rearranged to read;

$$R = \frac{\Delta P}{\dot{Q}} \quad \text{or} \quad R = \frac{P_{in} - P_{out}}{\dot{Q}}$$

So, this equation tells us that resistance (R) equals the difference in pressure (ΔP) at the inflow and outflow points, divided by the blood flow ($\dot{Q}$) through the vessel. Hence, if we can measure P_{in} and P_{out} and determine blood flow, we can calculate resistance. Let's proceed to examine the way in which the two types of resistance, series and parallel, are calculated.

1. Resistance in series: This diagram (Slide 79) shows a vessel with three resistances in series, R_1, R_2, and R_3. In man, R_1 might represent the resistance to flow in the arteries, R_2, the resistance of the arterioles and capillaries, and R_3, the resistance of the veins. The pressure at the initial inflow point, P_{in}, would be that in the root of the aorta, and the pressure at the outflow of the vessel, P_{out}, could be that of the right atrium where the blood returns to the heart.

   (Slide 80) The pressure difference (ΔP) from inflow to outflow consists of the sum of the individual pressure differences across the three resistances from P_{in} to P_1, from P_1 to P_2, and P_2 to P_{out}. Let's look more closely at this equation: (Slide 81)

$P_{in} - P_{out} = (P_{in} - P_1) + (P_1 - P_2) + (P_2 - P_{out})$

or; $\Delta P_{Total} = \Delta P_1 + \Delta P_2 + \Delta P_3$

As we discussed earlier, the flow ($\dot{Q}$) stays constant through each part of the system, that is, the blood volume passing through each segment per minute ($\dot{Q}$) is the same. The pressure difference (ΔP) at the several resistance areas may be divided by the constant flow ($\dot{Q}$) to calculate the series resistance, as follows: (Slide 82)

$$\frac{\Delta P_{Total}}{\dot{Q}} = \frac{\Delta P_1}{\dot{Q}} + \frac{\Delta P_2}{\dot{Q}} + \frac{\Delta P_3}{\dot{Q}}$$

Therefore, (Slide 85) since $R = \frac{\Delta P}{\dot{Q}}$, then;

$$R_{Total} = R_1 + R_2 + R_3$$

(Slide 84) These equations show that <u>the total resistance equals the sum of the individual resistances in series</u>. In man, this would mean that part of the individual resistances in the arteries, arterioles and capillaries, and veins.

2. <u>Resistance in parallel</u>: (Slide 85) The concept of conductance (G) will help you to understand how resistances in parallel are calculated. Previously, conductance was defined as the amount of blood volume than can pass through a vessel in a given time ($\dot{Q}$)

for a given pressure difference. Conductance is the reciprocal of resistance, so G = 1/R. Recall also that: (Slide 86)

$$\dot{Q} = \frac{\Delta P}{R} \qquad \text{and} \qquad \dot{Q} = \Delta P \times G$$

Now let's apply this information to calculate resistances (R) in parallel. (Slide 87) This diagram shows three conductances (G) in parallel, all connected to identical inflow and outflow vessels. For a given pressure difference (ΔP), a greater volume of blood will flow through all three parallel vessels than through any one of the vessels alone. Therefore, the total conductance for all three is greater than the conductance of any one of the single vessels in parallel. In fact, the total conductance equals the sum of the individual conductances. (Slide 88)

$$G_{Total} = G_1 + G_2 + G_3$$

Since conductance is the reciprocal of resistance (G = 1/R), 1/R may be substituted for G to yield:

$$\frac{1}{R_{Total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

In order to calculate the total resistance, both sides of the equation must be multiplied by R_{Total} (Slide 89) to yield:

$$1 = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) R_{Total}$$

And then divided by $(1/R_1 + 1/R_2 + 1/R_3)$, which changes the equation to;

$$R_{Total} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

Therefore, (Slide 90) for parallel circuits the total resistance is less than the resistance for any one of the individual vessels.

For example (Slide 91), let $R_1 = R_2 = R_3 = 3$ resistance units. Using the above equation:

$$R_{Total} = \frac{1}{\frac{1}{3} + \frac{1}{3} + \frac{1}{3}}$$

$$R_{Total} = \frac{1}{1} = 1$$

The total resistance is 1, which is less than any one of the individual resistances of 3 units.

Total Peripheral Resistance (TPR)

(Slide 92) Now let's see how resistance is determined clinically in the body by calculation of the total peripheral resistance (TPR). The TPR is the resistance offered to the total output of the heart by all of the peripheral vascular bed. It is the aortic pressure minus the central venous pressure (P_{cv}), divided by the total flow through the system, the cardiac output. Notice that this is the same as $R = \Delta P/\dot{Q}$:

$$TPR = \frac{P_{aortic} - P_{cv}}{\text{Cardiac Output}} \quad \begin{matrix}\text{in mm Hg} \\ \text{in ml/sec}\end{matrix}$$

The unit of measure of the total peripheral resistance is the peripheral resistance unit, or PRU.

It should be noted that since the systemic circulation consists of many series vessels which are in parallel with other vessels, the total peripheral resistance is always less than the resistance through a particular organ or limb.

(Slide 93) TPR varies in different physiological states. For instance, in essential hypertension the TPR is increased, due chiefly to the narrowing of the resistance vessels in the vascular bed. Conversely, during exercise, the total peripheral resistance in man falls below that at rest. This decrease in TPR enables a greater blood flow throughout the body without requiring a large increase in blood pressure.

Summary and Review

During this lesson a great deal of information has been presented. Therefore, it is important to review this material.

We have seen that flow ($\dot{Q}$) through a blood vessel is determined by a number of factors: (Slide 94)

1. Flow is directly proportional to the pressure difference (ΔP) tending to push blood through the vessel.
2. The resistance (R), or impediment to blood flow, is inversely proportional to flow. Resistance itself is composed of several factors. Flow is inversely proportional to the length of the vessel and the

viscosity of the fluid, and is directly proportional to the fourth power of the radius of the vessel. These relationships are summarized in Poiseuille's Law. (Slide 95)

In addition (Slide 96), we discovered that velocity of flow decreases as the cross-sectional area of flow increases. So, velocity is inversely proportional to area. (Slide 97) The relationship between velocity and the total cross-sectional area is described by the Continuity Equation. The Continuity Equation states that, at constant cardiac output, the velocity of flow multiplied by the cross-sectional area of flow is at all points the same.

The components of resistance (Slide 98) were isolated to show what part they played in the creation of resistance to flow. Alteration in the radius of the blood vessels of the vascular bed was identified as the chief cause for variations in the amount of resistance in the living body.

(Slide 99) We have learned that the blood vessels of the cardiovascular system are arranged so that their resistances are both in series and parallel to one another. Resistance to flow for each was calculated. For resistances in series, the total resistance equals the sum of the individual resistances in series. When calculating resistances in parallel vessels, the total resistance is less than the resistance for any one of the individual vessels.

(Slide 100) To show how resistance is determined clinically, the concept of total peripheral resistance was presented. The TPR is the resistance offered to the total output of the heart by all of the peripheral vascular bed. TPR is the difference between aortic and central venous pressures, divided by the total flow through the system, the cardiac output.

Comprehension of hemodynamics provides a foundation upon which a knowledge of pathophysiology may be built. Knowledge of pathophysiology may then be applied in patient assessment and appropriate nursing intervention. (Slide 101)

Hemodynamics Study Guide

Definitions

1. Proportion ($\propto$) describes a relationship of numbers, which may be proportional in two different ways:
   a. Directly: as x increases, y increases; as indicated by $x \propto y$ or $y \propto x$.
   b. Inversely: as x increases, y decreases; as indicated by $x \propto 1/y$ or $y \propto 1/x$.
2. Flow ($\dot{Q}$) is the change in volume / unit time.
3. Resistance (R) is the impediment to blood flow ($\dot{Q}$) through a vessel.
4. Conductance (G) is the measure of the amount of blood volume that can pass through a vessel in a given time ($\dot{Q}$) for a given pressure difference; the reciprocal of resistance, so $G = 1/R$.
5. Pressure (P) is the amount of force per unit area.
6. Pressure difference is indicated by ΔP.
7. Velocity (V) is the distance that a particle moves / unit time.
8. Viscosity (η), or fluid friction, is the internal resistance to motion of fluid itself. Viscosity tends to retard flow ($\dot{Q}$), and thus is an important component of resistance.
9. Compliance (C), or capacitance, is the volume change produced by a unit of pressure change.

10. Radius is symbolized by r, length by L, and area by A.

Relationships Between Pressure, Flow, and Resistance

Determinants of flow ($\dot{Q}$):

1. Pressure difference (ΔP) $\quad \dot{Q} \propto \Delta P$ or $P_{in} - P_{out}$

2. Resistance (R) $\quad \dot{Q} \propto \frac{1}{R}$

   a. Physical dimensions of the resistance vessel

   Length (L) $\quad \dot{Q} \propto \frac{1}{L}$

   Radius (r) $\quad \dot{Q} \propto r^4$

   b. Viscosity (η) of fluid $\quad \dot{Q} \propto \frac{1}{\eta}$

Mathematical Relationships:

$$\dot{Q} = \frac{\Delta P}{R} \quad \text{or} \quad \dot{Q} = \Delta P \times G$$

$$R = \frac{\Delta P}{\dot{Q}}$$

Poiseuille's Law:

$$\dot{Q} = \frac{\pi}{8} \frac{r^4}{\eta} \frac{\Delta P}{L}$$

Velocity, Flow, and Area

Relationships:

$$V = \frac{\dot{Q}}{A} \quad \text{or} \quad \dot{Q} = V \times A$$

$$V \propto \frac{1}{A}$$

Continuity Equation: At constant cardiac output, the velocity of flow multiplied by the cross-sectional area of flow is at all points the same.

Resistance to Flow in Vivo

Components of resistance: In vivo resistance is altered chiefly by variations in the radius of the blood vessels.

$$R \propto \eta$$

$$R \propto L$$

$$R \propto \frac{1}{r^4}$$

Resistance vessels:

1. <u>Series</u>: Blood flows through several resistances in sequence, one after the other. The total resistance in series vessels equals the sum of the individual resistances in series.

$$R_{Total} = R_1 + R_2 + R_3$$

2. <u>Parallel</u>: Blood flow can go through any one of two or more vessels simultaneously. For parallel circuits, the total resistance is less than the resistance for any one of the individual vessels alone.

$$R_{Total} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

Total Peripheral Resistance:

$$TPR = \frac{P_{aortic} - P_{cv}}{\text{Cardiac Output}}$$

References for Further Study

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CHAPTER IV

DISCUSSION

Implications of the Study

It must be emphasized that this model teaching unit on hemodynamics is simply a small part, a beginning, of a larger multimedia teaching program in cardiovascular nursing. This unit will be followed by a unit on arterial pressures, which will lead the students further into the clinical application of many of the principles of hemodynamics. As it is necessary to learn the alphabet before one can begin to spell or write, likewise it is essential to learn hemodynamics before many of the more advanced areas of cardiovascular physiology may be understood and applied clinically. The knowledge offered in this unit is one step toward greater professional competence in nursing. Future possibilities for the increased use of multimedia programs in nursing include the addition of materials in other areas of interest, such as neurology.

As discussed, there is a lack of multimedia teaching programs at the advanced content level. In addition, there are few appropriate content resources available for graduate student use in clinical nursing. The majority of reference materials are either too elementary, or discouragingly complex for nursing students at this educational level. Therefore, increasing the content bank in clinical nursing has high priority. Too many nurses, in looking at the resource materials available, decide that a subject is too difficult and, thus, is not intended for use in nursing, or believe that they have nothing more to learn. In presenting this unit on hemodynamics, the writer hopes to alter this view, by providing content at an intermediate level with an emphasis on nursing application.

A major key to the improvement of education in graduate clinical nursing lies in listening to the students, and encouraging their participation in curriculum planning. Interested students are urged to develop study aids and teaching programs in areas of content in which they have identified a need. Many of these students, experiencing a change in their role as nurses, work closely with medical students and physicians. These students are in an excellent position to assess needs upon which collaboration between the two professions may be based, and to note where problems may arise.

The media hold great potential for both nursing and medical education. It is hoped that this study will promote local interest in the development of multimedia teaching programs, by establishing recognition of the educational need, and creating familiarity with the available community resources.

Cost Analysis

Most of the materials used in the preparation of this multimedia teaching unit were items which were in stock at the medical graphics department. The remainder of the materials were purchased by the writer. Both sources were reimbursed with funds from the nursing grant in physiology. This cost totalled approximately one hundred dollars. The filming cost for the original glass-mounted slides was approximately three hundred dollars. Each additional set of cardboard-mounted slides cost thirty dollars.

A thorough analysis of cost must include notation of the time spent in the production of the multimedia teaching unit. The writer judges that nearly six hundred hours of her time were devoted to the planning and creation of the unit. In addition, close to one hundred hours of time were given by the expert consultants, seventy by the physiology professor and thirty by the medical illustrator. Furthermore, an undetermined amount of time was given by the writer's field study advisor during the three quarters in which this teaching unit was being prepared.

An analysis of the monetary cost of this time can be estimated by considering tentative salaries which might have been paid to the individuals involved in the production of the unit. At an estimated salary of one thousand dollars per month for a nursing educator and one hundred dollars per day for consultation services, the cost of time could approach four thousand three hundred dollars (three thousand dollars for the nursing educator and one thousand three hundred dollars combined fee for the consultants).

If the creation of the visuals had been done by a commercial medical graphics company, which was not subsidized by the institution, the cost would have been approximately five thousand dollars for one hundred slides. To explore a more feasible option, if the medical graphics department of the university, instead of the writer, had produced the visuals, then the fee would have been around one thousand two hundred dollars. In this case, the time spent by the writer would decrease to approximately two hundred hours, or one thousand two hundred dollars. The fee for seventy hours, or nine days, of consultation by the physiologist would stay at nine hundred dollars. Under these circumstances, the cost of time could have been three thousand three hundred dollars.

This multimedia teaching unit was produced by an unsalaried graduate student, and much of the consultation was given while the student was enrolled in a three-credit course in Biomedical Communications taught by the two consultants. As a result, no charge was made of the time spent in consultation. However, it is helpful to look at the actual cost to the institution of the time given by the consultants. At an average salary of one thousand dollars per month, one hundred hours of work by the consultants would be worth six hundred twenty five dollars to the institution. When this amount is added to the cost of filming and materials, an estimate of one thousand twenty five dollars is calculated to be the actual cost of creating the initial set of slides for this multimedia teaching program. As the number of duplicate sets of slides made from the original set is increased, the cost of each individual set of slides will decrease. For example, if ten more sets of slides are made, at a price of thirty dollars per set, then the average cost of each set is decreased to one hundred twenty dollars.

Recommendations

In future productions, the method should be revised slightly to include a story-board evaluation by students and peers. This would provide additional information at an early stage to increase assurance that the program would present clear, correct content material.

Evaluation of the multimedia teaching unit must follow, and could be the subject of another graduate nursing field study. The writer recommends the use of the provisions for evaluation outlined previously in the method section of this study. In addition, a variety of other measurements could be made. For purposes of comparison with the conventional lecture method of teaching hemodynamics, an experimental design could be formulated using either undergraduate or graduate nursing students. Students could be divided into three groups. One group would be instructed by the lecture method only, the second group by the lecture method plus the use of the multimedia teaching unit, and the third group would have access to the multimedia method of instruction only.

CHAPTER V

SUMMARY AND CONCLUSION

There is a lack of multimedia teaching programs at the advanced content levels required for the instruction of graduate students in clinical nursing. A model unit of multimedia instruction on a complex topic, hemodynamics, is presented and the method of its production are described. It is proposed that nursing educators can produce quality multimedia learning materials in their own institutions by using the talents and the resources available in the local educational community. In this way the lack of multimedia at advanced content levels, which are essential to graduate clinical nursing, may be partially alleviated.

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APPENDIX

Behavioral Objectives

BEHAVIORAL OBJECTIVES

Advanced Comprehension Level

The graduate nursing student will be required to:

1. Identify from a list the letter symbol and definition of the following key words:*

   a. Proportion
      Direct
      Inverse
   b. Flow
   c. Resistance
   d. Conductance
   e. Pressure
   f. Pressure difference
   g. Velocity
   h. Viscosity
   i. Compliance
   j. Radius
   k. Length
   l. Area

2. List the five factors which determine flow.*
3. Give an example of pressure difference.
4. Describe the proportional relationship between flow and pressure difference.
5. Describe the proportional relationship between flow and resistance.
6. Describe the proportional relationship between flow and conductance.
7. Write the mathematical relationship between flow, pressure difference, and resistance.
8. Write the mathematical relationship between flow, pressure difference, and conductance.
9. Derive the relationship between resistance and conductance from the equations in objectives 7 and 8.
10. List the three components of resistance.*

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*Indicates achievement of the objective requires 100% accuracy.

11. Identify quantitative relationships between pressure difference and the components of resistance in a list of questions.
12. Write Poiseuille's Law.
13. Identify the components of Poiseuille's Law.
14. Describe the proportional relationship between velocity and flow.
15. Describe the proportional relationship between velocity and area.
16. Describe the proportional relationship between velocity and area in the vascular bed.
17. Write the Continuity Equation.
18. Give an example of the Continuity Equation.
19. Describe the proportional relationship between resistance and viscosity.
20. Describe the proportional relationship between resistance and length of the vessel.
21. Describe the proportional relationship between resistance and radius of the vessel.
22. State the chief way that resistance is altered in vivo.
23. Define resistance in series.
24. Give an example of resistance in series.
25. Define resistance in parallel.
26. Give an example of resistance in parallel.
27. Calculate resistance in series from a labelled

diagram.

28. Calculate resistance in parallel from a labelled diagram.

29. Describe how total peripheral resistance is measured clinically.

30. Give five examples of physiological states in which the TPR may be altered from that of the resting state.

31. From a set of clinical situations, real or simulated, identify applications of hemodynamic principles.

Basic Comprehension Level

The undergraduate nursing student will be required to:

1. Identify from a list the letter symbol and definition of the following key words:*

   a. Proportion
      Direct
      Inverse
   b. Flow
   c. Resistance
   d. Conductance
   e. Pressure
   f. Pressure difference
   g. Velocity
   h. Viscosity
   i. Compliance
   j. Radius
   k. Length
   l. Area

2. List the five factors which determine flow.*
3. Give an example of pressure difference.
4. Describe the proportional relationship between flow and pressure difference.
5. Describe the proportional relationship between flow and resistance.
6. Describe the proportional relationship between flow and conductance.
7. List the three components of resistance.*
8. Identify quantitative relationships between pressure difference and the components of resistance in a list of questions.
9. Identify the mathematical components of Poiseuille's Law.*
10. Describe the proportional relationship between velocity and area.

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*Indicates achievement of the objective requires 100% accuracy.

11. Describe the relationship of velocity and area in the vascular bed.
12. Write the Continuity Equation.
13. Give an example of the Continuity Equation.
14. Describe the proportional relationship between resistance and viscosity.
15. Describe the proportional relationship between resistance and length of the vessel.
16. Describe the proportional relationship between resistance and radius of the vessel.
17. State the chief way that resistance is altered in vivo.
18. Define resistance in series.
19. Give an example of resistance in series.
20. Define resistance in parallel.
21. Give an example of resistance in parallel.
22. Describe how total peripheral resistance is measured clinically.
23. Give three examples of physiological states in which the TPR may be altered from that of the resting state.
24. From a set of clinical situations, real or simulated, identify applications of hemodynamic principles.

AN ABSTRACT OF THE FIELD STUDY OF

KRISTIE RICE MCCLURG

For the MASTER OF NURSING

Date of receiving this degree: June 7, 1974

Title: THE MULTIMEDIA APPROACH TO CONTENT: A TEACHING UNIT

Approved: [redacted]ield Study Advisor

There is a lack of multimedia teaching programs at the advanced content levels required for the instruction of graduate students in clinical nursing. A model unit of multimedia instruction on a complex topic, hemodynamics, is presented and the method of its production are described. It is proposed that nursing educators can produce quality multimedia learning materials in their own institutions by using the talents and the resources available in the local educational community. In this way the lack of multimedia at advanced content levels, which are essential to graduate clinical nursing, may be partially alleviated.