5-1-2012

Arthritis – An Interactive study of common rheumatic diseases

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Arthritis – An Interactive Study of Common Rheumatic Diseases

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Date:

May 2012
Thesis Approval

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DEDICATION

To my beloved family,
all both present and recently departed,
Thank You for your inspiration
and for always believing in me.
The purpose of this thesis was to develop an interactive educational tool about Arthritis for medical students at the University of Rochester School of Medicine (URMC). This consisted of an online tutorial that students can access at anytime on the web, containing all lecture material and supplemented by illustrations and animations on the subject. These audiovisual aids aim to engage the student in a study session where he/she can study the material and evaluate their progress in a direct self-paced manner during lecture or later during study sessions for future referencing. This website tutorial was designed using Macromedia Flash 8 with interactive elements such as: the Rheumatoid Arthritis (RA) and Osteoarthritis (OA) interactive joint buttons, OA X-ray, RA animation, RA quiz; as well as static illustrations highlighting key points from the text. Review of the finalized interactive website tutorial by URMC professor and thesis advisor Scott Tripler, MD, revealed that, with some more added content, the use of this tutorial would be advantageous for both the educator and the student as it further assists in teaching the course topics more in depth.
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INTRODUCTION

Medical students currently utilize a vast array of references and different course materials for their study. Educators use handouts and course outlines to guide students through the course topics; lectures are given in PowerPoint presentations, medical models are sometimes used, and aside from cadavers and specimens in Gross Anatomy courses, not much else is used to enhance the learning in a visual way. Often students are seeking additional references and resources online to supplement the information that their textbooks provide. From personal experience, having been a medical student in the past, this author can attest to the lack of accurate explanatory visual aids and interactive experiences that often times, and for many topics in particular, are greatly needed in order to understand complex medical topics. This setting was brought up to Scott Tripler, MD, professor at the University of Rochester School of Medicine, and thus after consideration of the need for such resources and the benefits of what an online educational aid would bring to medical students and professors, the idea for this interactive tutorial was born.

The purpose of this thesis was to develop an interactive educational tool for medical students on the topics of Arthritis. This would consist of an online tutorial that students can access at anytime on the web, containing all lecture material and supplemented by illustrations and animations on the subject. These audiovisual aids aim to engage the student in a study session where he/she can study the material and evaluate their progress in a direct self-paced manner. The student should also be able to use this tutorial for future referencing.
THESIS DEVELOPMENT
I. CONTENT DEVELOPMENT

Upon the selection of the topic of Arthritis, the collection of reference materials for the website tutorial content was started. Thesis Advisor, Scott Tripler, MD, provided some materials including course syllabus and lecture outlines for his lectures on rheumatic diseases at the University of Rochester School of Medicine, as well as very useful references including clinical skills videos and medical textbooks such as Essentials of Family Medicine (Sloane, et al. 1998) and Primer on Rheumatic Diseases (Schumacher 1988).

To begin organizing the content for the online tutorial an outline was written following Dr. Tripler’s course material. The outline included key elements found in each topic, such as common rheumatic diseases, descriptions, their symptoms, methods of assessment and diagnosis, treatment and therapies, prognosis, etc.

The web tutorial, content reads as follows.

Welcome

This website describes and studies in depth different types of rheumatic diseases, their symptoms, causes and treatment options. Interactive elements accompanying the text should help you visualize and understand the material. Select a section from above to begin. Should you have any questions or would like more information on the topic of arthritis visit the references section below for a full list of resources utilized in the making of this site, or contact the artist directly for inquiries and/or to leave any comments.
About this site

This site was created as part of a graduate thesis project for the completion of a Master of Fine Arts degree in Medical Illustration. This is a prototype educational online module for higher-level education students (e.g. medical students). All the material included in this site was carefully selected from medical textbooks and trustworthy online resources.

By no means is this site providing any medical advice for patients. If you are visiting this site and believe you might be experiencing some of the arthritis symptoms discussed, please consult your physician.

Arthritis

What is arthritis?

Nature of Condition

Overview
The term arthritis refers to more than 100 different diseases affecting the musculoskeletal system, particularly the joints, and in some cases, as in systemic types of arthritis, affecting other organ systems throughout the body (e.g. blood vessels, skin, eyes, heart, lungs, and kidneys.)

Arthritis can develop at any age, usually affecting more women than men, with 30% of the population having symptoms of arthritis at some time in their life.

Manifestation and Symptoms
Arthritis causes inflammation of the joint, resulting in:
• pain, swelling, tenderness, warmth and/or redness of the joint tissues
• diffuse and usually symmetric enlargement of the synovial membrane
• effusions: intra-articular collections of fluid, joint capsule appears distended, sometimes with synovial fluid thickening
• irregular bony enlargements
• cutaneous or subcutaneous nodular formations
• limited range-of-motion
• wasting of muscles associated with the joint

PATIENT ASSESSMENT

Physical Examination
With a detailed medical history and a thorough physical assessment the physician should be able to identify signs of the particular type of arthritis the patient is suffering from. During the physical examination, the physician should look for any evidence of systemic involvement, signs of swelling, redness or heat in the joints, associated rashes, range of motion, deformities such as osteophytes (spurs), contractures or instability, signs of synovial inflammation, tenderness over soft tissue areas around the joint.

Arthrocentesis & fluid analysis
Patients who present with acute inflammatory monoarticular arthritis should have synovial fluid aspirated from the affected joint to check for bacterial infection, white cell counts and presence of crystals.

Lab Work
In general, there are no sensitive or specific laboratory tests that are diagnostic for arthritis. Soft tissue diseases have no systemic effects and therefore will not have abnormal lab results. Although, not diagnostic by itself, in some cases blood work will confirm a diagnosis.
• ESR and CRP – erythrocyte sedimentation rate and C-reactive protein tests are sensitive but nonspecific indicators of inflammation. They are useful in separating true
inflammatory arthritis from soft tissue complaints when history and physical examination are not diagnostic.

- CBC – a complete blood cell count may be helpful.
- RF and ANA – Rheumatoid factor and Antinuclear antibody are non-specific indicators of inflammatory and connective tissue diseases.

**X-rays**

Soft tissues cannot be assessed in X-rays, therefore are not helpful in diagnosing during the early stages of the disease process. Affected joints, however, present an increased or decreased articular space.

**TREATMENT OPTIONS**

**Treatment**

Specific treatment methods vary from patient to patient based on the severity of the symptoms and the particular type of arthritis. The main objectives of treatment are: the relief of pain and suppression of symptoms, to restore and maintain function of the joints involved, and ultimately prevent and correct any physical disturbances or deformities to improve the patient’s overall physical and emotional health.

**Medication**

Once diagnosis has been reached, one or more of the following are indicated:

- Analgesics such as Aspirin or Acetaminophen
- NSAIDs - nonsteroidal anti-inflammatory drugs
- Systemic corticosteroids or steroids injections
- Anti-biologics
- DMARDs - Disease-modifying anti-rheumatic drugs
- Cyclo-oxygenase-2 (COX-2) inhibitors
- Immunosuppressants
- Glucosamine and chondroitin
Other treatment methods to consider are: Vitamins and mineral supplements, changes in diet, and acupuncture.

**Surgery**

In some cases, surgery is necessary to restore functionality of the extremity or to repair the severely damaged joint. Arthroplastic surgery is commonly indicated in severe cases, while partial or total replacement of the joint will usually be performed when other alternatives and medications are no longer effective.

**Prognosis**

Some types of arthritis can be completely cured with treatment, but most are chronic conditions that can only be treated to control pain and avoid further joint damage. Chronic arthritis frequently goes in and out of remission.

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**Rheumatoid Arthritis**

**NATURE OF CONDITION**

**Overview**

Rhuematoid Arthritis (RA) is a chronic systemic inflammatory disorder greatly affecting multiple joints specially the synovial membranes as well as non-articular tissues in a symmetrical pattern.

**Risk**

RA typically occurs in the 30s and 40s but may begin at any age including the geriatric years. It affects approximately 1% of the population, and is 3 times more common in women than in men.
**Manifestation**

RA typically affects several joints in a symmetrical bilateral pattern, most commonly:

- the metacarpophalangeal (MCP) joints, proximal interphalangeal (PIP) joints, intercarpal (IC) joints and/or wrists, elbow joints, shoulder joints, neck, hip joints, knees, ankles, metatarsophalangeal (MTP) joints of the feet and distal interphalangeal (DIP) joint of the great toe
- in some cases the temporomandibular joint (TMJ) and/or cricoarytenoid joint (CAJ) may be affected

Systemically organs systems such as the integumentary, ophthalmic, cardiac, pulmonary, and neurologic are also affected.

**Symptoms**

RA may have a slow onset or a rapid and very destructive development of symptoms. Patients experience: low fever, malaise and weight loss preceding symptoms of those related to the joints, fatigue, morning stiffness of at least one hour, soft tissue swelling and/or effusion in at least three joints, subcutaneous nodules, bone deformities in the hand resulting in ulnar deviation at the MCP joints and radial deviation at the radiocarpal joint ("zig-zag" deformity), hammer fingers, swan neck, and Boutonniere deformities, swelling, flexion contractures, dislocation of the elbow, joint capsule rupture and consequent subluxation of the humerus, flexion deformities of the toes, valgus deviation of the foot, and fixation of the ankle joint, granulomas cause vasculitis resulting in skin ulcers, scleritis in the eye, pleuritis, pericarditis, lesions in lungs, heart and bowel, osteoporosis, and splenomegaly.

**Immunology**

Although the definite cause of RA is still unknown, it is believed that a combination of factors might be involved in triggering the abnormal immune response that harms the tissues. These factors include:

- Defects in the immune system resulting in an ongoing inflammatory response
- Environmental factors such as stress, and infectious agents like viruses or bacteria
• Genetic predisposition
• Hormonal changes

PATIENT ASSESSMENT

Physical Examination
During the physical examination the physician must look for the characteristic features of RA such as symmetrical pattern of joint swelling, warmth, redness, tenderness to palpation, effusions, signs of muscle atrophy, nodules or lumps under the skin, assessment of joint mobility and pain, and examination of other areas of the body for signs of systemic involvement, such as peripheral neuropathy (sensory and motor loss) resulting from vasculitis, an enlarged spleen, and cardiac arrhythmias.

Arthrocentesis and fluid analysis
Joint aspiration is indicated if the patient exhibits effusions. The affected joint fluid will present an elevated WBC count and a high percentage of PMNs (polymorphonuclear cells).

Lab Work
There is no test that can accurately determine an RA diagnosis, but certain tests will be helpful in assessing the presence of inflammation, anemia and infections. C-reactive protein (CRP) indicates if there is active inflammation in the blood. Rheumatoid factor (RF) results become positive long after the onset of RA (even several years later); a positive RF is not diagnostic of RA. The RF and antinuclear antibody (ANA) tests are not useful as screening tests due to their non-specific results. An elevated erythrocyte sedimentation rate (ESR) is also indicative of inflammation.

X-rays
Radiographs of typical RA joints would reveal:
• bone erosions (usually not detectable in the first 6 months)
• narrowing of the joint space
• subchondral bone cysts caused by the hypertrophic synovium
• decalcifications

TREATMENT OPTIONS

Treatment
There is no known cure for RA, but with early treatment and highly effective drugs, RA symptoms can be put at ease and permanent damage to the joint can be avoided. Specific treatment depends upon the severity of the symptoms, the stage of the disease and the patient's lifestyle.

Medication
First-line drugs (aspirin, NSAIDs, low dose steroids) do not ease progression of bone erosion, and so second-line drugs (antimalarials, sulfasalazine, methotrexate, gold salts, D-penicillamine, azathioprine) and steroids (IV/IM) are indicated at early stages of the disease to reduce morbidity. Biologic response modifier drugs that counteract the autoimmune response, DMARDs- disease-modifying antirheumatic drugs to slow down the disease, and immunosuppressive drugs and steroids (corticosteroid injections) are indicated when strong pain relievers result ineffective.

Surgery
Orthopedic interventions such as synovectomy, tenosynovectomy, arthroplasty (resection), arthrodesis (joint fusion), and joint replacements are sometimes necessary to improve joint function and motion, eliminate debris, and relieve joint pain.

Osteoarthritis

NATURE OF CONDITION

Overview
Osteoarthritis (OA), the most common form of arthritis, not only affects the articular cartilage, but also involves the entire joint including the subchondral bone, ligaments, capsule, synovial membranes, and periarticular muscles.

**Risk**
OA has a prevalence of 15-18%, increasing to 20-30% in patients over 65 yrs of age. Although age is the strongest factor for development of OA, since prevalence increases with age, OA is age related but not age dependent. Other risk factors include: major joint trauma, repetitive stress or joint overload, obesity, genetic predisposition, and increased bone density.

**Manifestation**
OA typically affects:
- the DIP (distal interphalangeal) joints and/or PIP (proximal interphalangeal) joints of the digits of the hand
- the DIP, the MCP (metacarpophalangeal) and the CMC (carpometacarpal) joints of the thumb
- the hip and/or knee joints
- the DIP joint of the big toe
- the shoulders, wrists and ankles may be involved, though usually as a result of trauma or direct injury

**Symptoms**
The patient experiences a slow-onset development of symptoms with deep aching joint pains that remit and relapse; pain is often aggravated by activity and relieved by rest, stiffness of the involved joints may be experienced in the morning or after inactivity that usually lasts less than 30 minutes and is relieved by heat and movement of the joint. The bones and cartilage of the affected joints wear out, the synovial fluid thickens, osteophytes (bony spurs) develop at articular edges, inflammation spreads to the capsule and associated ligaments of the joint, effusions are present, and muscles associated with the joint begin to atrophy due to disuse.
Phalanges may present radial deviation; the spine and intervertebral disks undergo degenerative changes in the bone resulting in compression of nerves and stenosis of the spinal canal. Bunions may form in the great toe. Ultimately, the articular cartilage degenerates with fibrillation, fissures, ulceration and full thickness loss of joint surface.

**Immunology**

In OA the normal equilibrium between synthesis and degradation of articular cartilage becomes unbalanced or poorly regulated. The normal balance between synthesis and degradation of articular cartilage is maintained through cytokine-driven anabolic and catabolic processes. IL-1 and TNF have been identified as cytokines that induce production of metalloproteinases (e.g. collagenase and stromelysin), which degrade macromolecules in the cartilage matrix. Other cytokines, such as insulin-like growth factor (IGF) and transforming growth factor-β (TGF-β), inhibit metalloproteinase production, thereby limiting degradation of cartilage and promoting cartilage synthesis and repair. If the catabolic processes mediated by the metalloproteinase-inducing factors predominate over reparative processes for an extended period of time, joint changes typical of osteoarthritis will develop.

**PATIENT ASSESSMENT**

**Physical Examination**

During the physical examination it is important to determine if the pain originates in the joint or if it is non-articular or referred pain. OA affected joints typically appear enlarged and are tender, and may have a limited range of motion accompanied by crepitus or crackling with movement. The patient's gait should also be assessed. If the patient presents effusions, which are very unusual in OA, further assessment should be taken in consideration to rule out any other form of arthritis.

**Arthrocentesis and fluid analysis**

Joint aspiration might be indicated if the patient exhibits effusions, diagnosis seems unclear or if infection is suspected to rule out any other diseases.
Lab Work
There are no blood tests to diagnose OA, but blood testing may help in diagnosing or ruling out other diseases that might be the causing the symptoms (e.g. SLE, connective tissue disorders, RA).

X-rays
Radiographs of typical OA joints would reveal:
- joint space narrowing causing the collapse of the opposing bones resulting in deformities such as bowleggedness (varus) or knock knees (valgus)
- osteophytes (calcified protrusions from bony surfaces)
- sclerosis of subchondral bone
- subchondral cysts
- fragments of bone in the joint space

TREATMENT OPTIONS

Treatment
The main goals of treatment is to control the pain, improve function, avoid or limit side effects and complications of therapy, and to prevent further damage to the involved joints.

Treatment options recommended:
- exercise to strengthen the muscles around the affected joints
- heat to relieve pain or stiffness of the joint
- cold applications to reduce muscle pain due to spasms or to control swelling
- ultrasound or transcutaneous electrical nerve stimulation to reduce pain
- joint protection to reduce stress on affected joints
- walking aids, orthotic devices, splints
- weight reduction to ideal
Medication

• First-line treatments: non-narcotic analgesics such as acetaminophen and topical analgesics (e.g. capsaicin cream)

• Second-line treatments for episodes of pain not controlled by non-narcotic analgesics: anti-inflammatory NSAID agents, intra-articular steroid and hyaluronic injections

• Third-line treatments: narcotic analgesics for short-term use that target debilitating pain such as codeine, tramadol, and propoxyphene

• Other treatments such as glucosamine and chondroitin sulfate supplements have been found effective in relieving OA symptoms.

Surgery

Patients with severe damage to the joint, excruciating pain and/or partial to complete loss of joint functionality may require surgical intervention when other treatments have not been effective.

Surgical procedures that might be indicated are:

• arthroscopic debridement of cartilage and irrigation of joint space

• total joint replacement (e.g. total hip arthroplasty, total knee arthroplasty)

• lower-extremity wedge osteotomy or joint osteotomy fusion

• arthrodesis (joint fusion)

Other Types of Arthritis

What are other rheumatic diseases?

Ankylosing Spondylitis

A chronic disease that primarily affects the spine, causing pain, stiffness of the lower back, pelvis, and/or hips. The patient reveals muscle spasms, loss of the normal lordosis of the spine and loss of anterior and lateral mobility of the spine. Associated
inflammation affects other joints such as the shoulder joints and knees as the disease progresses. In severe cases, due to spine flexion, hip and knee flexion and lower extremities deformities develop, and ultimately may lead to stiffness of the back as the bones of the spine fuse together. Although the clear cause remains unknown, genetics factors seem to be involved. The HLA-B27 gene occurs in 90% of cases. Treatments include: pain management, exercise, posture correction, drug therapy (Rx: NSAIDs, Sulfasalazine) and surgery. AS primarily affects men with a gradual onset at 17–35 years of age.

Gout

An acute or chronic inflammation caused by the deposition of sodium urate (uric acid) crystals in the synovial cavity. Gout generally presents with a rapid onset of self-limited monoarthritis, but in some patients the condition is polyarticular. It typically affects the MTP (metatarsophalangeal) joint of the great toe, other joint of the foot, ankles, knees, IP joints of the digits, fibrocartilage of the ear. During gout attacks, the affected joint is swollen, red, warm, and the patient may present fever. Patients usually have asymptomatic periods of months or years between acute attacks. Gout has a prevalence of 1.5% in the general population and frequency increases with age; it most often occurs in men and postmenopausal women with hyperuricemia or family history of gout. Fortunately, gout almost always can be completely controlled with medication and changes in diet.

Pseudo-gout

An acute or chronic inflammation caused by the deposition of calcium pyrophosphate dihydrate crystals within the synovial cavity. Pseudo-gout typically presents with acute joint inflammation (usually the knees) and is often associated with leukocytosis and fever. In some cases it presents as a chronic polyarthritis. Calcified intra-articular cartilage (chondrocalcinosis) is seen in joint radiographs. NSAIDs and intra-articular steroid injections are indicated when necessary.
**Psoriatic Arthritis**

A chronic type of arthritis characterized by pain and swelling in joints, and scaly patches on skin. PA affects both males and females, with an onset of 30–55 years old. Approximately 10% of people with psoriasis develop psoriatic arthritis. The patient experiences pain and swelling in one or more joints in a symmetrical or asymmetrical pattern, and presents the typical silver or gray scaly spots usually on the scalp, elbows and knees. PA may affect the joints of the fingers, wrists, neck, back, lower back, buttocks, knees, ankles and feet. The patient should avoid harsh deodorant soaps, and use lanolin creams and/or ointments with vitamin D3. Light treatments such as sun light exposure, UVB (type B ultraviolet light), PUVA (psoralem medication in combination with type A ultraviolet light) might be recommended.

**Septic Arthritis**

Arthritis caused by an acute bacterial infection within the joint space. The most common cause of septic arthritis in urban populations is *Neisseria gonorrhea*, while the most common non-gonococcal cause is *Staphylococcus aureus*, followed by group A and B streptococcus. Septic arthritis typically presents with a rapid onset of joint pain, tenderness, and warmth, along with fever and/or chills. Treatment options include joint drainage by serial arthrocentesis or alternate surgical method to reduce intra-articular pressure. Antibiotics should also be administered.
II. MODULE DEVELOPMENT

During the development of the interactive site several versions of the design were published and tested. Changes in the layout of the site, addition of imagery, changes in button’s design and functionality, and the addition of information resulted in the evolution of a user-friendly module with an improved navigation and professional look.

This interactive module was designed and created using Macromedia Flash 8. The final product, a content and graphics loaded website tutorial, was published to a web host server and can be viewed online at http://www.giovannasantoni.com/Arthritis, as well as offline when published as a movie projector from Flash.

Design of the Interactive Module

Website Structure and Organization

Based on the content outline, the website was organized in the following way:

- **Home/Splash Page**: Welcome
- **NavBar**:
  - **Arthritis**
    - **Menu**: Nature of Condition | Patient Assessment | Treatment Options
  - **Rheumatoid Arthritis**
    - **Menu**: Nature of Condition | Patient Assessment | Treatment Options
  - **Osteoarthritis**
    - **Menu**: Nature of Condition | Patient Assessment | Treatment Options
  - **Other Types of Arthritis**
- **Footer**: About this Site | More Information and References | Contact the Artist
Color Palette

The interface design of this interactive educational module was created utilizing a combination of a cool and warm color palette. The cool blues are soothing, calming and encourage a reflective mood. The warm and soft cream, beige and browns inspire an earthy, relatable and optimistic feel, which also contrast and balance the coolness of the blues. Furthermore the blue tones and beige and brown colors harmoniously mirror the colors utilized to illustrate the anatomy of cartilage, bone and marrow respectively. Each topic has its own color background. Color-coding sections visually organizes information and helps the user understand where on the site he/she is (Figure 1).
User Interface and Navigation

On the top left of the module an icon of the pelvis serves as a button that takes the user to the Home page. A navigation bar (NavBar for short) in the form of tabs, a menu bar in each section, an interactive menu and a bottom menu, organize sections and help in establishing a hierarchy which should guide the student to focus on certain sections before moving to the next.

All buttons react on rollover (i.e. when the mouse cursor is over them) and when the button is pressed, giving the user feedback on what he/she is selecting or viewing (Figure 2).
a. NavBar

Figure 2. Design of User Interface and Navigation

The interactive module’s navigation was designed with (a) a horizontal NavBar in the form of tabs for each main topic of arthritis covered and (b) horizontal Menus and Submenus composed of thumbnail buttons within each topic.

b. Menus and Submenus

Fonts

The sans serif web-safe font Trebuchet MS was used for the website written content. This font was selected because it is considered to be a good web design font. San serif fonts are typically used on websites as they are easier to read than serif fonts at any size. Trebuchet is included in most computer operating systems making it a system friendly font that retains its visual appeal across different platforms and browsers.
Titles and call out text were written using the serif font Adobe Garamond Pro in Bold and Italic respectively with the latter creating an interesting script-like look useful in text that needed to stand out, such as in titles, headlines and callouts. Because this font was used in a bigger size and scale it is easy to read. This serif font was used to further stylize text while adding some distinction that would make the topic titles and text highlights standout from the main body text written in sans serif, while adding some interest and establishing text hierarchy throughout the site layout.

Some decorative dingbats from the font wmdesigns1 were placed throughout the site for an elegant touch.
III.

MEDICAL ILLUSTRATIONS AND GRAPHICS

The creation of effective supplemental medical illustrations and graphics to enhance the understanding of the arthritis topics was one of the most important goals of this thesis project. Multiple studies have reached the conclusion that audiovisual aids enhance the communication of concepts to all audiences, by improving retention of the material. Reading, seeing and hearing is much more effective than reading or seeing alone. Medical illustrations alongside of medical reading material, regardless of its complexity, will more often than not improve the learning experience of the viewer.

MEDICAL ILLUSTRATIONS

Selection of Concepts for Medical Illustrations

After careful study of the topics and material to be presented in lectures, key concepts were selected that would benefit from illustration: the affected joints of the body and, very importantly, the hands; the immunology of rheumatoid arthritis, a very involved process; the effects of arthritis in the cartilage and consequent deformities of the bones involved; and other concepts involving the effects of arthritis. These were illustrated in a schematic and stylized but precise manner with the purpose of facilitating the understanding of these processes.

Creation and Development of the Medical Illustrations

Once the material was studied in depth and the different concepts to be illustrated were established, each individual interactive element was sketched and steps to their individual creation were roughly planned out. Illustrative reference materials were collected by taking digital
pictures of a skeleton model as well as and making pencil sketches from the model’s leg from direct observation.

1. Working from a digital photo reference

Complex anatomy such as the skeleton would take a very long time to render from scratch. A time efficient solution for this was to create an illustration from a photo reference. To begin the process the best picture of the entire skeleton (Figure 3) was selected and opened in Adobe Photoshop CS2, where it was then extracted from its background. Once extracted from the background, all hardware was removed by using tools such as the paintbrush, clone stamp, and healing brush to fill in the bones.

The picture was then colorized and later copied into several layers where different artistic filters, such as Cutout, Dry Brush and Palette Knife were applied to give the skeleton a more illustrative look. To eliminate the obvious digital effect that often results from applying filters to pictures, and to achieve a more organic form, these filters were blended and combined with another layer where paint was added to fill in areas and smooth out edges.

Other adjustments were applied to achieve the desired level of contrast, hue and saturation and an overall painterly feel. Finally a “stroke” was drawn around each bone of the hand and some parts of the skeleton using the brush tool — instead of the pen tool — to create a further defined illustration while maintaining a more natural and organic appearance (Figure 3).
Figure 3. The Skeleton

Steps in the development of the skeleton medical illustration. First, (a) a digital photograph was taken as reference for the illustration, then using Photoshop (b) the photo was manipulated in the computer and the skeleton was extracted from the photograph’s background. Finally, (c) after colorizing the skeleton, applying several artistic filters, and touching up the image the desired effect was achieved and the final illustration was completed.

All the other images, the pelvis (Figure 4), and the close up of the posterior view of the skeleton hand (Figure 5) were worked on individually using the same process to maintain a consistent look and style throughout.
Figure 4. The Pelvis

Steps in the development of the pelvis medical illustration. First, (a) a digital photograph was taken as reference for the illustration, then using Photoshop (b) the photo was then manipulated in the computer to extract the pelvis from the photograph’s background, the bones were colorized, several artistic filters where applied, and the image was touched up until the desired effect was achieved and the final illustration was completed.

Figure 5. The Bones of the Hand

Steps in the development of the bones of the hand medical illustration. First, (a) a digital photograph was taken as reference for the illustration, then using Photoshop (b) the hand was extracted from the photo and the hand image manipulated in the computer, applying several artistic filters, and touching up the image to achieve the desired effect for the final illustration.

Once finalized, the illustrations were saved at different resolutions (300ppi for print, 72ppi for web), sizes (dimensions), color modes (CMYK for print, RGB for web) for the purposes of printing and web publishing.
2. Working from a sketch

The illustrations of the knees were created using a very different method. These were started from observational sketches, which were later modified using different stylizing effects.

The knee extension-flexion sketches were used as templates for vector illustrations done in Adobe Illustrator CS2. The vector illustrations were done in a schematic style. When these were completed they were imported into Photoshop and the sketches, after being colorized to a more brownish color, were overlaid on top of the vector illustrations to act as texture. Other details were then rendered by using the paintbrush to add some red color and suggest broken cartilage tissue and inflammation (Figure 6).

Figure 6. Extension–Flexion Knee
Steps in the development of the extension–flexion knee medical illustrations. First, (a) a sketch was rendered from direct observation, then using Illustrator (b) a vector illustration was created from the reference sketch. Finally, using Photoshop (c) the vector illustration was imported and the sketch was overlaid on top to add a realistic bone texture, and details were added until the desired inflammatory effect was achieved and the final illustration was completed.
The illustration of the X-Ray of the knee was created using an even more distinct method. As in the previous knee illustrations, the process to create this illustration began with a sketch from direct observation of a skeleton model. The sketch was then brought into Adobe Photoshop CS2, to clean up pencil marks and adjust levels and contrast. The bones were then separated and manipulated so the femur could overlap the tibia to show a typical osteoarthritic knee joint where the joint space is reduced by the loss of cartilage and the bones are touching each other (Figure 7).

Finally, the image was inverted so that blacks would turn into white, giving the appearance of a photograph negative, as in diagnostic films. Muscle shadows were added with the paintbrush tool. Several radiological films were used as reference to achieve the desired look (Figure 7).

Figure 7. Knee X-Ray
Steps in the development of the skeleton medical illustration. First, (a) a digital photograph was taken as reference for the illustration, then (b) a sketch of the normal knee was rendered from direct observation. (c) Later, the scanned sketch was then manipulated in Photoshop, inverting the image to its negative, and touching up the image until the desired effect was achieved and the final illustration was completed.
Again, the illustrations were saved in different resolutions (300 ppi for print, 72 ppi for web), sizes (dimensions), color modes (CMYK for print, RGB for web) for the purposes of printing and web publishing.

GRAPHICS

Creation of Graphics, Thumbnails and Icons from Medical Illustrations

Once all medical illustrations were completed, icons were created to be incorporated into buttons that would call upon the different medical illustrations within the interactive elements later discussed.

As previously mentioned, icons of the pelvis and hip joint at the top of each page serve as buttons that take the user to the Home page. Each submenu within the arthritis topic contains buttons created either as thumbnails from the featured illustrations, such as a cropped close up of the skeleton and hand, or a new image that describes the interactive element, such as loose leaf paper with a question mark for the Immunology quiz and a pelvis with RA and OA for the comparison table (Figure 8).
The same graphic image used for the Home page button and identity icon was used throughout in presentations and identity package materials, such as web favicon, desktop icon, presentation CDs and its cover labels, etc. (Figure 9).

Graphic icons and thumbnails were also created to accompany important information featured in callouts, to further describe the highlighted text and key concepts enhancing the learning of the content while creating a visually interesting element in the page. (Figure 10).
Figure 10. Callouts

Graphics and icons created from medical illustrations used throughout the site to accompany important text from the content resulting in visually interesting callouts highlighting key points on (a) arthrocenthesis and (b) patient assessment.

a. Arthrocenthesis callouts

b. Patient assessment callout
IV. INTERACTIVE ELEMENTS

Adding interactivity to the medical illustrations aims to engage the student in a more hands-on learning experience, proven sometimes more effective than passive studying of text and images. Rollovers, an animation with a voice over narration of events, and a diagnostic quiz were designed to address important concepts within each section.

Creative Process and Development of Interactive Elements

In order to create interactive elements, the illustrations were imported into Macromedia Flash 8, added to the library, and saved as symbols and movie clips for later use.

Each interactive element was created as a separate flash file and a swf was saved which would live on the server until a blank movie clip placed on the main website would call upon each of the interactive swf files at the push of its respective thumbnail button.

Most of these interactive elements were composed of several illustrations and components that require the student to do something to highlight the described arthritic condition, except for the Rheumatoid Arthritis and Osteoarthritis Comparison Table which was more static (Figure 11).
Figure 11. Comparison Table

One-on-one comparison table contrasts RA and OA and nicely shows the main differences in both conditions serving as a quick reference to distinguish them during patient assessment.

### Rheumatoid Arthritis vs. Osteoarthritis

<table>
<thead>
<tr>
<th>Condition</th>
<th>Rheumatoid Arthritis</th>
<th>Osteoarthritis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onset</td>
<td>Slow-onset or a rapid and very destructive development of symptoms</td>
<td>Slow-onset development of symptoms</td>
</tr>
<tr>
<td>Affects</td>
<td>Typically affects multiple joints in a symmetrical bilateral pattern</td>
<td>Affects few joints in a unilateral or bilateral pattern</td>
</tr>
<tr>
<td>Systemic</td>
<td>Systemic involvement</td>
<td>No systemic involvement</td>
</tr>
<tr>
<td>Morning Stiffness Lasts</td>
<td>Morning stiffness lasts for one hour or more</td>
<td>Morning stiffness lasts less than 30 minutes</td>
</tr>
<tr>
<td>Joints</td>
<td>Joints most commonly affected: MCP, PIP, IC of hands, DIP, MCP, CMC of thumb, wrists, elbows, shoulders, hips, knees, ankles, spine, DIP of greater toe, MTP of feet</td>
<td>Joints most commonly affected: DIP, PIP of digits, DIP, MCP, CMC of thumb, DIP of greater toe, hips, knees, spine</td>
</tr>
<tr>
<td>Other Joints</td>
<td>Joints most commonly affected: MCP, PIP, IC of hands, DIP, MCP, CMC of thumb, wrists, elbows, shoulders, hips, knees, ankles, spine, DIP of greater toe, MTP of feet</td>
<td>Joints usually affected after trauma: shoulder, elbows, wrists, ankles</td>
</tr>
</tbody>
</table>

### RA and OA Interactive Joints Buttons

In order to convert the skeleton, bones of the hand, and knee illustrations into interactive elements, the illustrations were made into buttons with different “up” and “over” states, requiring the user to perform an action to see the effects in the different images.

The skeleton and bones of the hand for both RA and OA were done so that the up state of the button just shows the affected joints highlighted and labeled, whereas the rollover state shows these joints glowing to further highlight their location (Figure 12).
Figure 12. Interactive Bones

Samples of interactive bone illustrations. The RA skeleton illustration (a) shows the joints that are affected by the condition and (b) when the student places the mouse over the illustration these joints glow to emphasize their location. In the same way, the OA bones of the hand illustration (c) shows the joints that are affected by the condition and (d) when the student places the mouse over the illustration these joints glow to emphasize their location.
The OA knees were done so that the up state of the button shows a normal right knee and arthritic left knee in an extended position, while the over state shows these same joints in a flexed position, where more of the interior joint anatomy is revealed during rollover (Figure 13).

**Figure 13. Interactive Knees**

The interactive OA knee joint illustration shows a comparison between a normal and an affected joints in an (a) extended position during up state and a (b) flexed position during the over state revealing more internal anatomy of the joint when the student places the mouse over the illustration.

(a) RA skeleton button up state

(b) OA bones of hand button up state
The OA knee X-Ray was created to simulate a lightbox examination, where the up state of the button shows a turned off light box, while the over state shows the light box turned on and the image gets brighter, facilitating the diagnosis of OA with joint space narrowing caused by erosion of the cartilage. An arrow appears during this state to further highlight the affected area where the femur and tibia bones have come in contact with each other (Figure 14).

**Figure 14. Osteoarthritis Knee X-Ray**

The interactive illustration of the OA Knee X-Ray. Because this illustration was incorporated into a Flash button, the different “states” show different images. On the (a) “up state” the X-Ray light box appears turned off. The student must then (b) rollover the button to turn on the light box and be able to see the X-Ray lit up to better see the effects of OA in the affected knee joint marked by an arrow.

**RA Animation**

The most challenging and exciting of the interactive experiences in this web tutorial is the animation “The Immunology of Rheumatoid Arthritis”, created to explain the immune processes taking place in the joint (Figure 15).
The process of the creation of this animation is further described in Part V of this thesis.

**Figure 15. “The Immunology of Rheumatoid Arthritis” Animation**

Screen capture of the RA animation showing the player, viewing area, sound indicator, label of cells, captions that go along with a voice over narration and playhead that permits the student to play, stop and restart the animation.

**RA Quiz**

To measure the student’s understanding of the concepts covered in the animation “The Immunology of Rheumatoid Arthritis”, a quiz was created. This quiz was written using simple Flash ActionScript 2.0 and was designed with options that would facilitate the student’s taking and retaking it for further learning. After the student has seen the animation he/she can then
answer the quiz and be graded on their responses, can choose to show all correct answers, or reset the quiz to erase all entries and retake it (Figure 16).

Figure 16. RA Quiz

Screen captures showing the (a) blank quiz, (b) the “show answers” option, (c) perfect score, and (d) partial score with incorrect answers.
V. ANIMATION

Including an animation is another way to incorporate interactivity into the website tutorial. Because of the complexity of the immunological response and multiple events taking place in the joint during rheumatoid arthritis, this topic was selected to create an animation. The animation, “The immunology of Rheumatoid Arthritis”, goes from an overview of the body at a macroscopic level to a more in depth look into the joint tissue at a cellular level.

Creative Process and Development of the “The Immunology of Rheumatoid Arthritis” Animation

1. Storyboard

The first step in creating the animation was to plan out the main events and concepts to show during the animation. A storyboard was created using photos from the previously made collection of images, and new rough illustrations were done to plan out the main steps in the immunologic response taking place in a joint affected by RA. Captions, labels and other markings were added to each image sequence to describe the movements and effects taking place in each step (Figure 17).

This storyboard was created using a combination of both Adobe Illustrator CS2 and Adobe Photoshop CS2.
2. Animatic

The next step was to create an animatic, or very rough animation in Macromedia Flash, to set up main events within the timeline. This process facilitates the visualization of the sequence of images in relation to motion and timing. In the animatic, still images are moved and maneuvered to create motions such as panning, zooming, tweens, to test the animation loosely and get a better sense of timing in the timeline. (Figure 18).
The animatic was created in Macromedia Flash 8 by incorporating some the illustrations of the skeleton and bones of the hand and creating new rough images in Flash.

**Figure 18. Animatic**

Screen captures of a sequence of events taken from the animatic created in Flash to mock up illustrations and facilitate the development of motions for the animation.

3. Animation

The final animation began to develop from a refined version of the animatic. Motions were tweaked, timing was improved, and the animation was smoothed out. Character illustrations, such as complements, antibodies, and cells were created in Adobe Illustrator and imported into the Flash file’s library (Figure 19). These were then added to the timeline and replaced rough placeholder characters used previously in the animatic. The same process was done with the
other illustrations, and a new joint illustration was also created with the native drawing tools in Flash.

Figure 19.

Animation Characters

The animation characters are all of the cells, and chemical components that play a role in the immunological response to the presence of the condition of RA in the joints. Some of these are the complements, complement split products, polymorphonuclear lymphocytes such as neutrophils, eosinophils, basophils; mononuclear cells B cells and CD4+ T helper cells, autoantibodies, autoantibodies, immune complexes, macrophages, PDGF, TNF–α, IL–1, among others.

A “player” was creating using flash drawing tools, and the animation was masked within its viewing area. A speaker icon was added to indicate sound. A playhead was created, enabling the viewer to play, stop and restart the animation as well as scrub through to a desired place in the timeline. Captions were also added to go along with the voice over narration (Figure 20).

The playhead as well as the animation’s functionality was all controlled by ActionScript 2.0.
The animation evolved slowly and timing was adjusted multiple times to achieve the best possible timing, pausing at the right times and moving along during other less content loaded
times. The addition of a voice over narration took effect in the timing, as this had to match the events taking place in the animation.

4. Voice Over Narration and Captions

A voice over narration was recorded to accompany the animation and highlight key events in the disease processes. Captions were added to accompany the narration, allowing students to see and read concepts with the narration volume turned on or off. The voice over narration reads as follows.

---

**Rheumatoid Arthritis - Intro Text**

Rheumatoid Arthritis (RA) is a chronic inflammatory disease of systemic manifestation and that primarily affects peripheral synovial joints bilaterally.

RA commonly manifests in the hands affecting the wrist joint, intercarpal (IP) joints, metacarpophalangeal (MCP) joints and proximal interphalangeal (PIP) joints.

**Rheumatoid Arthritis - Voice Over Script**

In the early phase of Rheumatoid Arthritis, lymphocytes and mononuclear cells such as CD4+ T helper Cells, and B cells infiltrate the synovium of the joint, leading to the production of autoantibodies.

In addition, AutoReactive Antibodies or Rheumatic Factors are also produced in the synovium, which in turn lead to the formation of Immune Complexes in the tissue.

Persistent Immune Complexes deposit in the articular cartilage resulting in the activation of the Complement Cascade.

Complement split products chemotactically attract PolyMorphoNuclear leukocytes such as neutrophils to the joint.

These neutrophils phagocytose the immune complexes while releasing destructive cytoplasmic factors, proteases and reactive oxygen intermediates that harm the joint
tissue.

Recruited Macrophages release cytokines and chemoattractants resulting in the formation of a vascularized granulation tissue or pannus.

During chronic stages of Rheumatoid Arthritis, the pannus, composed of mesenchyme and bone marrow-derived cells, stimulates the release of Interleukin-1 (IL-1), platelet-derived growth factor, prostaglandins and substance P [by macrophages], which ultimately cause cartilage destruction and bone erosion.

The main events taking place in the animation are:

- Introduction – Opening Title
- Anatomy orientation – location of joints affected by RA condition throughout the skeleton
- Anatomy orientation – location of joints affected by RA condition in the hand
- Anatomy orientation – MCP joint close-up
- RA Early Phase – Lymphocytes and mononuclear cells infiltration
- Production of antibodies
- Production of autorreactive antibodies
- Activation of complement cascade
- Complement split products
- Recruitment of polymorphonuclear leukocytes
- Neutrophil phagocytosis of the immune complexes
- Recruitment of Macrophages and pannus formation
- RA Chronic Stage – Pannus results in cartilage destruction and bone erosion

Every important immunological event featured labels, and icons of each character involved. These events were clearly described in the voice over and captions (Figure 21).
a. Play button

b. Introduction – Opening Title

c. Anatomy Orientation – Affected joints of the skeleton

d. Anatomy Orientation – Affected joints of the hand

e. Anatomy Orientation – MCP joint

f. RA Early Phase – Lymphocytes and mononuclear cells infiltration
g. Production of antibodies

h. Production of autorreactive antibodies

i. Activation of the complement cascade

j. Complement split products

k. Recruitment of polymorphonuclear leukocytes

l. Neutrophil phagocytosis of the immune complexes
Recruitment of macrophages and pannus formation

RA Chronic Stage – Pannus results in cartilage destruction and bone erosion

m. Recruitment of macrophages and pannus formation

n. RA Chronic Stage – Pannus results in cartilage destruction and bone erosion

Screen captures of main events in “The Immunology of Rheumatoid Arthritis” animation

**Figure 21. RA Animation screen captures**

Screen captures take from “The Immunology of Rheumatoid Arthritis” animation’s main events taking place during the immunological response in the body to RA in the joints. The main steps occurring in the animation after pressing the (a) play button, and seeing the (b) introduction title are: (c) Anatomy Orientation – Affected joints of the skeleton, (d) Anatomy Orientation – Affected joints of the hand, (e) Anatomy Orientation – MCP joint, (f) RA Early Phase – Lymphocytes and mononuclear cells infiltration, (g) Production of antibodies, (h) Production of autorreactive antibodies, (i) Activation of the complement cascade, (j) Complement split products, (k) Recruitment of polymorphonuclear leukocytes, (l) Neutrophil phagocytosis of the immune complexes, (m) Recruitment of macrophages and pannus formation, and (n) RA Chronic Stage – Pannus results in cartilage destruction and bone erosion.
VI. GALLERY EXHIBITION

A printed and mounted 36” x 24” poster exhibit was created for the gallery exhibition. This served as an attractive display introducing the audience to the thesis project, describing its topic and featuring images used in the interactive website (Figure 22). A computer was set up within the exhibition space, with a keyboard and mouse placed on a pedestal. A projector of the website was on display for the audience to browse through and experience the site without an internet connection (Figure 23). The presentation of this thesis to faculty and students took place on April 27th, 2007 at the RIT Bevier Gallery in the CIAS building. The exhibition ran April 27th–May 10th, 2007.

Figure 22. Gallery exhibition display

Gallery exhibition poster introducing the topic and briefly describing the thesis project, featuring some art taken from the collection of medical illustrations created for the site, as well as structural components of the website tutorial.
**Figure 23. Gallery exhibition computer set up**

A Mac computer was set up during gallery exhibition in which the audience could browse through the finalized website tutorial and experience the range of interactive elements including an animation on the topics of arthritis. To attract attention to the exhibit, a descriptive poster exhibit was also put up, introducing the audience to the project.
CONCLUSION

The Arthritis Interactive website tutorial developed into a very useful tool for medical students to supplement lecture materials being used. The format of the site, the content and the accompanying interactive elements were all well received by Dr. Tripler. During a post production review meeting with the thesis advisors, Dr. Tripler expressed his interest in the use of the interactive module as it would be very advantageous as supplemental material in his courses and that with some more course material additions and further developing, this interactive module could very well be incorporated in the curriculum. It was also concluded that this module would also be a beneficial tool for other family medicine topics taught in medical school.

Things to consider for future module developments like this, is to include the following:
• a section under each topic that would show more medical illustrations on how to perform physical examinations as part of the clinical assessment
• include test questions based on actual patient cases and practical medical scenarios
• an additional section with more information on current changes in the medical literature, regarding new developments and research findings, the best diagnostics tests and newest treatment options.
REFERENCES

PRINT


ONLINE RESOURCES

Abbot Laboratories - HUMIRA® (adalimumab)  http://www.humira.com

Abbot Laboratories - The Changing World of Rheumatoid Arthritis  http://www.ra.com
American Academy of Orthopaedic Surgeons (AAOS)  http://www.aaos.org

American College of Rheumatology (ACR)  http://www.rheumatology.org

American Pain Foundation (APF)  http://www.painfoundation.org

American Society for Surgery of the Hand  http://assh.org

Arthritis Foundation  http://www.arthritis.org

DePuy Orthopaedics, Inc. - All about arthritis  http://www.allaboutarthritis.com

MedlinePlus Health Information from the National Library of Medicine  http://www.nlm.nih.gov/medlineplus

National Institute of Arthritis and Musculoskeletal and Skin Diseases  http://www.niams.nih.gov

National Institutes of Health  http://health.nih.gov


Wyeth Pharmaceuticals Inc. - Education and motivation for people with rheumatoid arthritis  http://www.insidera.com