

# **Proposal**

## **Muscle Recorder**

### **Team 1**

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## **Executive Summary**

This document is expected to explain the following proposal by describing the details of the project. The plan is to design a device to record the Force-Velocity and Length-Tension Relationship for a variety of muscles. The Force-Velocity should be able to record both shortening and lengthening. The introduction contains the background where information about the client and his request is available, the purpose of the project, and information about products that are similar to this product as well patent search results. The objective provides an overview of the project describing what the product does and how the product will be implemented in order to meet the requirements of the client. A careful and meticulous explanation of the project is written in the methods section with a description of the project and how the building of the device is going to be accomplished and carried out. Pictures of what the set up would appear to be like are included in this section as well as graphs displaying what the relationships of the measurements might look like employing a computer program. In addition, a budget is incorporated in order to provide a rough estimate of the cost of building the device by listing the equipment required and making the effort to produce a cost efficient project by scaling the price to be less than 35% of prototype costs. This proposal completes its purpose summarizing the project by highlighting the essential components of designing the device.

## **1. Introduction**

### **1.1 Background**

Dr. John D. Enderle is the Program Director & Professor for Biomedical Engineering at the University of Connecticut. He has been looking to incorporate a muscle response experiment in the Biomechanics laboratory, a class designed for Biomedical Engineering undergraduates. Currently, undergraduate students in the Biomedical Engineering program perform experiments on frog muscles in the Physiology and Neurobiology class required by the program. Dr. Enderle would like to include a muscle experiment in the Biomechanics Laboratory to ensure that the undergraduate students gain a deeper understanding of muscle performance by analyzing muscle responses using a LabVIEW® program.

### **1.2 Purpose of the project**

The University of Connecticut's BME Dept. has requested a muscle recorder for use in the program's Biomedical Engineering Measurements course. The device will allow the students to understand the mechanics of muscle contraction by recording the force-velocity and length-tension relationships for a variety of muscles. Moreover, the students will learn how the LabVIEW® program operates in conjunction with the experiment in order to gain as much knowledge and practice in the course.

### 1.3 Previous work done by others

#### 1.3.1 Products

Muscle stimulation experiments have been conducted in numerous Anatomy and Physiology laboratories throughout the country as they fulfill an educational standard. Muscle function has also been studied by EMG, electromyography, which tests the muscles electric signals. The EMG test helps to diagnosis of muscle and nerve such as muscular dystrophy and carpal tunnel syndrome.

Noromed, a division of Myotronics-Noromed, Inc, is a leading company in musculoskeletal technologies. Noromed offers products for muscle testing, Surface EMG, and Dynamic Range of Motion.

Nicolet Biomedical also produces EMG products. The VikingSelect, pictured below, is their latest introduction.



MyoVision is also a leading company in producing Surface EMG systems. It has several products including the M8 Static sEMG, the Dynamic sEMG, and a screening booth, to name a few. The company also offers various training courses, including seminars and training classes, in different parts of the country. A presentation about the company is available online.

### **1.3.2 Patent search results**

The VikingSelect uses a patent pending Nicolet's FireWire (IEEE 1394) interface.

Noromed and MyoVision's product patents can be found on <http://www.uspto.gov/patft/>.

## **2. Project Description**

### **2.1 Objective**

The objective of this project is to build a muscle device that records the force-velocity and length-tension relationships for a variety of muscles at various stimuli percentages. The force-velocity measurement should be able to record both the shortening and lengthening of the muscle. The aim is to grant students the opportunity to take the literature and in-class lecture done in the Biomechanics course to a higher level by demonstrating in the laboratory what is being taught in class. This would be possible with the help of the muscle recording device by requiring students to utilize the set up that will be provided and performing the experiment. The experiment itself would be very straightforward and for some very familiar since this experiment is somehow related to an experiment performed in the Anatomy and Physiology course. The analytical part of the experiment would provide students the information about how data is analyzed through computer software applications and moreover it would be very rewarding since students would be writing the computer program that would take the data collected and output the mentioned relationships. The computer program known as LabVIEW® would take the measurements from the experiment and upon completion of writing the computer program, it should read out the data and output graphs showing the Force-Velocity and Length-Tension relationships.

The plan is to build a low cost device but that at the same time provides good and resistant quality. There are many muscle stimuli product in the market and many are very expensive but we tried to choose a rather non-expensive one since a couple of these machines would be needed in the laboratory. This device needs to be moderately small and light weighted in order to be moved around for the convenience of the experiment and the students. In order to build this device a list of the materials that are going to be is was provided. Materials needed include: a small animal muscle, free weights, saline solution, a sturdy steel stand, an arm with a claw small

enough to grip small muscles, a voltage source that ranges between + -100 mV, two free wire ends that provides stimulation to the muscle, a force transducer, and the LabVIEW® software. The device has to be built from scratch and needs to be something that can be equipped and set up in a short amount of time since students might need a lot of time to invest in the writing of the program.

## 2.2 Methods

The gastrocnemius muscle of the frog is ideal for propelling the animal high into the air. The powerful plantar flexor has come to be since the frog has an inherent need to jump relatively high, as it jumps higher than the entire height of the animal itself. In order to begin considering taking quantitative measurements of the muscle, an appropriate setup will be pertinent for success. A metal stand must be the foundation of the whole apparatus, as it can withstand strain from the muscle pulling down on it, and provide an accessory to piece together other equipment. Attached to the stand should be an arm sticking out perpendicularly with the function of holding the actual muscle in place. The arm will be the place where the muscle will be attached, and should be sturdy enough to well support 1 kilogram of mass, even though there will not be nearly this much mass attached to the stand. Steel would be an ideal choice to be the material of which the stand is made out of since steel is sturdy and durable. The arm should have a claw on the end of it with rubber clips that is reducible. There must be a way to reduce the size of the clip so that the clamp can be fit to size. A screw attached to the side of the clamp which can be manually loosened or tightened would be ideal for meeting this purpose. It can be manually controlled since it does not need to be perfectly tight, just tight enough so the object of interest stays in place. Then, a force transducer must be connected to the clamp, as to measure exactly how much force is being generated by the muscle. The force transducer will rest on a metal body so it can be motionless as it records to maintain accurate readings. Next, the muscle itself must be attached to the device. To do this, simple polyester string must be used to tie together the muscle and the transducer, holding them in place. The string must be wound tightly around the muscle, so as to transfer the full amount of force generated by the muscle. The string also must be tied tightly to the transducer since this is another point in which force could be lost if there is lack in the string. The other end of the string must be connected to a mass which will pull down on the muscle, so something pulls back against it when it contracts. A simple mass of somewhere 10 to 500 grams would provide enough weight on the muscle to produce adequate existing tension in the wire. This would be the physical apparatus which the user would have to set up. Other parts of the apparatus should be set up by the person running the lab group.

The muscle has to be stimulated by an electric pulse so that the muscle responds by contracting. In the body, this is done by the natural source of the motor unit, the nervous tissue which directly connects to the muscle fiber. In our case of this fabricated version of contracting a muscle, a muscle stimulator, should be used as opposed to mother nature's source in the body. The muscle stimulator we have

chosen is the RellaMed EMS 500 Digital Electrical Muscle Stimulator. We find that this stimulator is suitable for this experiment from the multiple advantages it provides to the user. First and foremost, this system should hopefully last a decent amount of time, and this comes with a five year warranty for the user. Secondly, it recently became on sale as it dropped from two-hundred ninety nine dollars to sixty nine dollars. Third, it is relatively small in size, about the size of a cellular telephone, which will be ideal for the small workspace available in most laboratories. Furthermore, the unit comes with a digital readout so that the numbers it generates are easily shown to the user, as oppose to some analogue systems which could provide a source of error as it is more prone to being misread. Finally, this specific device includes a channel connecting it to the muscle, which will reduce cost elsewhere by making a manually placed lead from the device to the muscle unnecessary.

The next integral piece of the apparatus is the connection from the force transducer to the computer. The force transducer takes the analogue reading of how much force is produced and translates it into digital code which is then readable by a computer. Another bonus to using the RellaMed EMS 500 is that the package contains leads which can be then installed from the force and delivered to the computer processor unit. Once the information reaches the computer, a program needs to be set up in order to understand, process, and implement the data which has been taken. National Instruments LabVIEW® program can be programmed to do a myriad of tasks. It can record data, organize it, and even output it into a graph in one simple user defined program. If a student were assigned to due this part of the task, it can easily comply with the existing materials. In reality students will need to use the device in a laboratory of one of a required course in the Biomedical Engineering department. Students will need to set up the experiment, record data, and write a program that would take the data with inputs and outputs like force, velocity, length, tension, shortening and lengthening aiming to make it work and obtain graphs of the force-velocity and length-tension relationships.

In order to attain desirable results from the experiment conducted, quantitative values for specifics must be given. Otherwise, the experiment is doomed to failure and these modifications would be exercises in futility. To achieve optimal result, the voltage should be set to a potential of 60 Volts. The current should run for a duration of 0.2 milliseconds, sent at a frequency of 1 stimulus per second. Care must be taken not to over stimulate the muscle too quickly, since in that case the muscle will expire, no action will take place, and the experiment will be ruined. Similarly, the muscle could experience damage if it dries out. A saline solution at a concentration of 0.9% would be ideal, since this will keep the muscle fresh. The condition a muscle is under outside the warmth and continuity of a body is extremely different from the atmosphere in the air. Using this solution would at least simulate the situation on the inside to the extent where the muscle is usable, and in good enough condition to give out strong real contractions.

Applying saline solution to the muscle can be done from a couple of methods. A simple, archaic method would be to have a squirt bottle filled with saline solution which could then be manually squeezed so that the solution came out the top of the bottle and effectively coat the muscle and keep it moist. This method poses a

potential threat to the experiment though since the muscle may not be coated completely, coated ineffectively, or too much time may be taken between applications of the saline and the muscle could easily dry out. Upon practice, most users of the device would not have difficulty keeping it wet, however it is likely that a select few groups of students would run into this as an issue, and their individual labs would greatly suffer. So as to alleviate this threat, an automated system may be installed with a function of keeping the muscle moist. The motor would churn water up in a timed manner, so that the moistness of the muscle remains constant. An ideal motor for this purpose would be the 6/12 Volt two speeds motor by GatewayAlex, model number 3200-023. The motor would be fitting for the purpose of this experiment, and its practicality fits nicely as well. The motor is in a general sense small, as the lengths for it are listed ahead. The motor length is 46 mm, the diameter is 41 mm, the shaft is 2.5 mm in diameter, and the shaft is 14 mm in length. Terminals are available on the sides of the motor in order to connect them to a power source. A capacitor is also installed on the motor so that noise released from the machine can be minimized. Finally, the most appealing aspect of the motor is its unit price is \$4.95, which is a bare minimum price compared to the total expense of the project.

General hygiene must be maintained in a good laboratory environment. Latex gloves should be worn at all times when working with these products for multiple reasons. Latex gloves eliminate the risk of infection from materials that could be worked with, and eliminate the possibility of irritation from the products used as well. It is possible a person could be intolerant to saline, so some barrier must be in place. Also, hand should not touch the muscle, as though unlikely, it could affect the results of the experiment. Powdered latex exam gloves from the company MEDIGAURD are available at a price of 1 box of gloves for \$3.60. 1 box of gloves contains 100 gloves, enough for 5 laboratories. There is the possibility that some students have a latex allergy, and for these students, some alternative should be made available. These would be rare cases though, and accommodations could be made on an individual case by case basis.

In order to run the muscle stimulator from above, nine volt batteries are necessary to supply voltage. The stimulator kit comes with batteries, but eventually, more will be required. Eveready sells 9 Volt batteries in individual packages at a rate of \$2.65 per unit. However, they are currently available at a low sale price of \$1.75 per battery. Many alternatives are available, but Eveready is the recognizable name brand battery available at the most affordable price.

One of the purposes of the ultimate device is to generate a length versus tension graph. The x axis would be the independent variable length, and the y axis would be the dependent variable tension. As the length of the muscle changes, the tension it generates changes as well. Unfortunately, due to the nature of the system, the system is nonlinear. Sarcomeres reduce in length when they contract. The action of the actins' head overlapping the myosin filaments physically reduces the size of the muscle. The order of the reduction is extremely small, as a good order to measure the length is between 0 and 3 micrometers. The curve generated shows three general stages, contraction, plateau, and relaxation. The curve also shows how changes in loading affect the tensile force development, and this allows for external

work to be performed. The relationship between length and tension can be surprising when examined, since a very small change in length results in a relatively great increase in tension. This is why the muscle becomes such a powerful tool for doing work.

The other curve hoped to be developed by the experiment is a curve analyzing force versus velocity. On this graph, velocity is the independent variable on the x axis, and force is the dependent variable on the y axis. The way the relationship develops is that a muscle undergoes shortening and lengthening under constant loads. In the case of this lab design, the constant load shall be the weight applied which is physically connected to the muscle. The velocity during shortening is measured by the devices already set in place, and the resistive force is recorded from the force transducer. Physiologically, the basis for the relationship is the quantitative result of the number of time for force bridges to attach. Though a muscle acts quickly, (within less than half a second when excited), it takes a few milliseconds for the cross bridges to form. As cross bridges attach, filament velocity increases. However, from the same process, force decreases from the fewer quantity of filaments now attached. The converse of this situation also holds to be true as well. If filament velocity decreases, more cross bridges have an opportunity to attach, and thus more force will be generated by the muscle. Ultimately, the determining factor for the shape of the force-velocity curve is the number of filaments that have developed cross bridges at that point. The two terms are related inversely, and as velocity goes up force goes down. As force goes up, velocity goes down. The following graphs gives an idea of what the actual results can appear to be. The first three graphs represent the force-velocity relationship in different situations, and the last graph in the next page shows what the length-tension relationship might appear to be.

Fig.1. Force-velocity and Length-tension relationship.

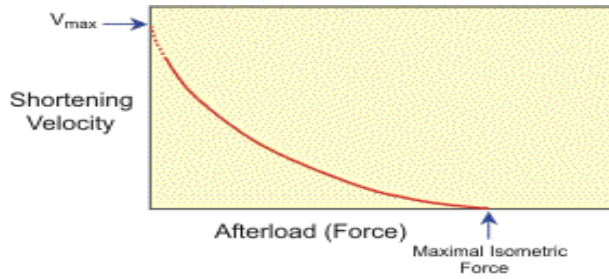


Figure 1. Force-Velocity relationship.

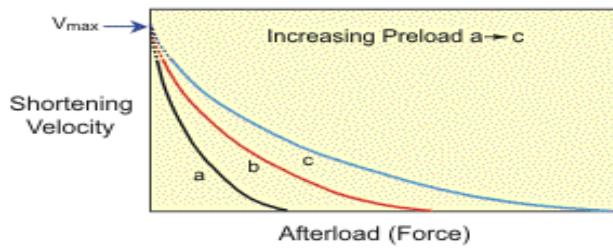


Figure 2. Effects of increasing preload (shift from curve a to c) on the force-velocity relationship.

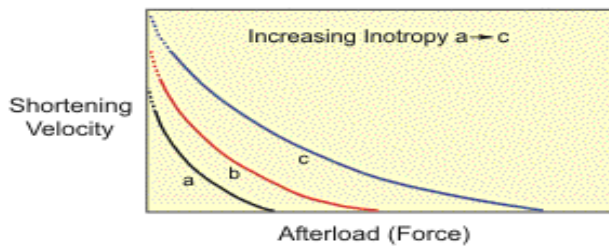
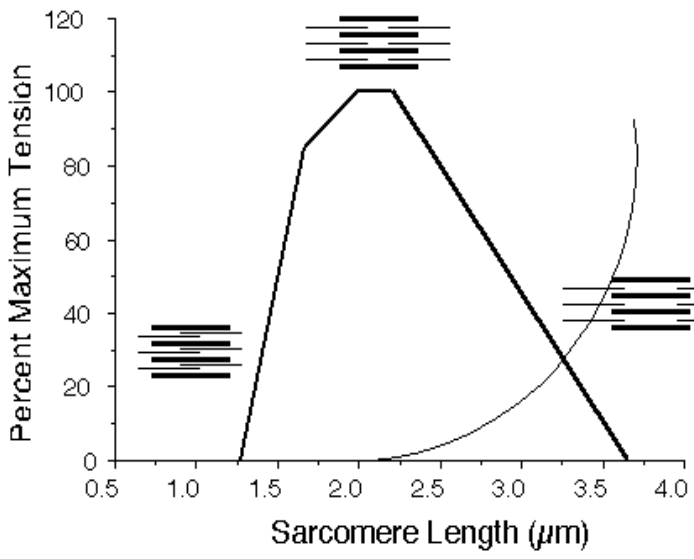
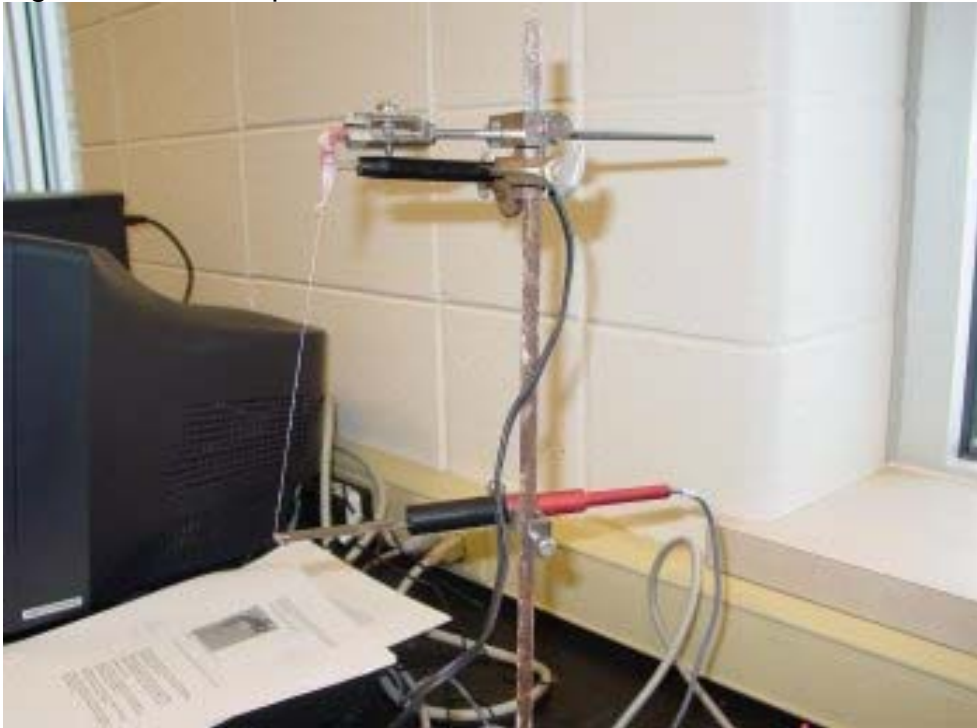


Figure 3. Effects of increasing inotropy (shift from curve a to c) on the force-velocity relationship.



The figure below shows what the muscle set up should look like. The stand and clamp set up looks close to what our final device would look like. Our device would have additional features as mentioned earlier as the weights, perhaps the automated solution being sprayed by means of the motor and a bucket right the muscle to collect the saline solution dripping out.

Fig.2. Muscle set up.



In this next figure one can see a close picture to what the entire set up might end up appearing and its features. The device should be a relatively good and practical in size, with the stimulator being perhaps smaller than the one shown in the picture and as mentioned before the experiment needs to be performed near a computer station in order to record the data and use the computer program for calculations and the final output.

Fig.3. Complete Set up.



### 3. Budget

In this table we list the cost of the products needed in the set up of the device. The budget is subject to change as we revise the design. The estimated cost for the device is \$174.15 which is less than 35% of the prototype cost. The aim is to keep the cost as low as possible since many stations need to be built for different groups in the laboratory. These products also need to be practical and durable since these are going to be used quite often by different students. The computer software needed for the display of the force-velocity and length-tension relationship is the LabVIEW® software program which is available in the Biomedical Engineering labs as well as other Engineering labs, therefore there is no need of purchasing this program. The motor is included in the list in case we decide to build the device that would spray the muscle automatically with the saline solution. The muscle cost can be subject to change as we are not exactly sure if we would need to dissect the muscle, ready to be tested, or obtained through the same department as the physiology and neurobiology department does. The electrodes are more expensive than the regular one since the ones needed are needle electrodes to stimulate the muscle. The price for the batteries will also increase as we think that more batteries will be needed throughout the experiment. The weights range from 10g to 1000g which can be ideal for different muscle sizes. We might increase the saline solution cost as we aim to find a bigger bottle with the solution. There are many muscle stimulators out in the market with different kind of prices. What we looked for was that we could pick a muscle stimulator that was going to be decent in price but that would have good features for the device and the experiment itself. Size is important and the whole device needs to be practical to be moved around and the stimulator has a good size and weight which combined with the rest of the products should be fairly easy to be relocated if necessary. We took into account gloves in order to preserve the specimen and for hygienic reasons and estimated free-latex gloves also as some students may be allergic to latex. Stands not too cheap are better since good gripping and support are needed for this device. The bucket is to prevent the spilling of the saline solution when sprayed to the muscle.

ITEMS	MARKET COST	ESTIMATED COST
Muscle	\$6.90 - \$28.00	\$6.90
Saline Solution	\$3.89 - \$10.99	\$5.95
Motor	\$1.95 - \$7.95	\$4.95
Muscle Stimulator	\$49.00 - \$2800.00	\$69.00
Weights	\$24.95 - \$199.99	\$24.95
Computer Software	\$2500.00 - \$5000.00	\$0.00
Stand ,clamp and bucket	\$32.75 - \$60.00	\$35.75
Electrodes	\$25.00 - \$101.12	\$25.00
Gloves	\$2.90 - \$3.60	\$2.90
Battery (9V)	\$1.75 - \$3.33	\$1.75
<b>Total</b>	<b>\$2649.09 - \$8214.98</b>	<b>\$177.15</b>

#### 4. Conclusion

Biomedical Engineering is a program in the School of Engineering at the University of Connecticut. The Major's curriculum consists of a course known as Biomedical Engineering 252: Measurements and Instrumentation. In Measurements and Instrumentation, a lab accompanies the course lectures. One lab which is in the design of the course is a lab concerned with frog leg's calf muscles. The calf is to be extracted and tested for its response to tension with length, and also responds to velocity versus time. The device we hope to build will record the force velocity and length tension relationships and allow students to learn on LABVIEW as this information is output.

In order for this experiment to have a setup yielding proper results, there should be certain materials used which limit the error in the experiment. The quality of the materials used is crucial, as goods needs to be considered which will be reliable enough to fit the desired function, but equally as important, must be well made enough in order to hopefully last for years. The total materials deemed necessary for execution of this experiment are the frog gastrocnemius muscle, saline solution, a motor, a muscle stimulator, weights, computer software, a stand, an arm clamp, a small bucket, electrodes, latex gloves and 9 Volt batteries. As the materials list becomes lengthier, the price in tandem for completion of the project increases as well. Also, as time taken in development of the project increases, the price of the whole project increases. Even though these two factors work against the quality of the product, one fact reduces the net cost of the price of the project by over 1400%. The LABVIEW program already exists within the University of Connecticut, and therefore eliminates \$2500 from the overhead of the project. At a minimum, the computer software would add an additional \$2500 to the cost of the manufacturing of the device. However, due to the fortunate situation of UConn already possessing the software, the estimated cost of this project drops from an estimated minimum of \$2700 to an estimated minimum \$180 per unit . Also, the research and development time on this venture does not earn a red cent since John Enderle employs his own students in his own class. This makes the absolute cost for that department \$0 leaving the total net cost per unit manufactured \$180.

Keeping cost down is paramount to the over all success of the business venture. In this situation, multiple set ups are needed, since multiple students are in labs simultaneously. A good target to shoot at to estimate total cost would be equal to the number of labs needed multiplied by the estimated cost per unit of lab equipment. Since these classes generally have 10 kids in each lab, six set ups would be an ideal number to shoot for, since this would allow for an extra set up in case there is an overflow of kids or if one set up does in fact fail. This brings the ultimate cost of the project up to about \$1100 dollars.

The University of Connecticut biomedical engineering department is a department which is currently seeking accreditation. In order for the department to achieve its goals, and for the director of the department to cement his goals of achieving accreditation, it would be helpful if all courses in the curriculum looked challenging and as though they would truly assist in helping students learn. If the ambitions of this project were sufficed, it would be a step in the right direction since it

would be impressive for creditors to look at the design of the whole major and see that at some point students are forced to meet the challenge of dissecting a frog muscle, record its responses to stimulus, develop a computer program to help do so, and learn from the overall experience.

## 5. References

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[http://www.washington.uwc.edu/about/faculty/schaefer\\_w/FrogMusclePage.htm](http://www.washington.uwc.edu/about/faculty/schaefer_w/FrogMusclePage.htm)

Noromed's website:

<http://www.noromed.com/about.cfm>

MyoVision:

<http://www.myovision.com>