http://www.hmmh.com/

Overview of Noise Metrics and Acoustical Objectives

Gene Reindel

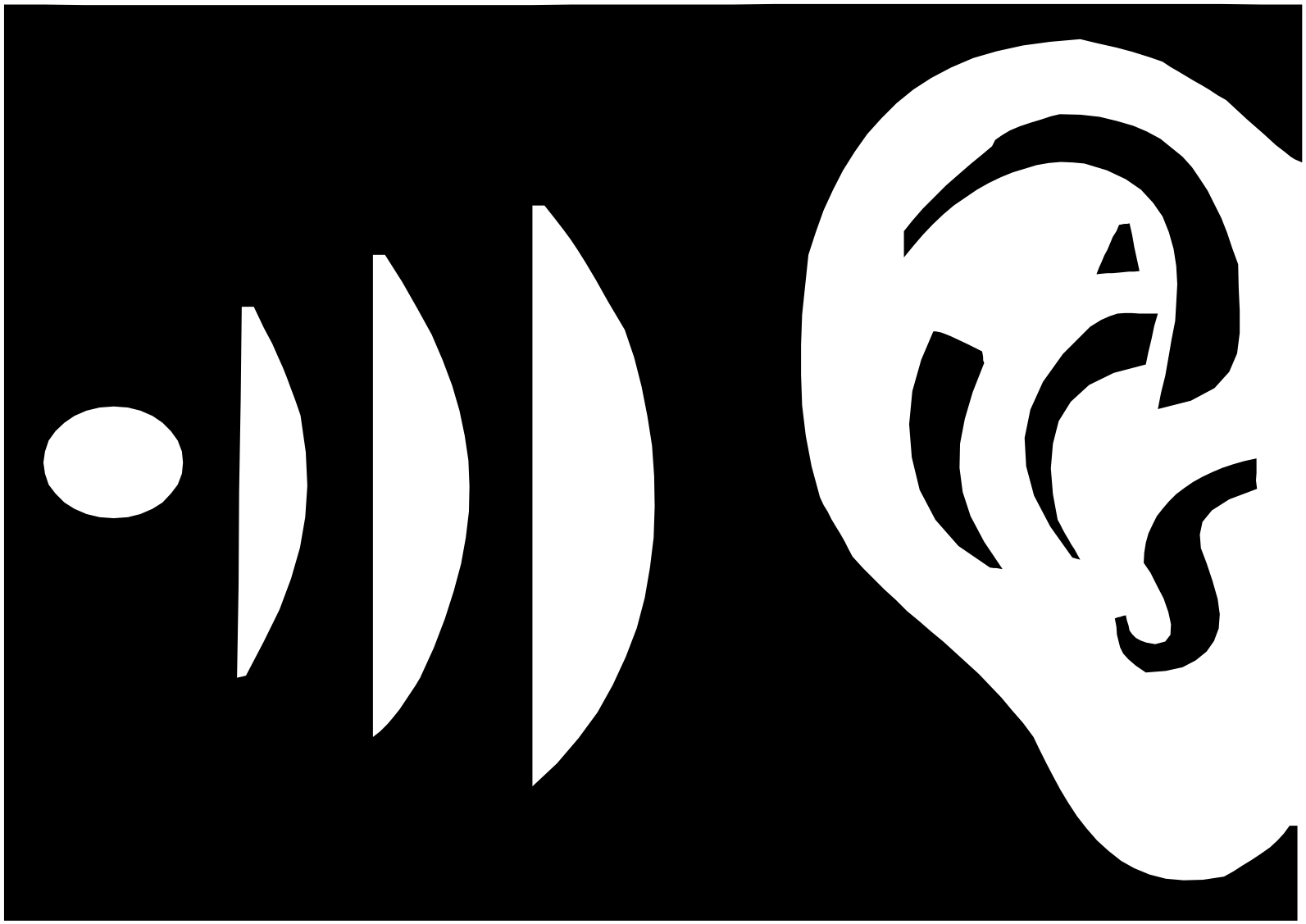
Senior Noise Consultant

Harris Miller Miller & Hanson Inc.

AAAE Sound Insulation Symposium

21-23 October 2001

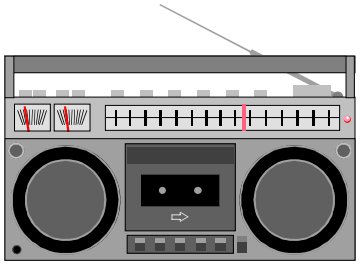
Introduction to Acoustics

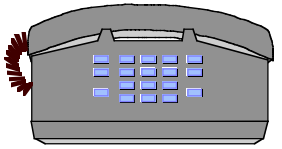


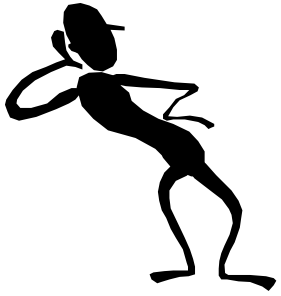
Sound and the Human Being

Functions of Sound

- Provides enjoyable experiences
  - *listening to music*
  - *singing of birds*
- Enables communication
- It can alert or warn
  - *ringing of the telephone*
  - *wailing of a siren*
- Allow for diagnostics
  - *chattering valves of a car*
  - *a squeaking wheel*
  - *a heart murmur*







Definition of Noise

Noise is unwanted sound

What is Sound?

Sound

Any pressure variation (in air, water or other elastic medium) that the human ear can detect.

- Weather changes are much to slow for the human ear to detect
- Atmospheric pressure changes that occur at least 20 times a second can be heard and are thus called sound
  - *A barometer cannot respond quickly enough, therefore cannot be used to measure sound.*

What is Sound?
Frequency Characteristic

- **Frequency in Hertz (Hz)**
  - *The number of pressure variations per second*
- **The frequency of a sound produces it's distinctive tone**
  - *Rumble of distant thunder is low frequency*
  - *A whistle is high frequency*
- **Normal range of hearing for a healthy young person is 20 Hz to 20,000 Hz (or 20 kHz)**
- **Range of the lowest to highest piano note is 27.5 Hz to 4186 Hz.**

The dB
Level Characteristic

Decibel

A main quantity used to describe sound is the size or amplitude of the pressure fluctuations.

- A healthy human ear can detect sound amplitudes from 20 millionths of a Pascal (20:Pa)
- The ear can tolerate sound pressures more than a million times higher
- The decibel (or dB) scale is used to accommodate this quite large range of pressures.

The dB

The decibel scale

- It is a ratio
  - *Measured quantity to agreed reference level*
  - *Threshold of hearing (20 :Pa) is the reference used when measuring sound pressure levels (SPL)*
- Threshold of hearing is 0 dB (re 20 :Pa)
- 1 million times 20 :Pa is 120 dB
- Threshold of pain is 140 dB

The dB

Sound Pressure Level (SPL)

$$L_P = 10\,Log_{10}\left[\frac{P_{rms}^2}{P_0^2}\right]$$

where

L_p = rms sound pressure level in dB

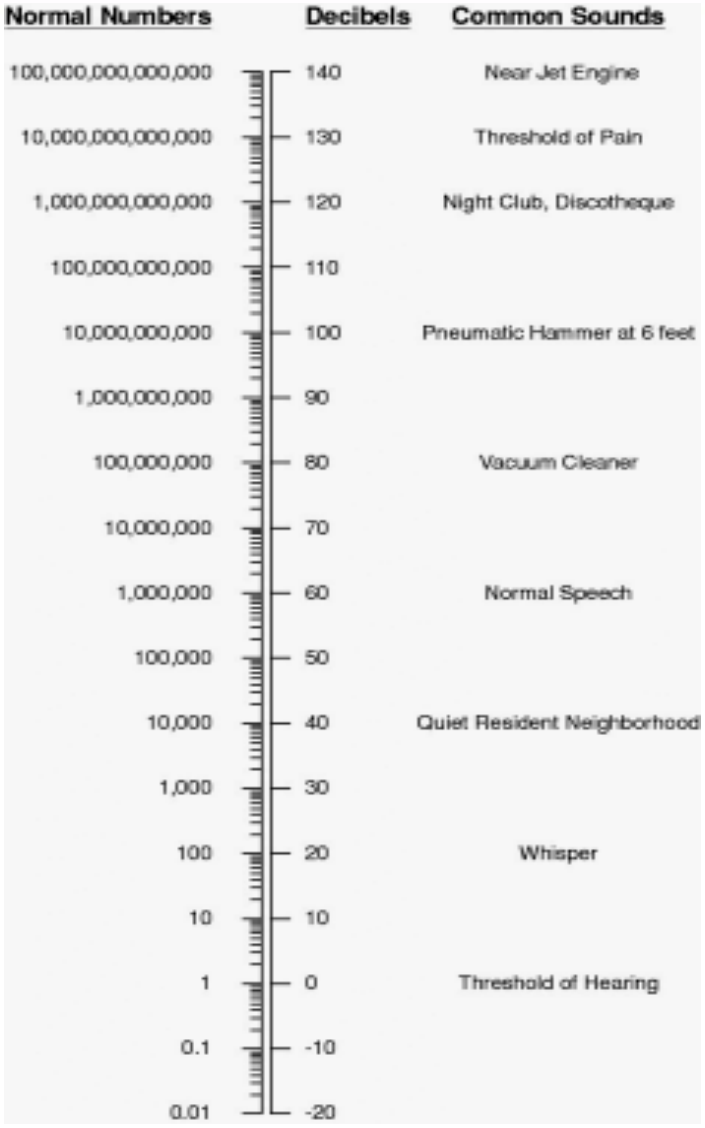
P_{rms} = rms sound pressure

P_0 = reference pressure of 20 x 10-6 N/m2 or 2.90 x 10-9 lb/in2

Log_{10} = base 10 logarithm

The dB

http://www.hmmh.com/

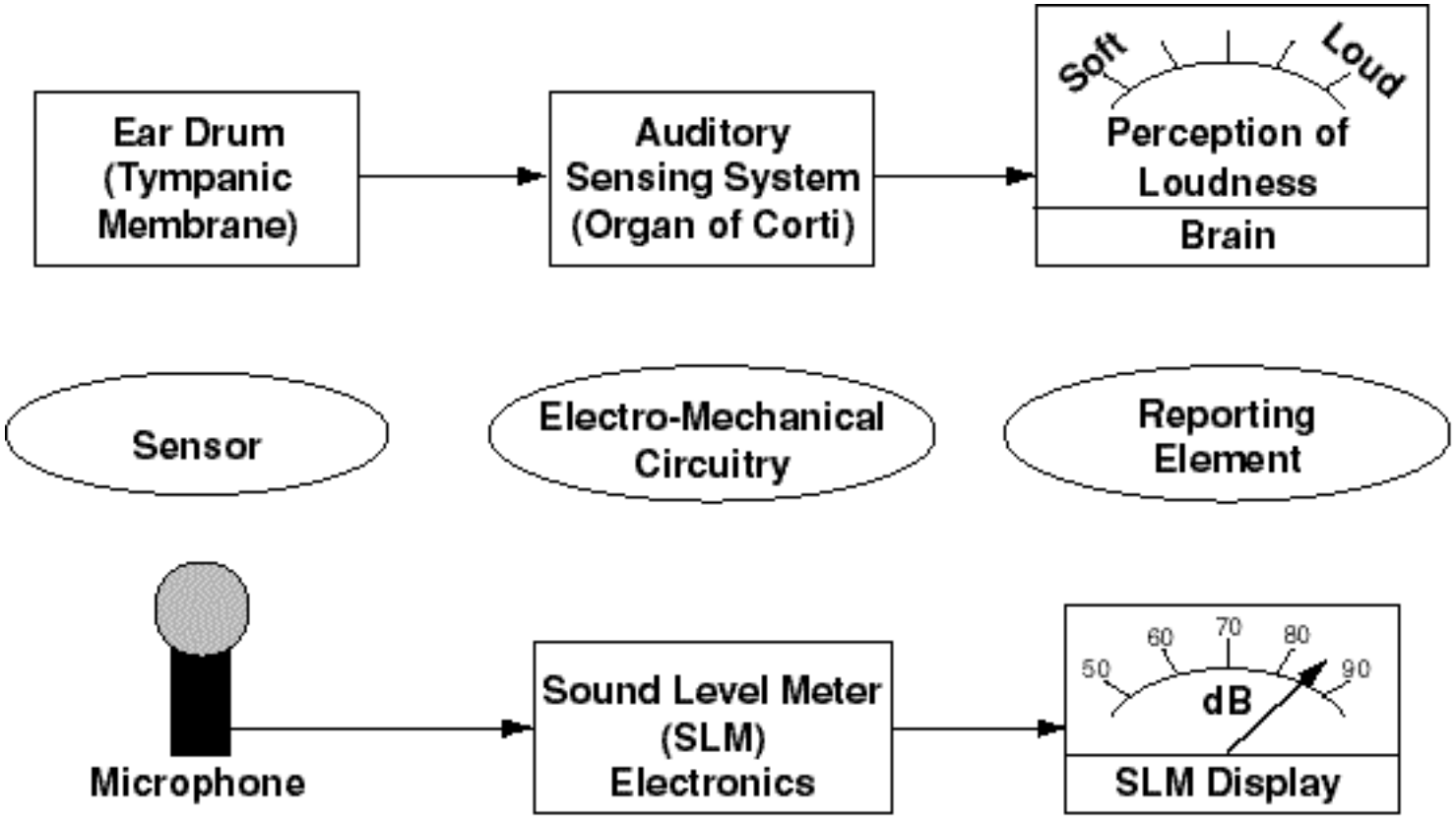


What do we hear?

- **Sound was already defined as any pressure variation which can be heard by the human ear.**
- **Frequency range**
  - *20 Hz to 20 kHz*
- **Sound Pressure Level (SPL)**
  - *Threshold of hearing (0 dB) and greater*
- **The smallest change in amplitude we can hear is about 3 dB (doubling of sound energy)**
- **A change of 6 to 10 dB is required before the sound subjectively appears to be twice as loud**

Human Ear - Sound Level Meter Relationship

http://www.hmmh.com/



Introduction to Noise Metrics

- Maximum Noise Level (Lmax)
- Sound Exposure Level (SEL)
- Equivalent-Continuous Sound Level (Leq)
- Day-Night Average Sound Level (DNL)
- Community Noise Equivalent Level (CNEL)

Sound Metric Equations - Lmax

- **Maximum Sound Level**

$$L_{\max} = \max\left(L(t)\Big|_0^T \right)$$

  - *In discrete form*:

$$L_{\max} = \max\left(L_i\Big|_{i=1}^n \right)$$

Sound Metric Equations - SEL

- **Sound Exposure Level**

$$SEL = 10 * \log_{10}\left(\frac{1}{\text{sec.}}\int_0^T 10^{L(t)/10}\,dt\right)$$

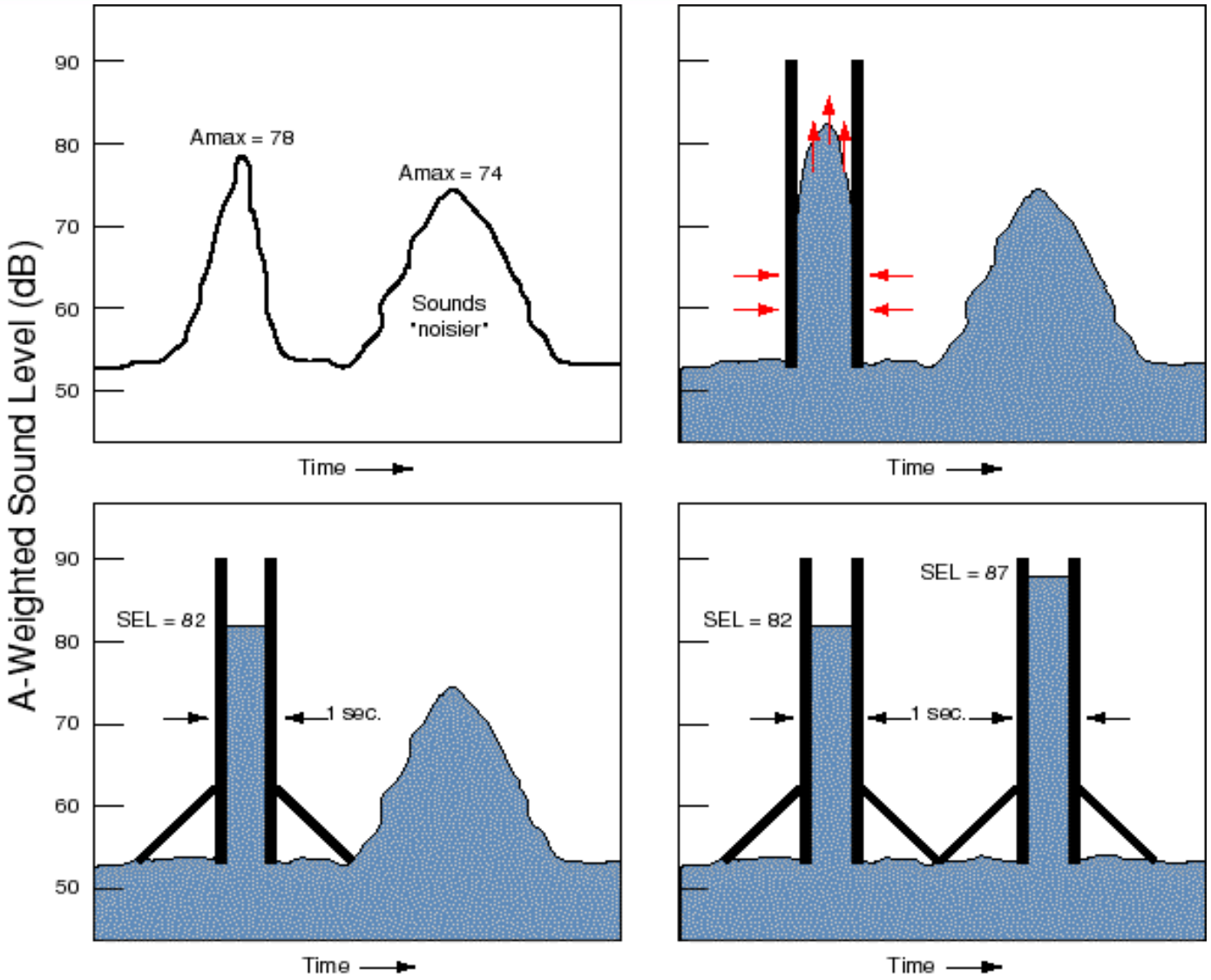
Not dividing by time
Required to get units right
(no units in dB ratio)

  - *In discrete form*:

$$SEL = 10 * \log_{10}\left(\sum_{i=1}^{n} 10^{Li/10}\right)$$

Sound Exposure Level (SEL)

http://www.hmmh.com/



Sound Metric Equations - Leq

- **Equivalent-Continuous Sound Level**

$$L_{eq} = 10 * \log_{10}\left(\frac{1}{T}\int_0^T 10^{L(t)/10}\,dt\right)$$

Dividing by time!

  - *In discrete form*:

$$L_{eq} = 10 * \log_{10}\left(\frac{1}{T}\sum_{i=1}^{n} 10^{L_i/10}\right)$$

Dividing by time!

Sound Metric Equations - Ldn

- **Day-Night Average Sound Level (DNL)**

$$L_{dn} = 10 * \log_{10}\left(\frac{1}{86{,}400}\left[\int_{7am}^{10pm} 10^{L(t)/10}\,dt + \int_{10pm}^{7am} 10^{(L(t)+10)/10}\,dt\right]\right)$$

Day *Night*

- ***In discrete form***:

Using SELs

$$L_{dn} = 10 * \log_{10}\left(\left[\sum_{i=1}^{n} 10^{SEL_i/10} + \sum_{i=n+1}^{m} 10^{(SEL_i+10)/10}\right]\right) - 49.4$$

Day *Night*

Sound Metric Equations – CNEL (California Only)

- **Community Noise Equivalent Level**

$$CNEL = 10 * \log_{10}\left(\frac{1}{86{,}400}\left[\int_{7am}^{7pm} 10^{L(t)/10}\,dt + \int_{7pm}^{10pm} 10^{(L(t)+4.8)/10}\,dt + \int_{10pm}^{7am} 10^{(L(t)+10)/10}\,dt\right]\right)$$

Day *Evening* *Night*

  - *In discrete form*:

    Using SELs

$$CNEL = 10 * \log_{10}\left(\left[\sum_{i=1}^{n} 10^{SEL_i/10} + \sum_{i=n+1}^{m} 10^{(SEL_i+4.8)/10} + \sum_{i=m+1}^{r} 10^{(SEL_i+10)/10}\right]\right) - 49.4$$

Day *Evening* *Night*

Introduction to Sound Insulation Goals

- **FAA Criteria**
  - 45 dB DNL (CNEL) inside residence
  - School-time Leq of 45 dB inside classroom
    - $Leq_{(7hr)}$, generally from 8 am to 3 pm
  - Minimum improvement of 5 dB noise reduction of structure

Determining Inside Levels

- **Determine noise reduction of structure**
  - Noise reduction is simply the difference in level of an outdoor noise source measured outside the residence and measured inside the residence.

    - NR = Noise Level Outside – Noise Level Inside

- **Determine outside noise levels**
  - DNL (CNEL) for residences (INM Modeled Levels)
  - $Leq_{(7hr)}$ for educational facilities (Estimated or Measured)

- **Compute inside levels**
  - Inside Level = Outside Noise Level - NR

Thank you!

Gene Reindel

Senior Noise Consultant

Harris Miller Miller & Hanson Inc.

945 University Avenue, Suite 201

Sacramento, California 95825

(916) 568-1116 ext. 224

ereindel@hmmh.com

WWW.HMMH.COM