Does Multidisciplinary Learning Help Global Problem: Covid-19 by Biomedical Engineering?

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ABSTRACT[1]

The academic field has been divided into each specialized field. Many problems in global society (including coronavirus disease 2019 (COVID-19)) cannot be solved by the single disciplinarian. They are waiting for the multi-disciplinarian. For students, it is not easy to find the way to learn a multidisciplinary field: the curriculum, the textbook, the learning team, and the teacher (the adviser). "Biomedical Engineering" is one of the multidisciplinary fields. It has many related fields: biology, medicine, informatics, and engineering. The topic includes case studies (education for the undergraduate, and the graduate courses) based on the author's experiences. Finding related subjects to case studies are effective to motivate students to learn in the multidisciplinary field. Multidisciplinary conferences give students opportunities to improve their communication ability. Inter-disciplinarians are necessary to make bridges over the barrier between global problems.

Keywords: Multidisciplinary Field, Learning, Biomedical Engineering, COVID-19, Communication and Students.

1. INTRODUCTION

The global society has given us the rapid circulation of things: materials and information. The rapid transportation system realized the fast movement of humans in the world. How can we control the pandemic of the coronavirus disease 2019 (COVID-19) in the global society [1]? If you select the traditional methodology of quarantine, you might have an image of "isolation". In this case, the face-to-face communication between people should be controlled. The original goal of "the public health," however, is to follow the health of the whole population. The purpose includes promoting healthy lifestyles. If we select keeping daily social activity, we should look for a new way to control the spread of viruses.

The academic field has been divided into each specialized field. The modern communication tools (internet and database), on the other hand, promote multidisciplinary academic fields [2]. Artificial intelligence helps humans to propose the best answer from big data [3]. Users of big data should understand the background. "The multidisciplinary field" is not just a collection of fields, but a fusion among fields [4]. Many problems in the global society cannot be solved by a single disciplinarian. The global society is waiting for a multi-disciplinarian. For students, it is not easy to find the way to learn a multidisciplinary field: the curriculum [5-12], the textbook [13], the learning team, and the teacher (the adviser).

"Biomedical Engineering" is one of the multidisciplinary fields. It has many related fields: biology, medicine, informatics, and engineering [14-18]. The field also relates to economics, sociology, ethics, and religion [4]. For example, the extracorporeal membrane oxygenator (ECMO) has been highlighted in COVID-19. It should be designed to realize collaboration with human natural systems: the blood circulation system, the respiratory system, and the nervous system [3]. The contents of this article are based on the author's experience: multi-doctoral thesis defenses, and a variety of affiliations [14].

2. METHODS

The learning course of Biomedical Engineering welcomes undergraduate and graduate students every year. The textbook of "Introduction to Biomedical Engineering" includes the following contents (with case studies) [13]:

1) Organism and Machine.
2) Units and Measurement.
3) Material (Hemolysis).
4) Flow (Blood circulation).
5) Energy (Oxygenator, Dialyzer).
6) Movement (Joint prosthesis).
7) Design and Machining (Artificial organs).

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In the course, students answer several questions related to COVID-19. It is a disease caused by a new type of coronavirus (SARS-CoV-2). The virus has caused a pandemic. The pathology has not been elucidated. Several treatments have been tried. While the unique answer to each question has not been decided yet by specialists, the questions give motivation to students to find topics of global multidisciplinary problems.

Questions

(1) Select your behavior in the past two weeks to be "free of COVID-19 infection".

1) Asymptomatic; I have been facing others in the normal life.
2) Facing others in normal life, I have been paying attention to disinfection: masks, and distancing from others.
3) I have been managing my own health by measuring body temperature without facing others.
4) Facing others in the normal life, I have been checking for the negative signs of COVID-19 infection by a PCR (polymerase chain reaction) test every day.
5) I have been facing others in the normal life, taking medications to control COVID-19 symptoms.
6) I have been facing others in the normal life, after receiving the vaccine against SARS-CoV-2 virus.
7) I have been facing others in the normal life, after confirmation of negative signs by a PCR test after the recovery from COVID-19.

(2) Select three effects of everyday-masks on COVID-19.

1) Prevent the outflow of the virus.
2) Enhance the immune capacity by maintaining humidity in the oral cavity.
3) Reduce splashing of water droplets including virus accompanied with sneezing.
4) Prevent elevation of the body temperature.
5) Prevent the inflow of the virus.
6) Prevent direct touch by your hands to the mouth (or the nose).

(3) Choose three answers related to COVID-19 as a method to directly reduce your chances of infection.

1) Wash your hands frequently.
2) Do not eat with bare hands without washing hands.
3) Disinfect the area you touch with alcohol.
4) Do not get together with many people.
5) Do not eat meals, which are exposed to the space of everyone's conversation, at the buffet.
6) Do not stay in a place with poor ventilation.
7) Keep a distance from others.
8) In a room with multiple people, refrain from the following action: talking, deep breathing, and singing a song.
9) Do not shake hands with others.

(4) Choose three answers to directly reduce the probability of the movement of COVID-19 virus from yourself to others

1) Wash your hands frequently.
2) Wear a mask when singing.
3) Use alcohol to disinfect your hands, and to disinfect the areas you touch.
4) Do not go into the crowd.
5) For sneezing and coughing, cover the mouth and the nose with sleeves and a handkerchief.
6) Do not stay in a place with poor ventilation.
7) Keep a distance from others.
8) Wear a mask when speaking.
9) Do not touch where many persons touch.

Topic Selection

The problem of COVID-19 includes many topics to be solved. Students try to find a new idea related to the topic, after questions.

(5) Choose multiple answers from the following future technologies related to COVID-19 that you consider important.

(6) Choose multiple answers from the following future technologies related to COVID-19 that seem to be feasible.

(7) Choose multiple answers from the following future technologies related to COVID-19 that you would like to realize.

1) Automatic generation of vaccine.
2) Automatic determination of effectiveness of vaccine without clinical trials.
3) Detection of cytokine (substance secreted by cells) release syndrome.
4) Diagnosis without facing the patient.
5) High-speed diagnosis of inspected data by artificial intelligence.
6) Prediction of infection.
7) Portable respirator.
8) Implantable oxygenator.
9) Technology that reduces oxygen consumption in living tissues.
10) Face-to-face communication technology without vocal conversation.
11) Telemedicine.
12) Medical robot.
13) Remote care.
14) Nursing robot.
15) Remote childcare.
16) Childcare robot.
17) Barber robot.
18) Artificial reality.
19) Remote sports.
20) Self-driving car.
21) Everyday activity tracking technology.
22) Everyday behavior monitor.

Your Proposal
In relation to COVID-19, students make a report. Students select topics in relation to biomedical engineering. They discuss quantitatively on their own ideas, using illustrations for explanation. The report should include the following items: an informative title, the motivation, methods, and contributions to society.

Presentation in a Multidisciplinary Conference
Students make presentations in the "World Multi-Conference of the International Institute of Informatics and Systems (IIIS, http://www.iiis.org/)."

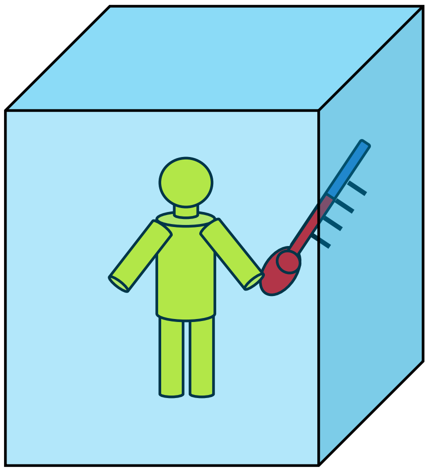

Fig. 1: Measuring body temperature without contacting others.

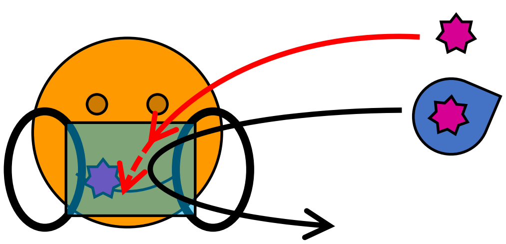

Fig. 2: Mask cannot stop virus.

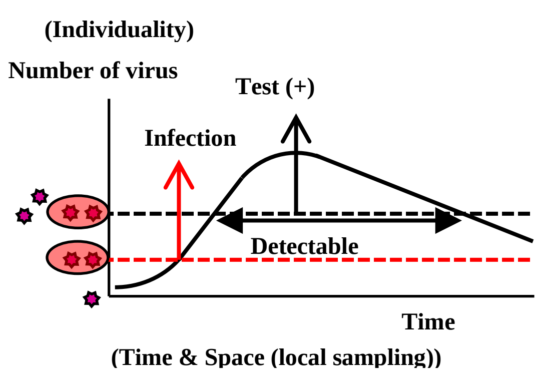

Fig. 3: Detection of virus.

3. RESULTS

Distributions of answers of students for each question are shown in the following tables, respectively.

Table 1: Select your behavior in the past two weeks to be "free of COVID-19 infection" (number of samples: 80).
*recommended.

Question	Ratio
Asymptomatic; facing others.	3%
Facing others: masks, and distance from others.	59%
*Measuring body temperature without facing others.	31%
Facing others, negative by PCR test every day.	1%
Facing others, medications.	0%
Facing others, vaccine against COVID-19.	1%
Facing others, recovery from COVID-19, negative.	5%

While every answer in Table 1 appears to follow precautions for COVID-19, no answer can guarantee that someone is virus-free. Because virus moves from person to person, "without facing others" is preferred (Fig. 1). There are several patients who are asymptomatic. While many students follow the rule of the mask, the virus can pass through a mask (Fig. 2, Table 2).

The results of PCR (polymerase chain reaction) tests depend on the timing and the sampling (Fig. 3). Some medications mask the symptoms. A vaccine has several points for discussion: the efficacy to the virus, the acquisition rate of antibodies, and the duration of immunity. More information is necessary on several points about the patients: the recurrence, and after-effects.

Table 2: Select three effects of everyday-mask on COVID-19 (number of samples: undergraduate 80, graduate 16).
*recommended.

Question	Undergraduate	Graduate
Outflow of virus.	83%	67%
*Maintaining humidity.	54%	31%
*Water droplets.	63%	100%
Body temperature.	0%	0%
Inflow of virus.	46%	38%
*Hands to mouth.	85%	63%

Many students expect the effect of the mask to be a barrier for the virus (Table 2). To stop the virus with a size smaller than 0.1 μm, a mask with a smaller pore size is necessary (Fig. 2). Keeping humidity in the oral cavity helps the immune capacity. The droplets can be captured by the mask (Fig. 2). The virus can move from your hand to your oral cavity by direct touch.

Table 3: Choose three answers related to COVID-19 as a method to directly reduce your chances of infection (number of samples: undergraduate 80, graduate 16). *recommended.

Question	Undergraduate	Graduate
Wash hands frequently.	64%	56%
*Not eat with bare hands.	26%	25%
Disinfect touching area.	25%	13%
Not get together.	60%	75%
*Not eat meals at buffet.	15%	19%
Ventilation.	41%	50%
Keep distance.	41%	25%
*Not talk, not sing.	24%	38%
Not shake hands.	1.3%	0%

We have several social rules recommended against infection in Japan. Students follow the rules: hand-washing, ventilation, and distancing (Table 3). We have few reports about infection in the crowded quiet space of public transportation. Virus can get into the oral cavity during eating with chatting. Ventilation is important during chatting (Fig. 4).

Table 4: Choose three answers to directly reduce the probability of the movement of COVID-19 virus from yourself to others (number of samples: undergraduate 80, graduate 16).
*recommended.

Question	Undergraduate	Graduate
Wash hands frequently.	18%	6%
*Wear mask when singing.	10%	6%
Disinfect your hands and areas.	18%	13%
Avoid crowds.	68%	88%
*Cover mouth with sleeves.	53%	50%
Ventilation.	18%	19%
Keep distance from others.	46%	38%
*Wear mask when speaking.	59%	56%
Not touch where people touch.	11%	25%

Many students agree to the rule of distancing (Table 4). Making barrier against droplets including the virus is effective to directly reduce the probability of movement of COVID-19 virus from yourself to others (Fig. 5).

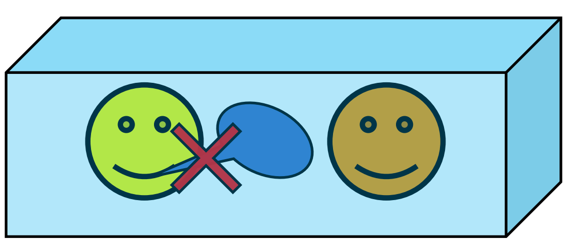

Fig. 4: Do not chat without ventilation.

Table 5: Choose multiple answers from the following future technologies related to COVID-19 (number of samples: undergraduate 80, graduate 16): Important (A), Feasible (B), and Realization expected (C).

Topic	Undergraduate			Graduate		
	A	B	C	A	B	C
Vaccine automatic	71%	23%	75%	56%	25%	100%
Vaccine without trial	48%	11%	56%	44%	6%	56%
Cytokine detection.	13%	6%	17%	6%	6%	31%
Remote diagnostics	75%	54%	64%	63%	63%	44%
Diagnosis by AI	46%	41%	58%	38%	44%	56%
Infection prediction	66%	58%	56%	63%	25%	63%
Portable respirator	28%	14%	39%	19%	0%	50%
Implant oxygenator	30%	25%	41%	13%	13%	31%
Reduce oxygen	13%	5%	25%	6%	0%	19%
Communicate no vocal	28%	31%	26%	0%	38%	25%
Telemedicine	71%	41%	55%	44%	44%	56%
Medical robot	61%	59%	59%	31%	50%	63%
Remote care	30%	16%	33%	19%	25%	31%
Nursing robot	35%	53%	46%	13%	25%	50%
Remote childcare	16%	6%	5%	0%	13%	19%
Childcare robot	15%	18%	16%	0%	0%	19%
Barber robot	6%	20%	13%	0%	6%	6%
Remote sports	6%	11%	15%	0%	19%	0%
Artificial reality	6%	11%	26%	13%	13%	25%
Self-driving car	14%	60%	56%	13%	44%	44%
Activity tracking	11%	30%	8%	13%	31%	6%
Behavior monitoring	6%	33%	11%	19%	25%	13%

Popular topics to students were as follows: "Vaccine automatic generation," "Diagnostics without facing the patient," "Prediction of infection," "Telemedicine," and "Medical robot" (Table 5). Many students thought that "Self-driving car" is feasible.

Table 6: Category of topics proposed by students: number.

Topic	Undergraduate	Graduate
1) Protection (ventilation).	18	0
2) Management.	4	4
3) Sterilization.	6	1
4) Body temperature.	12	1
5) Test.	20	5
6) Telemedicine.	6	0
7) Artificial organs.	15	3
8) Drug.	3	1

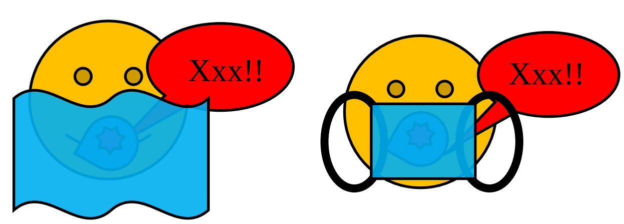

Fig. 5: Wear a mask when speaking.

Many topics proposed by students were related to tests for virus detection (Table 6, Fig. 3). Minimized artificial organs were also popular to students.

Table 7: Examples of ideas proposed by students.

1) Intracellular oxygen recycling.
2) Synthetic lymphocyte.
3) Microfluidic artificial lung.
4) Encapsulated micro artificial organ.
5) Engineered vessel wall for virus capture.
6) Highly functional mask.
7) Rehabilitation spirometer with virus detector.
8) Non-contact control screen.
9) Game for public health (accumulation of points).

Some students proposed innovative ideas related to a multidisciplinary background (Table 7). Many problems related to biology can be studied in the field of informatics with the big data of genomics.

Presentation in Multidisciplinary Conference

The cumulative number of participating students from author's program in the "World Multi-Conference of IIIS" was 62 from 2002 to 2020. The topics of presentation in the summer conference in 2020 were as follows:

1) Micro Back-markers on Thin Film of Scaffold to Measure Repetitive Local Contraction of Myotubes In Vitro.
2) Design of Flow Channel for Cell Sorter by Dielectrophoresis with Photolithography Technique.
3) Alignment of Myoblast Cultured on Micro Striped Ridge After Centrifuge Stimulation: Before and After Division.
4) Hysteresis Effect of Shear Flow Field on Migration Velocity of Cell: After and Before Division of L929 and 3T3-L1.
5) Velocity of Flowing Myoblast Cell at Oblique Micro Grooves.
6) Tracings of Myoblasts Orientation under Shear Flow In Vitro.
7) Cultured Myoblasts Orientation under Couette Type of Shear Flow between Parallel Disks: Fusion and Division.
8) Basic Study on the Mechanism of Earphone Hearing loss: About Correlation between Ear Age and Real Age.
9) Basic Study on the Directivity in an Oblique Projection Drawing: the Influence of Time on the Directivity.
10) Basic Study on the Recognition of Height (Vertical Length) and Width (Horizontal Length) of Squares.
11) Basic Concept of the Data Base on Music and Sound: Examples of Frequency Analysis.
12) Basic Concept of the Data Base on Music and Sound: Frequency Analysis to Beethoven's Piano Sonatas.

The annual conference of IIIS includes participants from a large number of countries: from 27 to 52. The number is rather large compared with the other international conferences on specialized fields. It is a good stimulus for young students to join in the multi-disciplinary society. WMSCI (World Multi-Conference on Systemics, Cybernetics and Informatics) gives a chance for each participant to experience a multidisciplinary society and a cross-cultural society, simultaneously [4].

Students enjoy a variety of research activities in the interdisciplinary field of biomedical engineering: nano /microsystems, cellular mechanics, biomechanics, biomaterials, bio-simulation, medical robotics, medical systems, biomedical informatics, bio-control engineering, bio-measurement, and biomimetics.

4. DISCUSSION

COVID-19 caused by SARS-CoV-2 virus is one of global problems in 2020. "Do not spit the virus." "Do not breathe the virus." These are two key-points to decrease probability of infection from person to person (Fig. 6). Students are using the clean room for micro machining. They also learn cell culture techniques. They are familiar with the clean space and sterilization. The pore size of the normal mask is larger than the size of the virus [1]. The virus passes through the mask. The droplet with viruses, on the other hand, can be captured by the mask. A huge number of droplets can be exhaled from the mouth when speaking and singing (Fig. 7a). You can make a shield with the sleeve when you do not have a mask. Students proposed new functional masks.

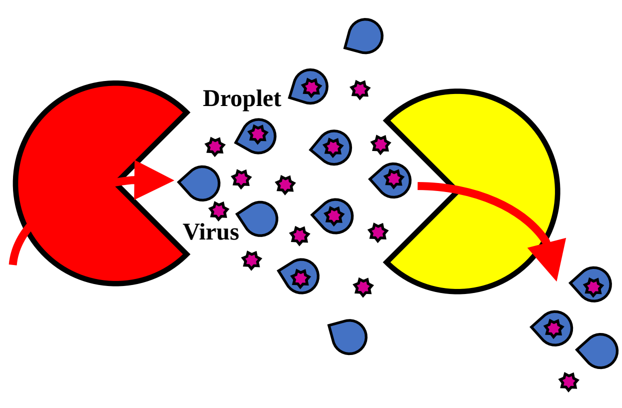

Fig. 6: Virus moves from person to person.

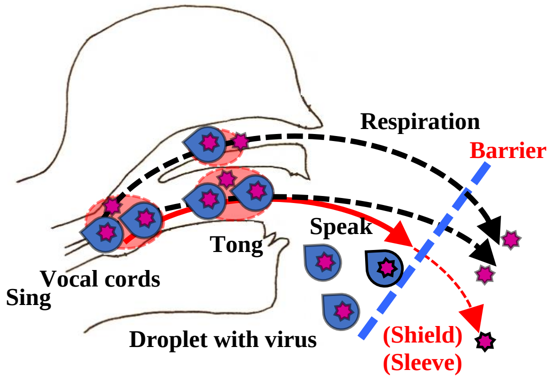

Fig. 7a: How can we make barrier for droplet with virus?

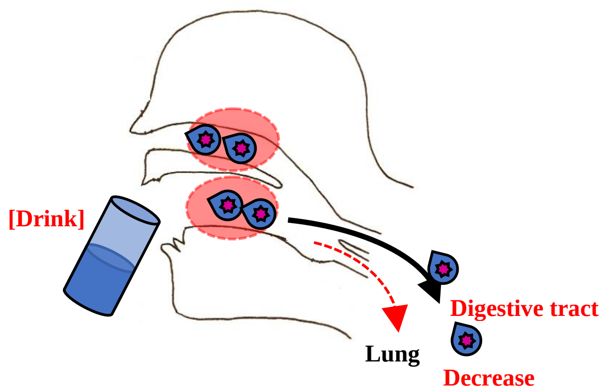

Fig. 7b: How can we reduce flow of virus into lung?

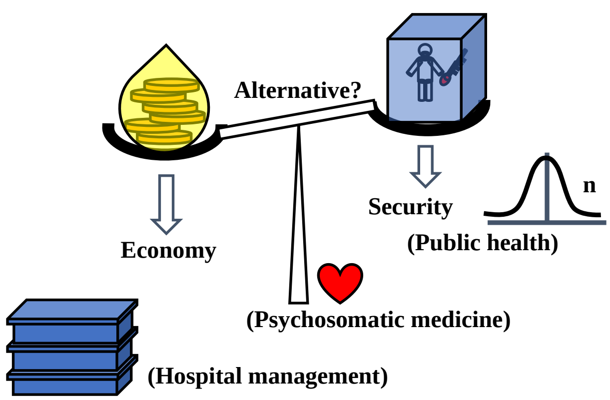

Fig. 8: Protection from virus vs. economy in pandemic.

How can we reduce the flow of viruses into the lung, when we have viruses in the oral cavity (Fig. 7b)? If we drink a cup of water, the virus would flow into the stomach. To prevent invasion of external enemies, the wall of the digestive tract might have higher ability than the alveolar membrane. If you do not have a mask, a bottle of water will help you to reduce the probability of invasion of viruses. Drinking water also reduces the risk of heat stroke.

To detect the targeted virus, a PCR test demands several conditions: the timing and the point for sampling (Fig. 3). These conditions depend on individuality, which includes the immune function. A PCR test also demands some execution time. If the virus moves from person to person before the virus is detected by the test, the movement of the virus cannot be controlled. If the negative results of the test before the detectable timing are used in the wrong way, misjudge occurs for the control of the movement of viruses. A new faster detection method is necessary. Personal gene information could help to predict who is more likely to be infected.

Is the relation between economy and security different in a pandemic (Fig. 8)? The emotion of people is related to both of them. The public health is supported by data and statistics. Isolation of a person for security against viruses can lead to psychosomatic illness. Management of the hospital also relates directly to the economy.

The medical care system should be maintained (Fig. 9). Even during a pandemic, the regular medical activity should be maintained: the emergency, the operation, and the examination. The purpose of public health is to minimize the number of deaths in the society. Even if we can reduce death by COVID-19, deaths by another cause could increase: cancer, cardiovascular disease, heat stroke, flu, and suicide.

The rapid increase of isolation of people who test positive for COVID-19 can exceed the medical care capacity. Patients might refrain from consultation at the hospital in the pandemic. Other vaccinations done according to correct timing are important. Biomedical engineers can help the health care system with self-check systems, telemedicine, medical robotics, database, and artificial intelligence.

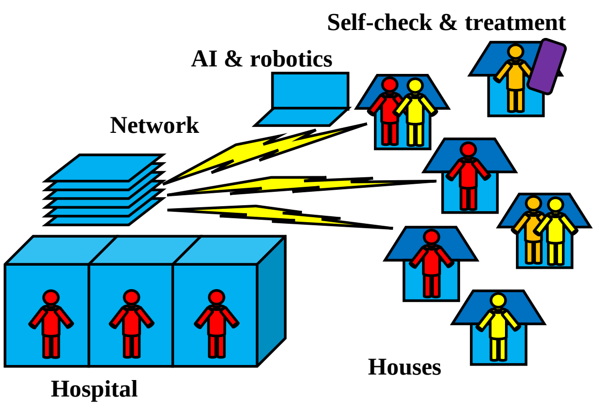

Fig. 9: How do you keep the medical care system from being flooded with an increase of patients?

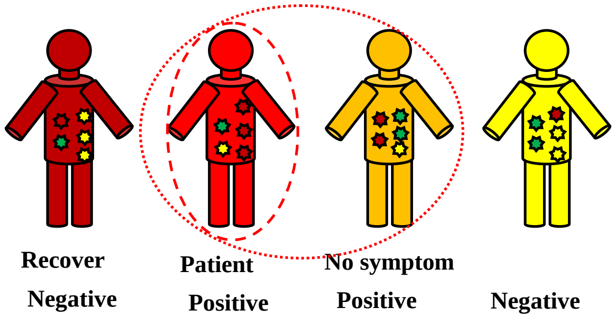

Fig. 10: Which virus should be detected?

There are two ways of isolation from viruses: the positive pressure system, and the negative pressure system [1]. Which way do you prefer to take? Can you keep yourself in the clean room forever? The human body has some kinds of viruses inside: symbiosis [2] (Fig. 10). The test should have enough sensitivity and resolution to find SARS-CoV-2 virus. The human body has the immune system. Infection is controlled by the immune system. Do we need the barrier between people? Do we make the barrier between different points (nationality, language, and culture)? Uniformity is the goal of the global society? Can we accept diversity? An inter-disciplinarian would make bridges between disciplines to break through barriers [1].

5. CONCLUSION

After learning the course of "Biomedical Engineering," students have realized that engineering relates to many special fields of study. As a case study, students have studied COVID-19, and found several key points related to pandemic. The multidisciplinary learning has given the motivation to find innovative topics for the new society. Many global problems are waiting for multi-disciplinarians.

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