 

The GH-Method

# Viscoelastic and Viscoplastic Glucose Theory (VGT #124): Using Three Different Energy Methods, Time-Domain, Space-Domain, and Frequency-Domain, to Compare Results of Waveform Fluctuation of PPG Output versus Constant Food Input and Exercise Input Over a Period of 4+ Years from 5/8/2018 to 8/6/2022 with 3,271 US Home-Cooked Meals and 82 Airline Prepared Meals Based on Math-Physical Medicine Method (No. 715)

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**Note:** This article is an expanded version of Paper No. 003.

**Keywords:** Viscoelastic; Viscoplastic; Food; Exercise; Postprandial plasma glucose; Fasting plasma glucose; Type 2 diabetes; Fast Fourier transform

**Abbreviations:** FFT: fast Fourier transform; PPG: postprandial plasma glucose; FPG: fasting plasma glucose; FD: frequency domain; SD: space domain; TD: time domain; MPM: math-physical medicine

## 1. INTRODUCTION

For many years, by analyzing the lifestyle influential factors of type 2 diabetes particularly glucose, the author has identified the most critical factor that forms the postprandial plasma glucose (PPG) level which is the insulin resistance resulting from the damage to pancreatic beta cells. This can also be indicated by the level of fasting plasma glucose (FPG) in early morning.

Other than this “insulin” baseline factor, carbohydrates and sugar intake amount is the next most critical contribution factor (~60% of carbs and exercise) and post-meal exercise intensity is another critical and effective contribution factor (~40% of carbs and exercise). In addition to these 3 primary factors, different type and dosage of diabetes medications, body weight, anxiety, stress, traveling, illness, sleep quality/disturbance, and glucose measurement delay are secondary causes of glucose fluctuations. In summary, about 20 factors for PPG and 6 factors for FPG have been identified by the author previously. All of these elements are considered as major and minor influential factors in glucose formation.

Prior to COVID-19 pandemic, the author traveled heavily around the world to deliver 120+ presentations at 63 medical conferences. He has found out that his glucose control became much harder during traveling days, especially during flight hours for two reasons. Airline-prepared meals are not diabetes friendly in terms of carbohydrates and sugar contents along with post-meal exercise as being a difficult task.

Paper No. 003 written on 3/14/2019 discussed the author’s average daily glucose values and metabolism index (MI) values on traveling days. Although it was informative in regard to his higher glucose levels and MI scores while traveling, the study was a simple arithmetic calculated data comparison. In Paper No.712, he will apply three different math-physical medicine (MPM) methods, including time domain (TD) from statistics, space domain viscoelastic & viscoplastic theory (SD-VGT) from engineering, and frequency domain fast Fourier

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transformation (FD-FFT) from physics to examine this similar research. The MPM approach can delve into the problem deeper and identify certain findings easier.

The author has developed a software APP on the iPhone to collect and store 3+ million data regarding his health, medical conditions, and lifestyle details. He has entered 8,375 food and meals related data (with meal photos) from 5/1/2015 to 8/6/2022 with an average carbs/sugar intake of 13.8 grams per meal and 4,294 steps of post-meal walking exercise over the 7+ year period. He then applies the developed "data-mining" tool to extract related data for US home-cooked meals versus various airline-prepared meals from his database stored in a cloud server.

The following section briefly describes his analysis methods.

## 2. METHODS

### 2.1 TD, SD, and FD analysis tools

This section has brief descriptions of TD correlation analysis with other observational results, SD VGT analysis with hysteresis loop area's energy results, and FD analysis with frequency curve area's energy results.

First of all, using a TD analysis tool, we can examine the curves' moving trend and pattern visually along with their correlation numerically. We can also study the extremely high or low data values in the dataset. The visual observation or calculation-derived interpretations are a part of statistical analysis results which can indeed provide some useful hints or even derive some accurate conclusions. However, we must be aware of the limitations of the data we select and be cautious of the appropriate statistics tool we choose.

The author would like to describe the essence of his developed "hybrid model" that combines the SD viscoelastic/plastic VGT analysis method and FD FFT analysis method with a comparison against the traditional time-domain statistical correlation analysis.

It is described in 10 steps in the English language instead of using mathematical equations to explain it. In this article, he has applied the SD-VGT operations (steps 1-7) and the FD-FFT operations (steps 8-10). As a result, it is aimed at readers who do not have an extensive background in those academic subjects of engineering, physics & mathematics.

The first step is to collect the output data or symptom (strain or ε) on a time scale. The second step is to calculate the output change rate with time (dε/dt), i.e. the change rate of strain or symptom over each period. The third step is to gather the input data or cause (viscosity or η) on a time scale. The fourth step is to calculate the time-dependent input or cause (time-dependent stress or σ) by multiplying dε/dt and η together. The "time-dependent input or cause equation" of "stress σ = strain change rate of dε/dt * viscosity η" is the essential part of "time-dependency". The fifth step is to plot the input-output (i.e. stress-strain or cause-symptom) curve in a 2-dimensional space domain or SD (x-axis versus y-axis) with strain (output or symptom) on the x-axis and stresses (time-dependent inputs, causes, or stresses) on the y-axis. The sixth step is to calculate the total enclosed area within these stress-strain curves or input-output curves (i.e. the hysteresis loops), which is also an indicator of associated energies (either created energy or dissipated energy) of this input and output dataset. These energy values can also be considered as the degrees of influence on output by inputs. The seventh step is the assembly of the area values of the selected periods to compare the "progression and contribution of condition" over certain time periods.

For the frequency domain, the eighth step is to define a "hybrid input variable" by using "strain*stress" which yields another accurate estimation of energy ratio similar to the SD-VGT energy ratio associated with the hysteresis loop. The ninth step is to present these hybrid models' results of (strain*stress) in TD and then perform the FFT operation to convert them into FD. The enclosed area of the frequency curve (where the x-axis is the frequency and the y-axis is the amplitude of energy) can be used to estimate the total FD-FFT energy. The tenth step is to compare these FD energy results against the SD-VGT energy results, or even TD energy results.

After providing the above 10-step description, the author uses the following set of VGT stress-strain mathematical equations in a two-dimensional SD to address the unique "time-dependency characteristics" of selected medical variables:

Strain
= ε
= individual strain value at the present time duration

Stress
= σ (based on the change rate of strain multiplying with a chosen viscosity factor η)
= η * (dε/dt)
= η * (d-strain/d-time)
= (viscosity factor η using individual viscosity factor at present time duration) * (strain at present quarter - strain at previous time duration)

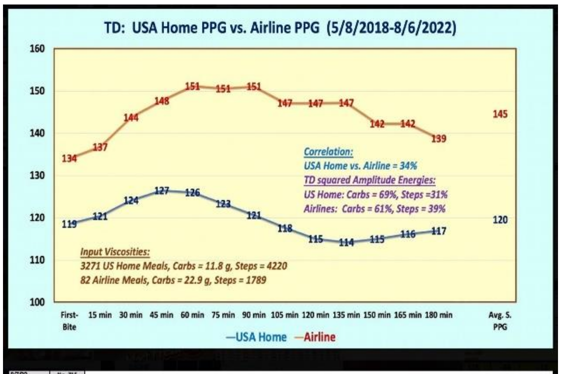
Some of these inputs (causes or viscosity factors) are further normalized by dividing them or being divided by a normalization factor using certain established health standards or medical pieces of knowledge. Some examples of normalization factors are 6.0 for HbA1C, 120 mg/dL for glucose, 25 for body mass index (BMI), 4,000 steps after each meal, 10,000 or 12,000 steps for daily walking exercise depending on time-period selection, 15 or 20 grams of carbs/sugar intake amount per meal depends on time-period selection. If using the originally collected data, i.e. the non-normalized data, it would distort the numerical comparison of the hysteresis loop areas. Using this "normalization process", we can remove the dependency of the individual unit or certain unique characteristics associated with each viscosity factor. This process allows us to convert the originally collected variables into a set of "dimensionless variables" for easier numerical comparison and result interpretation.

In this particular study, he uses 11 grams and 3,000 walking steps as the "normalization factors" for his two viscosities, food carbs/sugar amount and post-meal walking exercise.

**Note:** For a more detailed description, please refer to the "consolidated method" section which is given at the beginning of the special issue.

## 3. RESULTS

Figure 1 shows his data table and time-domain diagram.




| 8/7/22 | No. 715 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| USA Home | Strain | Viscosity 1 | Viscosity 2 | 11 | 3000 | Strain Rate | Strain | Stress 1 | Stress 2 | Area 1 | Area 2 | | | FD 1 | FD 2 |
| Sensor PPG | S. PPG | Carbs | Steps | N. Carbs | N. Steps | Total Rate | S. PPG | Carbs | Steps | Carbs | Steps | Period # | Period % | Carbs | Steps |
| First-Bite | 119 | 12 | 4220 | 1.07 | 0.71 | 0.0 | 119 | 0.0 | 0.0 | 0.0 | 0.0 | | | 0 | 0 |
| 15 min | 121 | 12 | 4220 | 1.07 | 0.71 | 1.9 | 121 | 2.0 | 1.3 | 1.9 | 1.2 | | | 240 | 159 |
| 30 min | 124 | 12 | 4220 | 1.07 | 0.71 | 3.7 | 124 | 4.0 | 2.6 | 11.1 | 7.4 | | | 496 | 329 |
| 45 min | 127 | 12 | 4220 | 1.07 | 0.71 | 2.3 | 127 | 2.5 | 1.7 | 7.6 | 5.0 | 0-60 min | | 316 | 210 |
| 60 min | 126 | 12 | 4220 | 1.07 | 0.71 | -0.5 | 126 | -0.5 | -0.3 | -0.5 | -0.3 | 33.4 | 38% | -62 | -41 |
| 75 min | 123 | 12 | 4220 | 1.07 | 0.71 | -2.6 | 123 | -2.8 | -1.9 | 4.4 | 2.9 | | | -351 | -233 |
| 90 min | 121 | 12 | 4220 | 1.07 | 0.71 | -2.7 | 121 | -2.9 | -1.9 | 7.9 | 5.2 | | | -355 | -235 |
| 105 min | 118 | 12 | 4220 | 1.07 | 0.71 | -3.0 | 118 | -3.2 | -2.1 | 9.3 | 6.2 | 75-120 min | | -381 | -253 |
| 120 min | 115 | 12 | 4220 | 1.07 | 0.71 | -2.6 | 115 | -2.8 | -1.8 | 7.7 | 5.1 | 48.8 | 55% | -317 | -210 |
| 135 min | 114 | 12 | 4220 | 1.07 | 0.71 | -0.8 | 114 | -0.9 | -0.6 | 1.4 | 1.0 | | | -98 | -65 |
| 150 min | 115 | 12 | 4220 | 1.07 | 0.71 | 0.8 | 115 | 0.8 | 0.5 | 0.0 | 0.0 | | | 93 | 61 |
| 165 min | 116 | 12 | 4220 | 1.07 | 0.71 | 1.2 | 116 | 1.3 | 0.9 | 1.3 | 0.9 | 135-180 min | | 152 | 101 |
| 180 min | 117 | 12 | 4220 | 1.07 | 0.71 | 0.7 | 117 | 0.8 | 0.5 | 0.8 | 0.5 | 5.8 | 7% | 92 | 61 |
| Avg. Sensor PP | 120 | 12 | 4220 | 1.07 | 0.71 | -0.13 | 120 | -0.1 | -0.1 | 52.9 | 35.1 | 88.0 | 100% | -14 | -9 |
| Squared PPG | 3271 meals | 1.2 | 0.5 | N.Vis. Ratio | 1.51 | | | Stress Ratio | 1.51 | Area Ratio | 1.51 | | FD Energy | 2081296 | 803634 |
| Enerey Ratio | TD Enerey | 69% | 31% | | | | | | SD Energy | 60% | 40% | | FD Energy | 72% | 28% |

| Airline | Strain | Viscosity 1 | Viscosity 2 | 11 | 3000 | Strain Rate | Strain | Stress 1 | Stress 2 | Area 1 | Area 2 | | | FD 1 | FD 2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sensor PPG | S. PPG | Carbs | Steps | N. Carbs | N. Steps | Total Rate | S. PPG | Carbs | Steps | Carbs | Steps | Period # | Period % | Carbs | Steps |
| First-Bite | 134 | 23 | 1789 | 2.08 | 1.68 | 0.0 | 134 | 0.0 | 0.0 | 0.0 | 0.0 | | | 0 | 0 |
| 15 min | 137 | 23 | 1789 | 2.08 | 1.68 | 2.7 | 137 | 5.6 | 4.5 | 7.5 | 6.1 | | | 767 | 617 |
| 30 min | 144 | 23 | 1789 | 2.08 | 1.68 | 6.9 | 144 | 14.4 | 11.6 | 69.6 | 56.0 | | | 2078 | 1674 |
| 45 min | 148 | 23 | 1789 | 2.08 | 1.68 | 3.9 | 148 | 8.2 | 6.6 | 44.6 | 35.9 | 0-60 min | | 1212 | 976 |
| 60 min | 151 | 23 | 1789 | 2.08 | 1.68 | 3.5 | 151 | 7.2 | 5.8 | 26.8 | 21.6 | 268.1 | 75% | 1092 | 880 |
| 75 min | 151 | 23 | 1789 | 2.08 | 1.68 | -0.5 | 151 | -1.1 | -0.9 | -1.7 | -1.3 | | | -173 | -139 |
| 90 min | 151 | 23 | 1789 | 2.08 | 1.68 | 0.5 | 151 | 1.1 | 0.9 | 0.0 | 0.0 | | | 161 | 129 |
| 105 min | 147 | 23 | 1789 | 2.08 | 1.68 | -3.9 | 147 | -8.2 | -6.6 | 13.9 | 11.2 | 75-120 min | | -1202 | -968 |
| 120 min | 147 | 23 | 1789 | 2.08 | 1.68 | -0.1 | 147 | -0.2 | -0.1 | 0.3 | 0.3 | 22.7 | 6% | -25 | -20 |
| 135 min | 147 | 23 | 1789 | 2.08 | 1.68 | 0.1 | 147 | 0.2 | 0.2 | 0.0 | 0.0 | | | 31 | 25 |
| 150 min | 142 | 23 | 1789 | 2.08 | 1.68 | -5.0 | 142 | -10.3 | -8.3 | 25.1 | 20.2 | | | -1470 | -1184 |
| 165 min | 142 | 23 | 1789 | 2.08 | 1.68 | 0.1 | 142 | 0.2 | 0.1 | -0.4 | -0.3 | 135-180 min | | 24 | 19 |
| 180 min | 139 | 23 | 1789 | 2.08 | 1.68 | -3.6 | 139 | -7.4 | -6.0 | 12.9 | 10.4 | 67.9 | 19% | -1029 | -829 |
| Avg. Sensor PP | 145 | 23 | 1789 | 2.08 | 1.68 | 0.36 | 145 | 0.7 | 0.6 | 198.6 | 160.0 | 358.6 | 100% | 113 | 91 |
| Squared PPG | 82 meals | 4.3 | 2.8 | N.Vis. Ratio | 1.24 | | | Stress Ratio | 1.24 | Area Ratio | 1.24 | | FD Energy | 13156953 | 8521828 |
| Enerey Ratio | TD Enerey | 61% | 39% | 194% | 236% | | | | SD Energy | 55% | 45% | | FD Energy | 61% | 39% |

**Figure 1:** Data table and TD analysis results.

Figure 2 depicts his two SD-VGT strain-stress energy analysis results.

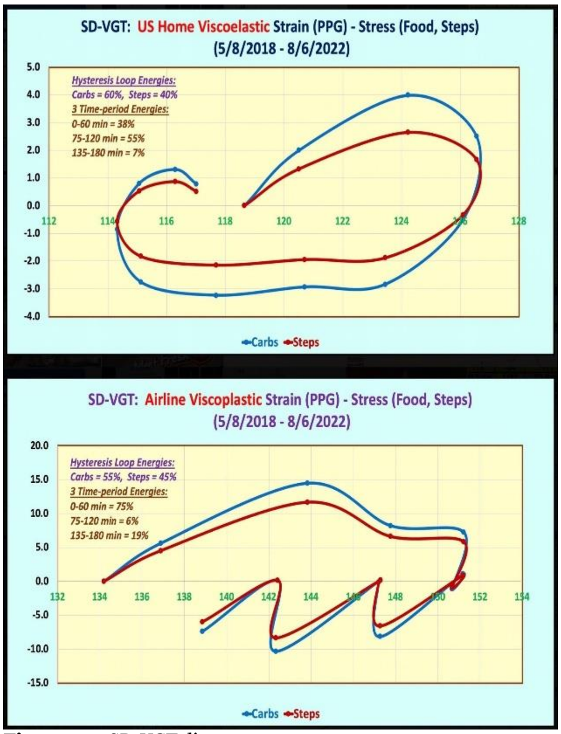



**Figure 2:** 2 SD-VGT diagrams.

Figure 3 displays his two FD-FFT energy analysis results.

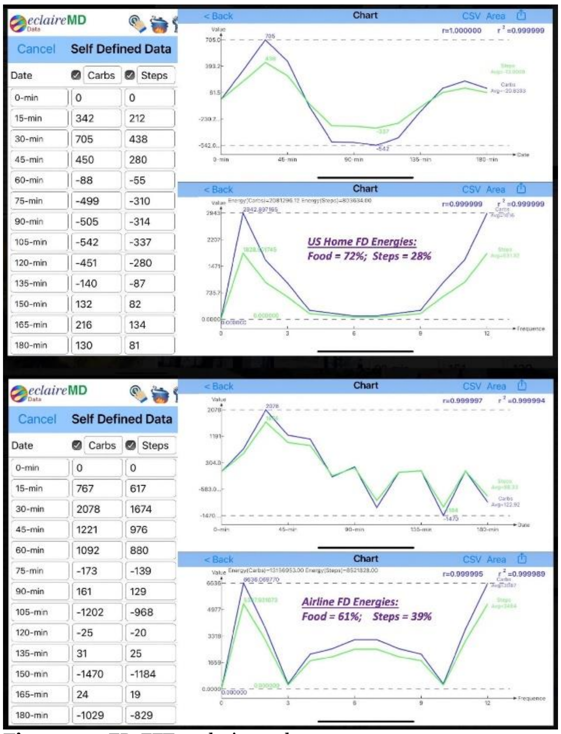



**Figure 3:** 2 FD-FFT analysis results.

## 4. CONCLUSION

There are 7 conclusions observed from this study:

(1) From the TD diagram, the input viscosities are: For 3,271 US home-cooked meals, average carbs = 11.8 grams, average steps = 4220. For 82 airline-prepared meals, average carbs = 22.9 grams, average steps = 1789. Again, his total of 8,375 meals collected data from 5/1/2015 to 8/6/2022 with an average carbs/sugar intake of 13.8 grams per meal and 4,294 steps of post-meal walking exercise over these 7+ years. The airline meals have a higher average carbs/sugar intake amount which is resulted from the combination of much higher carbs/sugar amount with much fewer walking steps after meals.

(2) From the TD diagram, the correlation between US home and airline is 34% which is a very low correlation(almost none). Using squared amplitude approach, the energy ratios are: For US home-cooked meals: Carbs = 69% & Steps = 31%. For airline-prepared meals: Carbs = 61% & Steps = 39%.

(3) From SD-VGT energy analysis results, the following strain-stress (or symptom-cause) energy ratios are observed: For US home-cooked meals, Carbs = 60%; Steps = 40%. For airline-prepared meals, Carbs = 55%; Steps = 45%.

(4) From SD-VGT energy analysis results, the following PPG waveform time-period energy ratios are observed: For US home-cooked meals, 0-60 minutes (1st hour) = 38%; 75-120 minutes (2nd hour) = 55%, 135-180 minutes (3rd hour) = 7%. Not only is the strain-stress curve of US-cooked meals behave like a viscoelastic curve, but also has 93% of intake energy dissipated within the second hour and only 7% of energy left over within the third hour.

(5) From SD-VGT energy analysis results, the following PPG waveform time-period energy ratios are observed: For airline-prepared meals, 0-60 minutes (1st hour) = 75%; 75-120 minutes (2nd hour) = 6%, 135-180 minutes (3rd hour) = 19%. Most of the intake energy builds up within the first hour (75%) and only 6% of energy is dissipated within the second hour (due to low walking steps). Therefore, the left-over energy of 19% is still left behind and stored inside of the body within the third hour. This airline meal strain-stress curve is a viscoplastic curve.

(6) From FD-FFT energy analysis results, the following ratios are observed: For US home meals, Carbs = 72%; Steps = 28%. For Airline meals, Carbs = 61%; Steps = 39%.

(7) By comparing the energy ratios between carbs and steps, these 3 different energy methods have yielded similar ranges of energy ratios. It is interesting to point out that the SD energy ratio for US home meals (the majority of his total meals) is carbs = 60% versus steps = 40%. This finding not only matches with his previous results using different analysis methods but also matches with the biomedical physiopathological pathways of diet = 8 versus exercise = 5.

This study has demonstrated that PPG values are mainly influenced (55%-72%) by the carbs/sugar intake amount and, in a minor way (28% to 45%), by walking exercise. In the author's case, the US home-cooked meals (the majority of his total meals) generate energy via food within the first hour and dissipate via exercise within the second hour; therefore, only a small amount of left-over energy within the third hour and after.

These three energy methods can indeed explore deeper findings and certain subtle information regarding glucose and diabetes.

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# Viscoelastic and Viscoplastic Glucose Theory Application in Medicine

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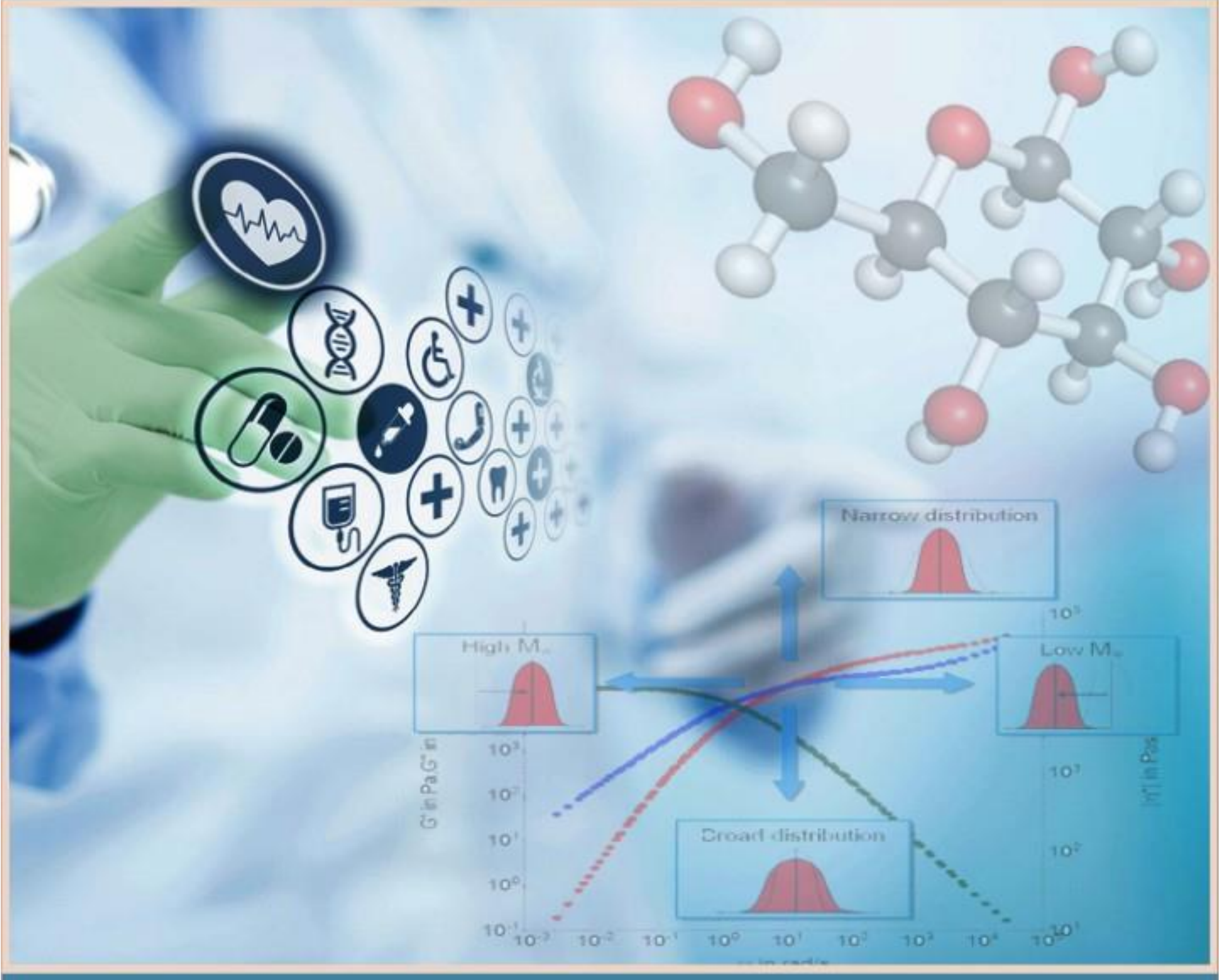


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